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Authors: Natalia Nuño-Villanueva, Ignacio Martín-Nieto, Cristina Sáez-Blázquez and Arturo Farfán-Martín

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Geothermal energy as a solution to heating demand: Economic analysis vs. conventional supply

La geotermia como solución a la demanda en calefacción. Análisis económico frente a suministro convencional

Natalia Nuño-Villanueva[1*] https://orcid.org/0000-0001-7022-119X , Ignacio Martín-Nieto[1] https://orcid.org/0000-0003-3984-7228 Cristina Sáez-Blázquez[1] https://orcid.org/0000-0002-5333-0076 Arturo Farfán-Martín[1] https://orcid.org/0000-0002-1506-1207

Departamento de Ingeniería Cartográfica y del Terreno, Universidad de Salamanca. Escuela Politécnica Superior de Ávila. Hornos Caleros 50, 05003. Avila, Spain**.**

Corresponding author: Natalia Nuño-Villanueva

E-mail: id00816629@usal.es

KEYWORDS
Energy supply; renewable resources; comparative analysis; energy economics
Abastecimiento de energía, recursos renovables, análisis comparativo, economía de la energía

ABSTRACT: Renewable energies lead the energy transition towards a more sustainable and environmentally friendly energy system. Decarbonization and environmental policies, such as Europe's 2030 Climate Target Plan, favor and encourage this change. Geothermal energy as a renewable energy can play a critical role in the decarbonization within the heating sector. It is an efficient, safe, and clean energy that is not being implemented with the same trend as its counterparts. This study addresses two issues in the implementation of geothermal energy: the calculation of thermal needs and the economic difference in implementation compared to conventional supplies. Therefore, this study presents a simple methodology for sizing calculations for housing developments and economic comparison of the same installation powered by natural gas or low-enthalpy geothermal energy. The comparative terms considered are the initial installation and the annual expense. This comparison seeks to calculate the payback period of the initial geothermal installation, which has been carried out considering various economic scenarios.

RESUMEN: Las energías renovables encabezan la transición energética. La descarbonización y las políticas ambientales, como el Plan del Objetivo Climático para 2030 de Europa, favorecen y apremian este cambio. La geotermia como energía renovable puede ser un factor clave para la descarbonización en el sector de la calefacción. Se trata de una energía eficiente, segura y limpia que no se está implantando con la misma tendencia que sus homólogas. En este estudio se abordan dos problemáticas de la implantación de la energía geotérmica: el cálculo de las necesidades térmicas y la diferencia económica de implantación frente a los suministros convencionales. Es por ello que en este estudio se presenta una metodología sencilla de cálculo de dimensionamiento para urbanizaciones y una comparativa económica de la misma instalación alimentada por gas natural o por geotermia de baja entalpía. Los términos comparativos tenidos en cuenta son la instalación inicial y el gasto anual. Esta comparativa busca calcular el periodo de retorno de la instalación inicial geotérmica y se ha realizado teniendo en cuenta diversos escenarios económicos.

1. Introduction

Geothermal energy has proven to be a valuable source of renewable energy for supplying not only Domestic Hot Water (DHW) [1] but also for heating purposes [2]. Considering the current state of the fossil fuel market and its fragility due to recent events, this type of energy is even more recommended as an alternative to commonly used sources such as natural gas. In fact, geothermal energy systems can play an essential role in decarbonizing the heating and cooling sector, contributing to the reduction of greenhouse gas emissions [3].

Over the years, some research has been carried out on the efficiency of geothermal-based supply installations [4] [5], including studies on the advantages of collective installations compared to individual ones [6]. This has led to the development of a heating system known as District Heating (DH), whose objective is to supply an entire group of buildings. DH has been used in Europe since the 14th century [7], with more weight in northern European countries, where installations of this type currently exist. Additionally, new models are being investigated [6] [8] [9].

In addition to being a mature technology with its fourth generation (4GDH) [10] [11] [12] and the development of its fifth generation (5GDHC) [13] [14] [15] [16], this type of heating offers various advantages compared to the conventional model, including the reduction of fossil fuel consumption with its consequent reduction in CO_2 and greenhouse gas emissions [17]. Thanks to the successful research activities in the field, more and more 5GDHC have been built in Europe during the last years, serving as heat distribution networks with temperatures below zero up to 20ºC, and commonly low temperature spreads [18].

Despite the above, the use of geothermal district heating has been restricted to local systems, particularly in China and Europe [19], considering the limiting factors, including the spatial mismatch between heat sources and heat sinks. However, the direct heat use in these systems usually has a temperature level sufficient to satisfy the energy needs of the set of buildings that make up these heating networks.

In any case, geothermal district heating systems have numerous advantages, such as those mentioned above, which have made their development significant in recent times [20], especially in those areas with favourable geological conditions. However, despite these benefits, the initial investment in geothermal DH represents an important limitation factor when compared to other conventional fossil sources. Costs related to the required drillings of the well field and the geothermal heat pump are usually responsible for the high initial investment commonly attributed to these energy solutions [21]. Beyond this aspect, it is mandatory not only to consider this initial cost but also the operating costs associated with the system, which, in general terms, are much more advantageous in the case of geothermal energy [22].

For all of the above, and in order to clarify the limitations and advantages of the aforementioned geothermal DHs with respect to a conventional natural gas installation, this study intends to consider the annual expenditure of both heating solutions during the same period of years in order to verify the payback period and observe in general terms which solution is the most economical.

2. Methodology

This research employs a simplified approach to calculate the demand for an entire urbanization, allowing for a comparison between two heating supply sources: geothermal energy and natural gas. The methodology is presented through a workflow diagram, as shown in **Figure 1**, which outlines the various stages and software tools used in the study. The economic comparison is reached through this process and serves as the primary conclusion of the article.

The starting point of this methodology consists of selecting a residential area that can be classified in such a way that the houses can be individualized. The Geographic Information System of Agricultural Parcels (SIGPAC)[23] from Spain is a tool that allows the visualization and measurement of desired zones on a map. However, any Geographic Information System (GIS) can be used to define a zone of interest as long as it uses geographically referenced information. This is a key concept in order to make the replicability of the methodology feasible. After selecting the residential state, the subsequent stage is to designate a solitary plot along with its distinct house as the foundation for the calculations. The greater the resemblance between houses within the residential development, the lesser the margin of error in the demand calculation. Since this calculation will be later applied to all the houses, having a minimum error is desired.

There are numerous programs for calculating the energy demand based on the building construction, which perform the calculations based on the current regulations of the normative building code. This software is usually based on the energetic certification of the building studied. Some examples of these tools are LIDER/CALENER (HULC), CERMA, CEX, CE3 and CYPETHERM HE Plus. In this case, the software used for the calculation is CEX.

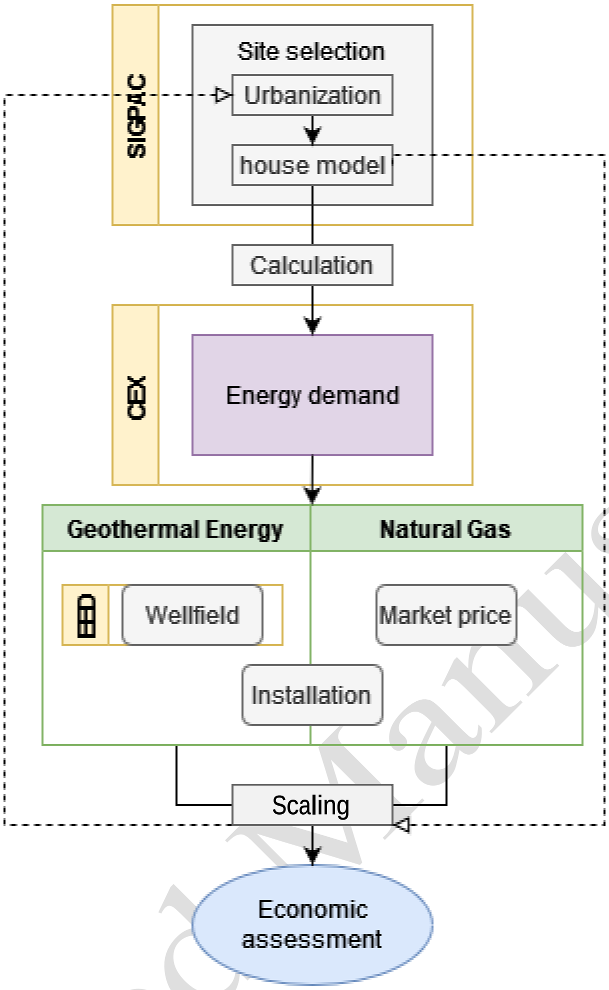


Figure 1 Methodology workflow

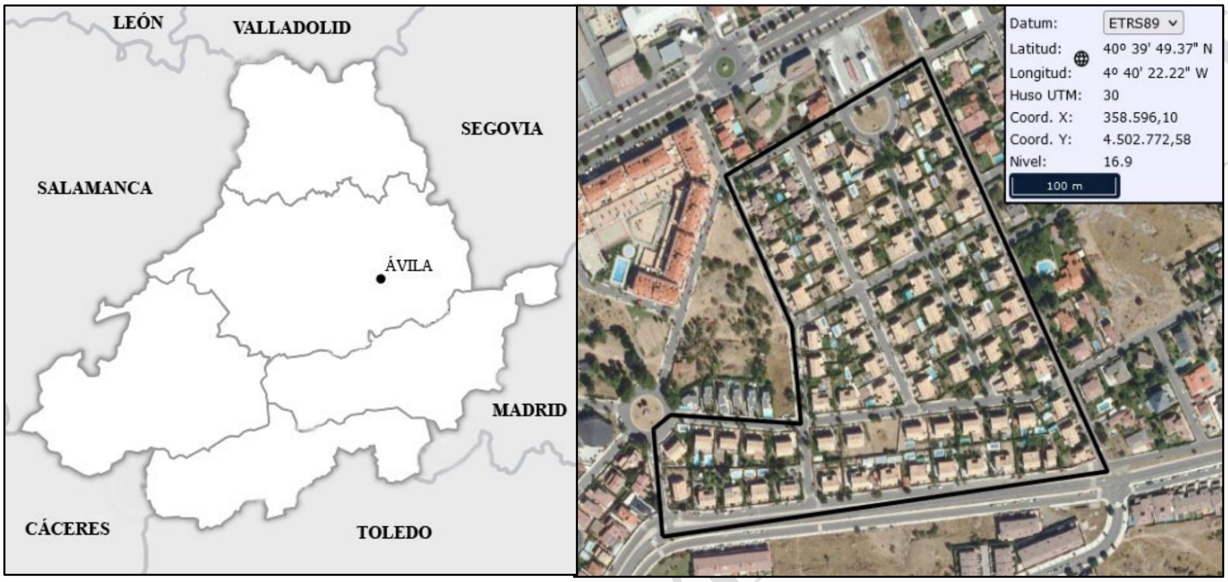
As previously stated, this study proposes an economic comparison between two methods of meeting heating demand: the conventional and widely-used natural gas, and an alternative renewable energy source such as geothermal energy. Both methods will be evaluated using the same time frame. The cost of installation will be considered to arrive at a comprehensive conclusion on the economic disparities in terms of initial investment and the upkeep.

3. Suitable study locations

The research can be duplicated and executed in residential communities where the homes are either identical or similar. This study analyses a single house in the community, which will then be scaled to all houses. Consequently, any existing or planned residential community whose houses are designed as replicas could benefit from this calculation. Although it remains feasible to estimate the calculation in other types of residential developments, the likelihood of error increases.

It should be noted that geothermal energy is highly dependent on the terrain in which it is located since it affects the performance of the geothermal heat pump installations. As this research intends to create the wellfield within the residential area, the calculations will be more favourable when the thermal conductivity of the land on which the urbanization is built is higher.

The study site selected in this research is based in Ávila in the autonomous community of Castilla y León, Spain. The exact location is presented in **Figure 2** using SIGPAC.



Datum: ETRS89
Latitud: 40º 39' 49.37" N
Longitud: 4º 40' 22.22" W
Huso UTM: 30
Coord. X: 358.596,10
Coord. Y: 4.502.772,58
Nivel: 16.9

Figure 2 Study site selected as example (Ávila, Castilla y León, Spain)

This urbanization has the same type of house built despite the change in the distribution of its individual plot, which does not interfere with the calculations. It consists of 83 houses, as shown in **Figure 3**.

Furthermore, using the geothermal map of the Ávila region [24], the thermal conductivity of the terrain in which the urbanization was built can be obtained (**Figure 4**), resulting in approximately 2.8-3W/m·K.

Figure 3 Single selection of the houses

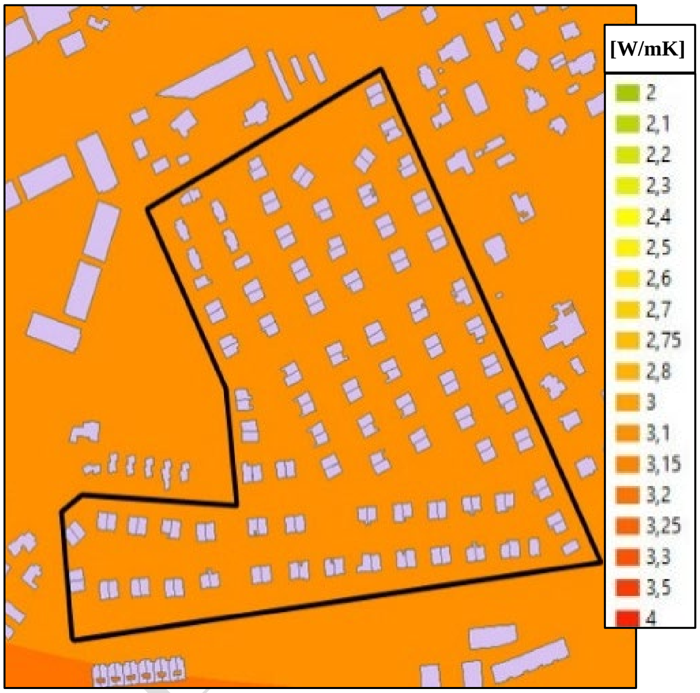


Figure 4 Selected study site with its thermal conductivity (W/m·K) presented

4. Calculation, results, and discussion

4.1. Calculation of energy demand

As specified in **Figure 1,** the selection of a core house must be made in order to ease the calculation of the demand. Therefore, the example house plot consists of an area of 783m^2 (27x29m). This area remains approximately the same for the rest of the houses, even if the length and width of the plots change. The house itself is 210m^2 as seen from above (15x14m), and consist of 3 floors where one of them is half the surface due to the indoor parking. These measures result in 525m^2 in total.

In order to calculate the demand with the CEX software, it is necessary to make some estimations and previous calculations:

- The corresponding factors included in the Spanish Technical Building Code will be applied. In this scenario, the reference demand of DHW for buildings of private residential use will be obtained considering needs of 28l/day·person [25].
- The average distribution of the house will be two bedrooms that are equivalent to 3 people.[25]

Considering the advantages of CEX in autocompleting based on regulations and climatic zones, only the general data of the house and its facade structure need to be provided. The estimated values of building thermal characteristics, including enclosures and other parameters affecting energy efficiency, are determined by CEX according to current thermal regulations during project development (building construction year). This estimation guarantees the minimum thermal properties of the different components forming the building envelope.

In this case, **Table 1** presents the data used as input for the calculation.

Table 1 Building data entered in CEX software

Building characteristics	Value
Construction year	1999
Usable living area	525 m^2
Number of habitable floors	2
Daily DHW demand	84 l/day

The model used to calculate the DHW demand is based on the following Equation (1) as stated in its manual:

$$DWH\ Demand\ \left[\frac{kWh}{m^2}\right] = 360 \cdot \rho \cdot C_p \cdot Q_{DHW} \cdot \frac{\left(T_{ref} - T_{AF}\right)}{3600 \cdot area} + P_{ac} \qquad (1)$$

Where:

- ρ: water density
- C_p: specific heat capacity of water
- T_{ref}: reference temperature (60°C)
- T_{AF}: mean annual reference cold water temperature (based on climate zone designated by the Spanish Technical Building Code)
- $area$: usable living area
- Q_{DHW}: Domestic Hot Water flow rate (28l/day·person)
- P_{ac}: energy losses.

A heating demand of 99.1 kWh/m^2 has been calculated for a single house, resulting in 52MWh. It must be considered that the orientation of the houses influences this heating demand, so it will be adjusted to 55MWh of heating demand per house per plot annually.

4.2. Natural gas installation

Calculating the installation and maintenance of natural gas for heating is simpler than calculating the geothermal counterpart. Since natural gas is the most widely used in Spain, there are more estimated prices for the calculation of the facilities. An example of the cost of an average natural gas installation in single-family homes is presented in **Table 2**.

Table 1. Price of natural gas installation in single-family homes[26]

Description	Total (€)
Individual receiver facility	1,420
Technical calculation report and individual gas installation certificate	

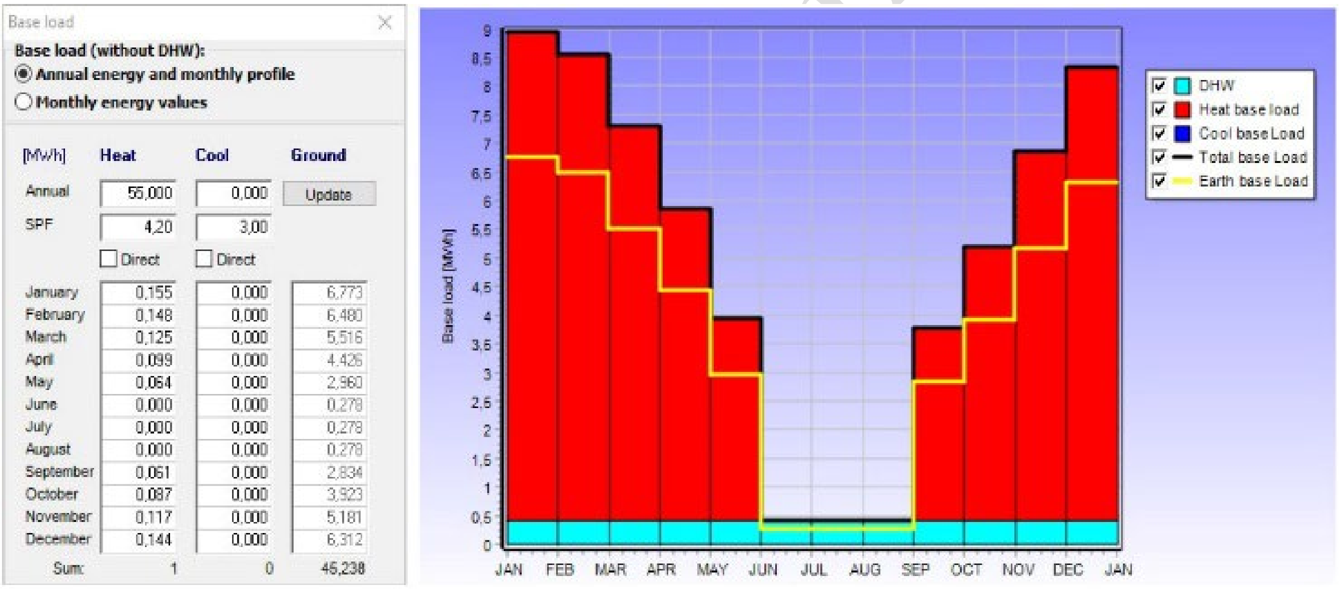
Management and processing of licenses, permits, and commissioning	
Regulation cabinet	
Connection steam to service	
Condensing boiler	1,000
TOTAL	**2,420**

Scaling the cost to the 83 total homes that make up the urban complex is a total of €200,860.

4.3. Geothermal installation

In order to adequately meet the heating demand with geothermal energy, it is necessary to calculate two factors: (I) the design and sizing of the wellfield and (II) the installation.

The EED[27] (Earth Energy Designer) software has been used as a tool for designing ground source heat pump systems and borehole thermal storage. The input for this software is the estimated annual heating demand of 55MWh. The monthly distribution with the corresponding consumption factors can be seen in **Figure 5**.



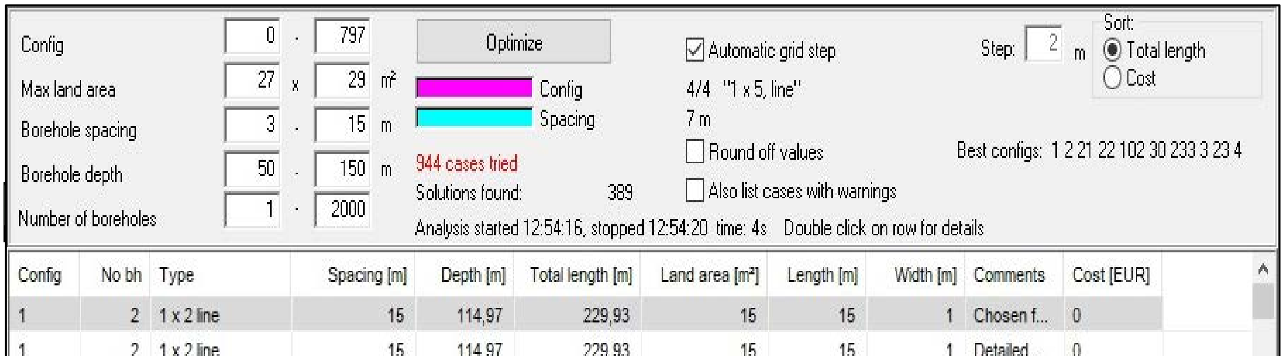
Base load

Base load (without DHW):
● Annual energy and monthly profile
○ Monthly energy values

[MWh]	Heat	Cool	Ground
Annual	55,000	0,000	Update
SPF	4,20	3,00	
	☐ Direct	☐ Direct	
January	0,155	0,000	6,773
February	0,148	0,000	6,480
March	0,125	0,000	5,516
April	0,099	0,000	4,426
May	0,064	0,000	2,960
June	0,000	0,000	0,278
July	0,000	0,000	0,278
August	0,000	0,000	0,278
September	0,061	0,000	2,834
October	0,087	0,000	3,923
November	0,117	0,000	5,181
December	0,144	0,000	6,312
Sum:	1	0	45,238

Figure 5 Base load of heating demand and its graphic representation

In **Figure 6,** different optimized configurations created by EED can be seen. The first part has as priority the least number of boreholes, whereas the second prioritizes the depth of the boreholes. In both cases, the first option is highlighted in grey as they are considered the optimal solution.



Config 0 - 797
Max land area 27 x 29 m²
Borehole spacing 3 - 15 m
Borehole depth 50 - 150 m
Number of boreholes 1 - 2000

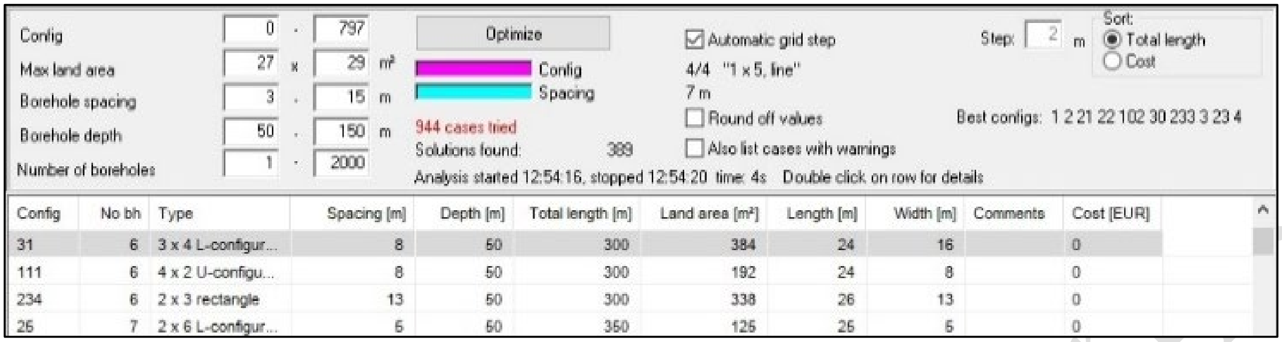
944 cases tried
Solutions found: 389
Analysis started 12:54:16, stopped 12:54:20 time: 4s Double click on row for details

☑ Automatic grid step
4/4 "1 x 5, line"
7 m
☐ Round off values
☐ Also list cases with warnings

Step: 2 m
Sort:
● Total length
○ Cost

Best configs: 1 2 21 22 102 30 233 3 23 4

Config	No bh	Type	Spacing [m]	Depth [m]	Total length [m]	Land area [m²]	Length [m]	Width [m]	Comments	Cost [EUR]
1	2	1 x 2 line	15	114,97	229,93	15	15	1	Chosen f...	0
1	2	1 x 2 line	15	114,97	229,93	15	15	1	Detailed...	0



Config 0 - 797

Max land area 27 x 29 m²

Borehole spacing 3 - 15 m

Borehole depth 50 - 150 m

Number of boreholes 1 - 2000

Optimize

Config

Spacing

944 cases tried

Solutions found: 389

Analysis started 12:54:16, stopped 12:54:20 time: 4s Double click on row for details

☑ Automatic grid step

4/4 "1 x 5, line"

7 m

☐ Round off values

☐ Also list cases with warnings

Step: 2 m

Sort:

● Total length

○ Cost

Best configs: 1 2 21 22 102 30 233 3 23 4

Config	No bh	Type	Spacing [m]	Depth [m]	Total length [m]	Land area [m²]	Length [m]	Width [m]	Comments	Cost [EUR]
31	6	3 x 4 L-configur...	8	50	300	384	24	16		0
111	6	4 x 2 U-configu...	8	50	300	192	24	8		0
234	6	2 x 3 rectangle	13	50	300	338	26	13		0
25	7	2 x 6 L-configur...	5	50	350	125	25	5		0

Figure 6 Design solutions provided by EED software

For this comparison, the first configuration of 2 boreholes of 115m depth will be used. This configuration is presented in **Figure 7,** as its fluid temperature curve for 25 years. It can be verified that the final temperature (approximately -6ºC) is far from the freezing point of the selected fluid (Monopropylenglycole and water at 33% with a freezing point of -17ºC).

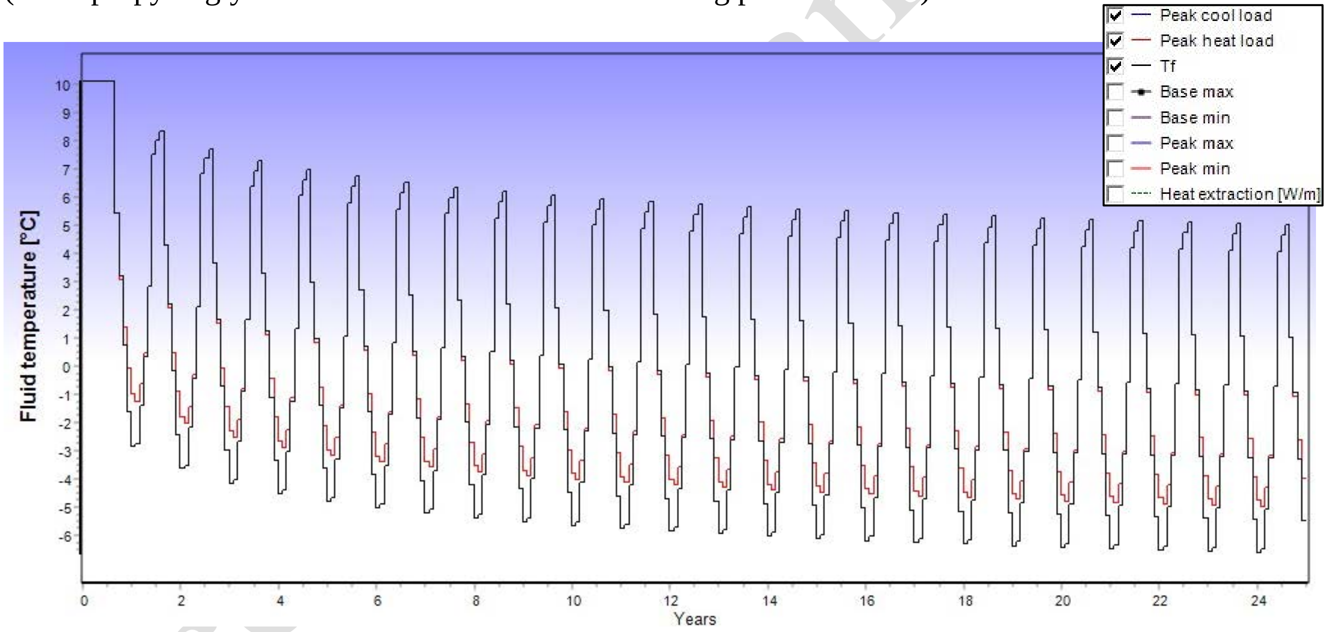


Figure 7 Temperature evolution in 25 years provided by EED software

Having the calculation of the wellfield allows an easy calculation of the heat pump needed. An estimated calculation with a Coefficient of Performance (COP) of 4 and 2,400h of work a 0.01MW of pump power is obtained. A COP of 4 is used as a standard to indicate good energy efficiency and to meet regulatory requirements and performance expectations in the Heating, Ventilation, and Air Conditioning (HVAC) industry. **Table 3** shows the summary of the design selected.

Table 2. Summary of design and installation per house

Wellfield	**Nº of boreholes**	**Depth (m)**	**Spacing (m)**
	2	115	15
Heat pump	**Power (MW)**	**COP**	**Operating hours**
	0.01	4	2,400

CYPE engineers [22] has an extensive library of Spanish work prices, which will be used for the estimated calculation of the installation work. **Table 4** breaks down the required budget for the wellfield installation using CYPEs registered data.

Table 3. Estimated price of the wellfield installation per house

Unit	**Description**	**Efficiency**	**Unitary price (€)**	**Total (€)**
h	Hydraulic equipment on crawler carriage […]	0.13	105.84	13.76
h	Injection equipment for geothermal drilling	0.13	34.16	4.44
			Equipment subtotal	**18.20**
h	Official construction of civil works	0.46	19.93	9.15
h	Civil works construction assistant	0.46	18.92	8.68
			Workforce subtotal	**17.83**
%	additional direct costs	2	36.03	0.72
			TOTAL	**36.75***

**Rounded up for further calculations to 40€/m*

Doing the calculations with the design selected of 2 boreholes of 115m each (total of 230m) and scaled to the totality of the 83 houses results in €763,600, the cost of the total wellfield.

Regarding the necessary heat pump, it must be considered that larger heat pumps work with higher COP Therefore, the COP used will be changed from 4 to 4.5, as estimated. The operating hours are maintained. In order to calculate the heating power needed, the demand obtained per house will be multiplied for the total number of houses in the housing development (83) divided by the COP of the heat pump. This results in a total demand of 1,015MWh or 0.43MW, which for this study purposes it will be rounded up to 0.5MW.

As an example of a geothermal heat pump, the geotherm variant of Vaillant[28] will be used as an estimated price, as shown in **Table 5**. This geothermal heat pump has an associated COP of 5.2 under optimal conditions. Therefore, the estimated value used of a COP of 4.5 falls within a valid and safe estimation.

Table 4. Price of heating pump for the housing development

Description	Heating power (kW)	Quantity	Unitary price (€)	Total (€)
Vaillant geoTHERM VWS 460/3 400 V	49.9	10	18,235.91	182,359.1

As a result, the geothermal installation costs are shown in **Table 6**.

Table 5. Summary of total cost of geothermal installation

Description	**Total (€)**
Wellfield installation	763,600
Heat pump installation	182,359.1
TOTAL	**945,959**

4.4. Comparison result

The difference obtained in the initial installation of each energy vector is shown in **Table 7**. This difference was expected due to the wellfield design and excavation, which significantly increased the initial cost.

Table 6. Summary of the initial cost of installation

Description	**Total (€)**
Natural gas initial installation	**200,860**
Geothermal initial installation	**945,959**

However, the comparison presented in this article is not only developed with the initial investment but also with its prolonged use. This calculation is complex since it depends on the market price of electricity and natural gas. As the objective of this research is the comparison in general terms of the cost, the values presented in **Table 8** are estimations of the mean market value. The years selected for this study coincide with stages in the market that define variations in price. The year 2019 has been considered the normative price trend. The year 2020 has been marked by the global COVID-19 pandemic, creating a downward trend in prices. Lastly, the year 2022 has been taken as a reference for an upward trend in prices due to the war between Russia and Ukraine, which affected the supply of natural gas. Further explanation of the market can be found in section "4.5 Market evaluation and discussion".

Table 7. Market value of electric kWh and natural gas in different significant years

Year	**Market value**	
	Electricity (€/kWh)	**Natural gas (€/kWh)**
2022	0.2773	0.2166
2020	0.1214	0.0480
2019	0.1115	0.0736

The price of electricity has been taken as the average of the electricity market for the month of October, while for natural gas, the average price of three companies has been used: Endesa, Iberdrola and Repsol. All three of them operate in Spain.

Equation (2) has been used to determine the cost for the geothermal installation, whereas equation (3) has been used to calculate the natural gas cost.

$$IC_{geo} + \left(C_{elec} \cdot \left(\frac{AHD}{COP} \right) \right) \tag{2}$$

Where:

- IC_{geo}: initial cost of the geothermal installation
- C_{elec}: cost of the electricity
- AHD: annual heating demand
- COP: coefficient of performance.

$$IC_{NG} + (C_{NG} \cdot AHD) \tag{3}$$

Where:

- IC_{NG}: initial cost of the natural gas installation
- C_{NG}: cost of the natural gas
- AHD: annual heating demand.

In both equations, the factor added to the initial cost is considered the value of the annual usage cost.

Figure 8 and **Figure 9** are the graphical representation of the cost of both systems, starting with the initial investment detailed in **Table 7,** plus the annual cost of covering the heating demand and maintaining this coverage for 10 years.

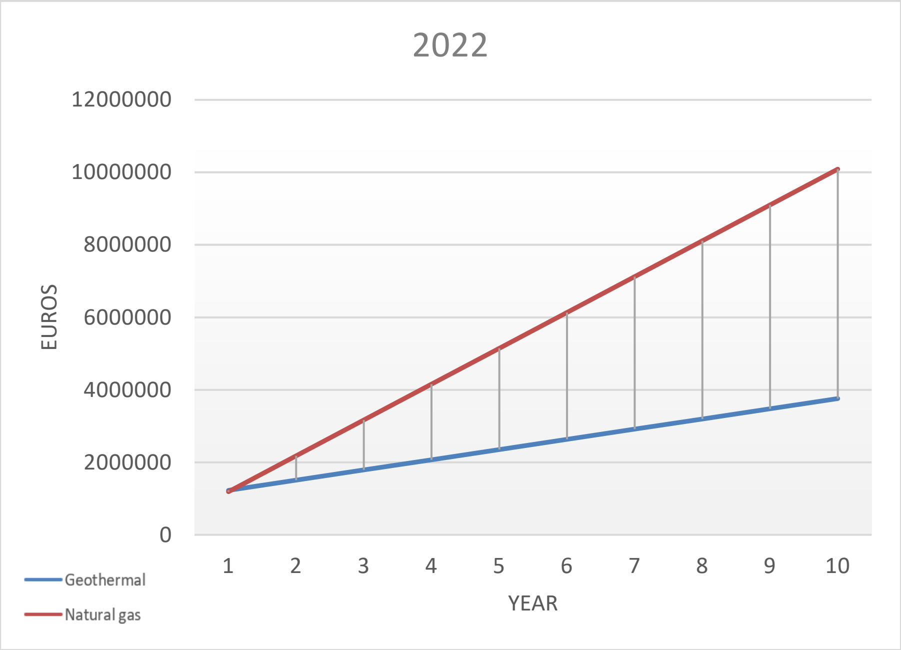


Figure 1. Graphic representation of the cost of both systems in 10 years (2022)

The cut-off points of the graphs presented (year 1 in 2022, year 8 in 2020, and year 3 in 2019) represent the years when the geothermal system matches the natural gas system and initiates the payback period. As seen in the graphs, the savings are significant once this point is surpassed.

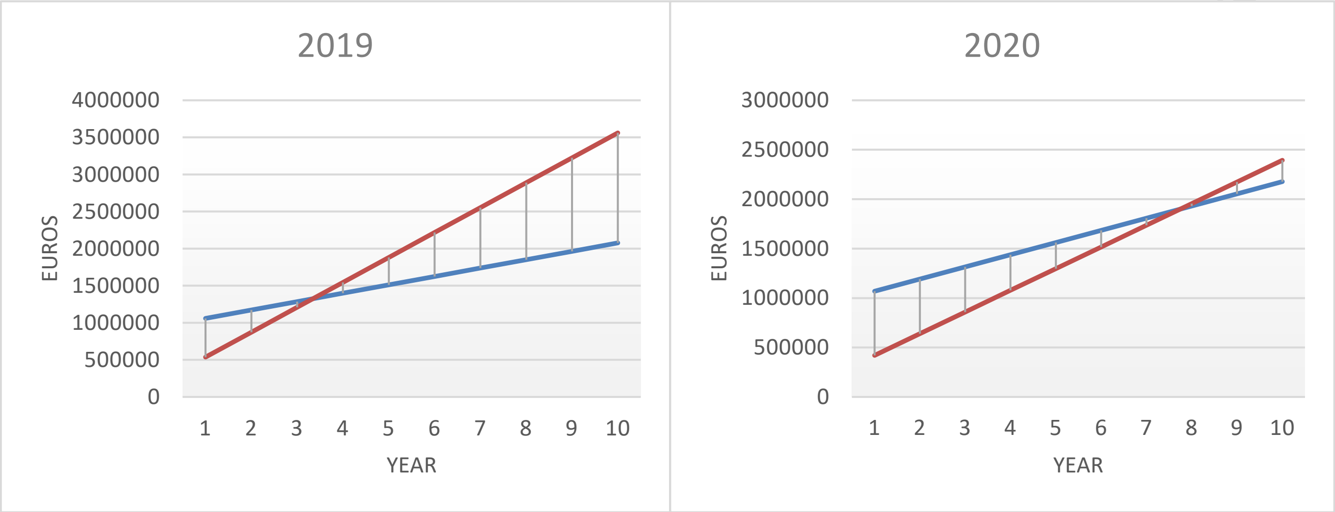


Figure 2. Graphic representation of the cost of both systems in 10 years (2020 and 2019)

4.5. Market evaluation and discussion

The scenarios presented in the previous section show evidence of variation in the return period. From 2019 to 2020, within a one-year period, the return period extended from 3 years to 8 years. It should be noted that there is a variation of 5 years just by considering the average price of the year, without intermediate market fluctuations. If it was evaluated with the daily prices, it would be a complex calculation that would not allow for a quick comparison of the two energies.

The fluctuation of the natural gas market is determined by factors such as supply and demand, production, government policy, and weather conditions. In addition, considering that the main natural gas-producing countries are Russia, the United States, Canada, and China, and the main consumers are the United States, China, and the European Union, it can be deduced that any significant event affecting producers will be reflected in the market price. In recent history, the following events modified the market prices:

- In the mid-2000s, the price of natural gas in the United States increased significantly due to growing demand and declining production. However, starting in 2008, the introduction of new extraction technologies, such as hydraulic fracturing, allowed the extraction of natural gas from previously inaccessible deposits, leading to a significant increase in supply and a drop in prices.
- Between 2010 and 2014, natural gas prices in the United States remained relatively low because of increased production and reduced demand for heating due to warmer-than-usual winters.
- In 2014, natural gas prices rose due to a cold wave in the United States and an increase in heating demand. However, in the following years, natural gas prices fell again due to increased production and lower demand.

- In 2020, the price of natural gas plummeted to historically low levels due to the COVID-19 pandemic and the resulting decrease in energy demand. In addition, the price war between Russia and Saudi Arabia in the oil market also contributed to the fall in natural gas prices.
- In 2022, the market was affected by the war between Russia, the main producer, and Ukraine. This event increased the natural gas value since Ukraine is an important transit country for natural gas transported through Russian pipelines to Europe, a main consumer.

This reasoning is why only the average annual price is taken into account.

To assess when the electricity used to power geothermal systems becomes less profitable than natural gas, one could analyse a scenario with a fixed price. While this approach might illustrate the general trend in cost comparison between the two energy sources, it would not reflect a realistic scenario due to the price fluctuations of natural gas, as previously discussed.

However, the following scenarios are presented using the average prices of both natural gas and electricity in 2019 and 2020 (**Table 9** and **Figure 10-12**). The year 2022 is excluded from this average, as it represents a peak price in the historical prices caused by the current Russia-Ukraine war.

Table 9. Market fluctuation scenarios

Scenario	Description	Market value	
		Electricity (€/kWh)	Natural gas (€/kWh)
1	Maintaining the mean prices	0.1165	0.0608
2	Equalizing with the price of electricity	0.1165	0.1165
3	Equalizing with the price of natural gas	0.0608	0.0608
4	Triple the price of natural gas	0.1825	0.0608
5	Triple the price of electricity	0.1165	0.3494
6	Scenario 5 interchanged	0.3494	0.1165

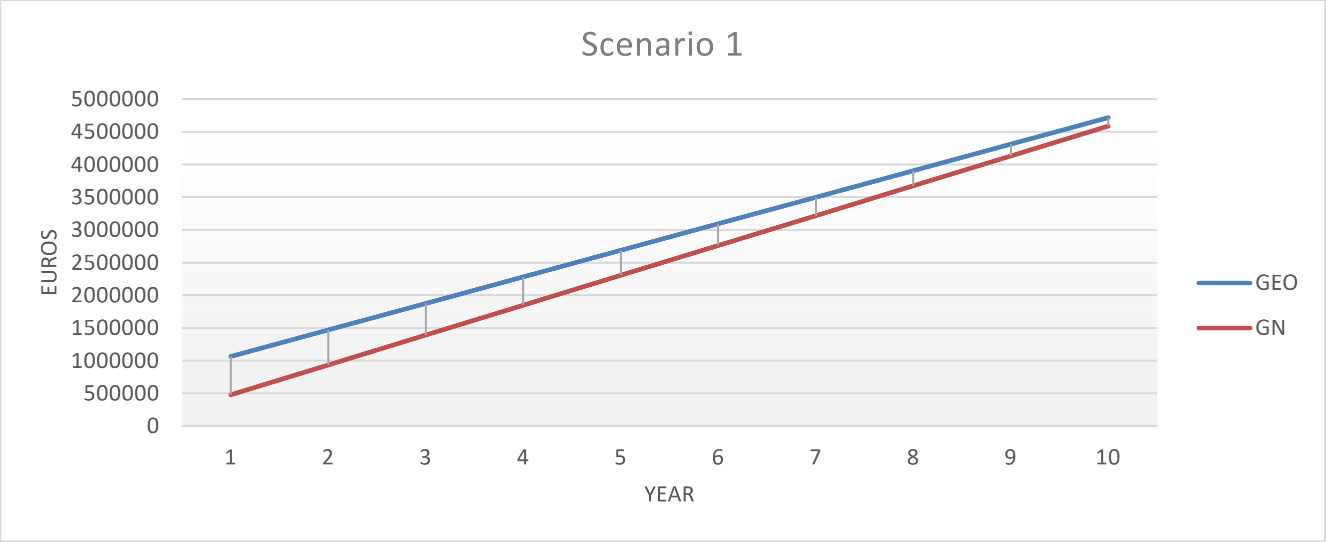


Figure 10. Graphic representation of the market fluctuation scenario 1

As observed in this first scenario, the cut-off occurs at more than 10 years, so it would not be a scenario that favours the inclusion of geothermal energy. In this case, the electricity price is twice that of natural gas.

If we analyse scenarios 2 and 3 together (**Figure 11**), we can see that the payback period is achieved before 4 years in both cases. The difference in the amount once the payback period is reached is more pronounced the lower the price of both, as in scenario 3, both take the value of natural gas, which was the lowest price value.

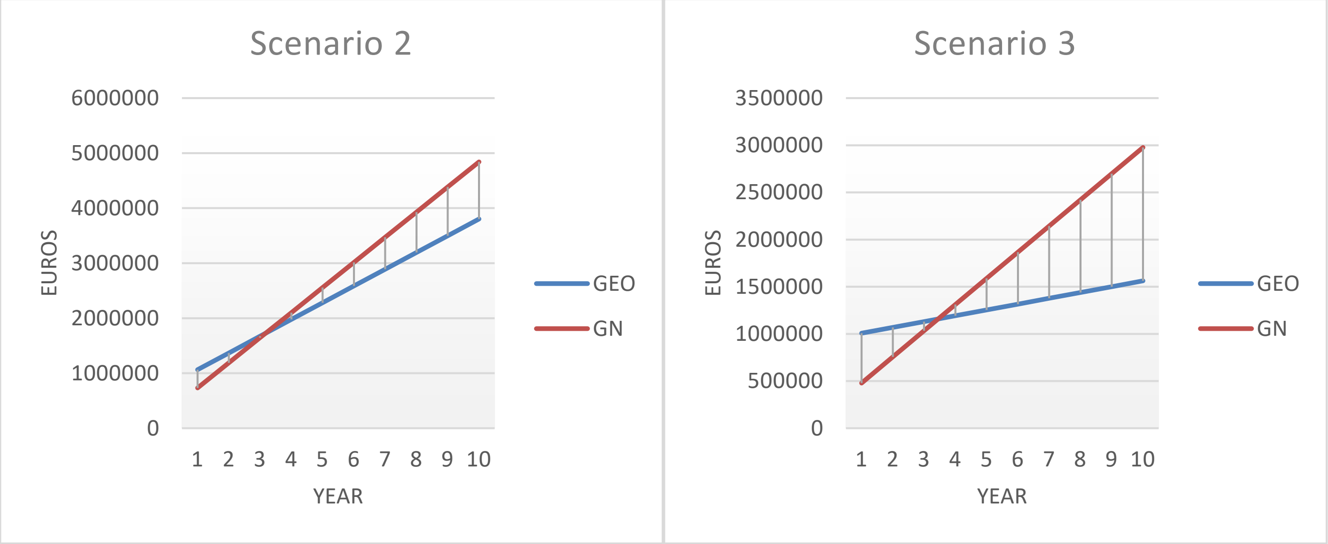


Figure 11. Graphic representation of the market fluctuation scenarios equalizing prices

In **Figure 12**, the comparison between scenarios 4 and 5 is shown. In these scenarios, an extreme situation is presented where one price becomes three times higher than the other. This representation aims to show some boundary scenarios.

As can be seen, if the price of natural gas is significantly higher, the payback period occurs instantaneously, as it surpasses the geothermal installation. In the case that the price of electricity is significantly higher than natural gas, the payback period still occurs, but in more years.

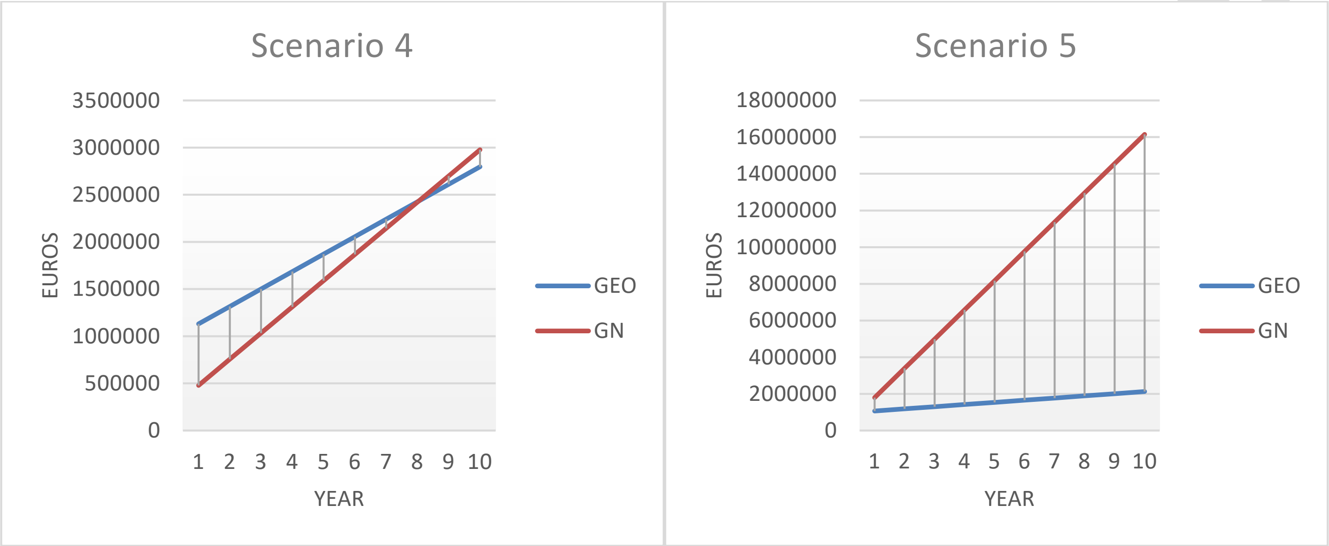


Figure 12. Graphic representation of the market fluctuation scenarios triplicating the base prices

Finally, in **Figure 13,** the extreme scenario of triple the electricity price from Scenario 5 is preserved, but for the representation of Scenario 6, the values are exchanged. This comparison highlights the importance of the specific price of the energies as well as the difference between them.

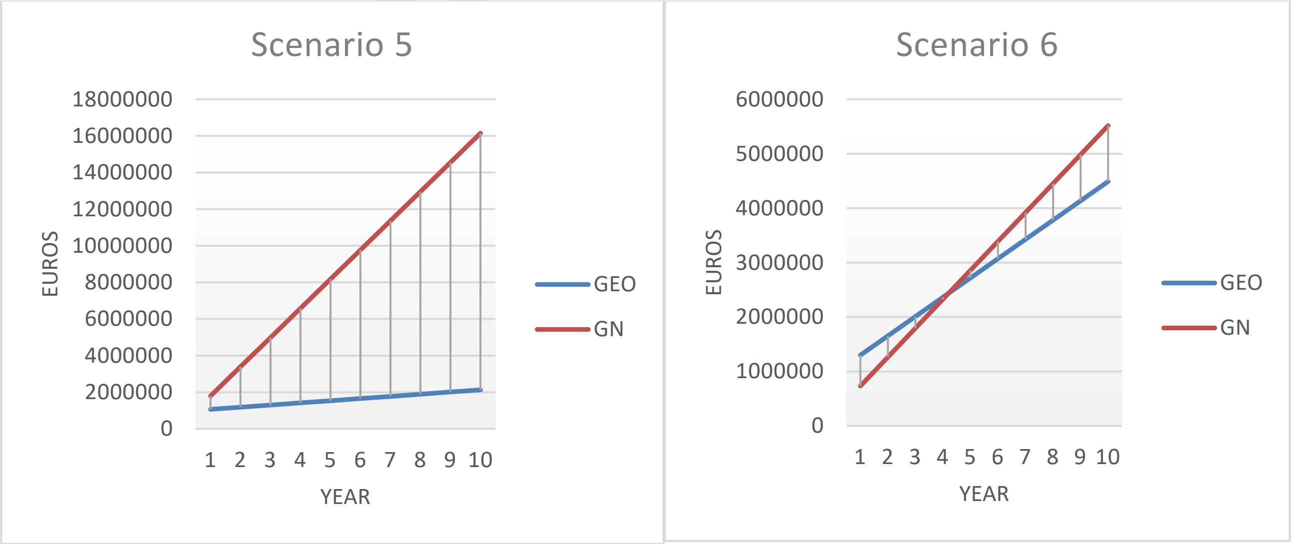


Figure 13. Graphic representation of the market fluctuation scenarios triplicating the prices but maintaining the same prices

The situational graphs shown are not enough to evaluate different scenarios, once it has been proven that the price unit must be taken into consideration. The graph represented in **Figure 14** shows the payback period (years) according to the price of natural gas (GN) and the price of electricity (GEO), both in a range up to 0.50 €/kWh.

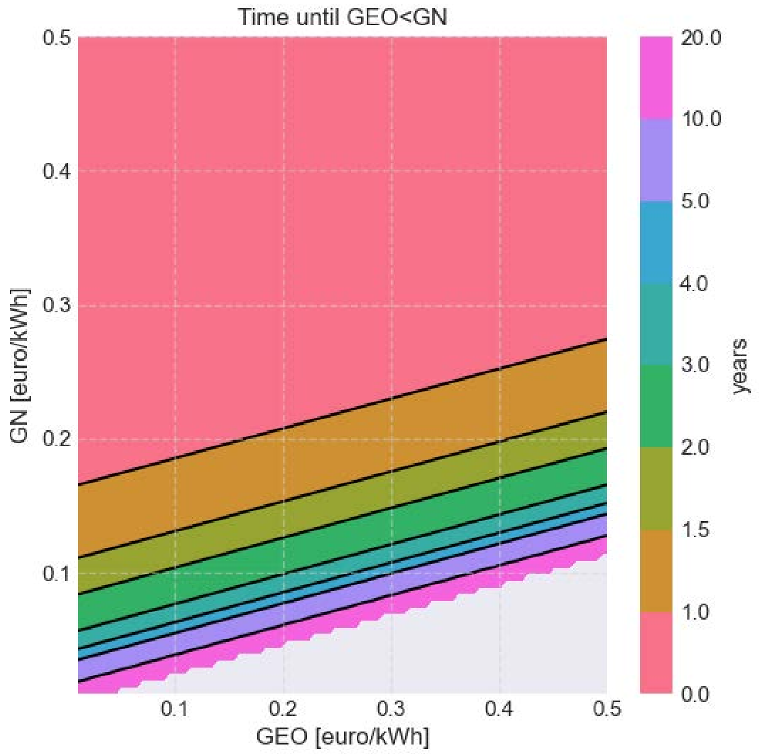


Figure 14. Graphic representation of the return point in the investment based on market price

A viable alternative to consider would be the installation of photovoltaic panels on the rooftops of houses as a solution to reduce electricity consumption from the grid. In the case study of this research, 0.01 MW must be supplied for the heat pump of the 83 houses. This results in a generation capacity of 121W per house, which, for engineering and market purposes, results in a commercially sold 150W panel. Although this measure would increase the initial investment in geothermal installation, it would also decrease the annual maintenance cost due to the reduction in electricity consumption. It is important to note that light-solar factors condition electricity production from photovoltaic panels, so it would not allow for a completely independent installation from the grid but a reduction in energy consumption.

Based on the results obtained in the research, if the investment cost per house in geothermal energy is approximately €9,200 and the price of a 150W panel installation kit is around €300, then the total cost would increase by 3.26%. Therefore, an *initial increase of 3% would result in a continued benefit over the lifespan of the installation*.

Hence, it is important to emphasize that the results obtained in this research are broad comparisons that demonstrate the feasibility of using geothermal energy as a solution to heating demand in urban areas. Prices can be adjusted by including the measures, such as generating electricity through photovoltaic panels or programming the heat pump to work during off-peak hours. This would further reduce the difference between conventional natural gas and geothermal installations. However, the initial investment for geothermal installation will always exceed the initial investment for natural gas installation. The benefit of geothermal installation lies in its annual consumption and maintenance.

5. Conclusions

An undeniable point of geothermal energy is its significant initial cost (**Table 7**), being approximately five times the initial cost of the natural gas installation. However, this initial outlay is compensated by the annual cost of its use, highly dependent on the market and its stability. Due to the influence in this market of political disputes, it can be seen in the period of 4 years how prices have varied. Compared to 2019, there has been an increase of 149% in the case of electricity and a rise of 195% in the case of natural gas. However, within the most stable period between 2019 and 2020 prices hardly vary. Even so, the return period is reached early, considering that the temperature of the fluid and the installations are guaranteed for 25 years, since none of them reach 10 years.

A more conservative approach considering other factors ignored in this study, such as the fluctuation of the market or selecting the electric kWh during off-peak hours since the heat pump can be programmed to work on determined hours, can be taken and expect a payback return around half the years needed to maintain the heat pump or the boiler (25 years approximately depending on the model, not counting the annual revisions for both systems).

This study is noteworthy not only as an exploration of investment potential in this type of technology but also as a demonstration of geothermal energy's viability as a renewable resource accessible to any country, highlighting its feasibility and practical application. Suppose the correct study of the construction zone is done, and it results in an acceptable thermal conductivity. In that case, it is a system to consider for any country that is not a primary producer of natural gas, thus making it less dependent on the supply conditions. The methodology outlined for calculating the demand and designing the geothermal installation presented in this study provides a quick method for evaluating the potential feasibility of implementing a geothermal district heating system. The evaluation of potential areas for this type of energy and the subsequent calculation of the wellfield are critical points for the implementation of geothermal-powered systems. Consequently, being able to detail specific cases and then scale them to find an appropriate solution represents significant progress.

6. Declaration of competing interest

We declare that we have no significant competing interests including financial or non-financial, professional, or personal interests interfering with the full and objective presentation of the work described in this manuscript.

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9. Authors contributions

Conceptualization, methodology, investigation, and wrote the paper: N. Nuño-Villanueva; formal analysis, investigation, and looked for resources: I. Martin Nieto; conceptualization, methodology, and software. C. S. Blázqueza ; data curation, contributed data, and carried out the formal analysis: A. Farfán-Martín

10. Data available statement

The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary materials.

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