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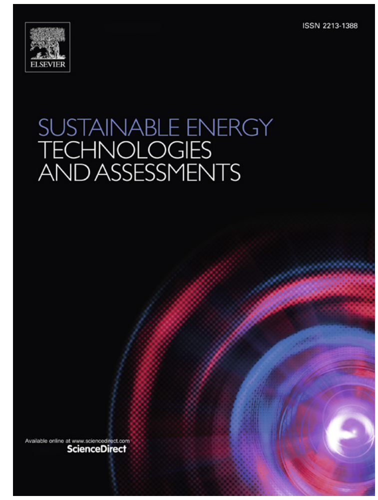

Integration capacity of geothermal energy in supermarkets through case analysis

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INTEGRATION CAPACITY OF GEOTHERMAL ENERGY IN SUPERMARKETS THROUGH CASE ANALYSIS

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Abstract

This article discusses the potential of economic and energy consumption savings in addition to the reduction of greenhouse gases that the use of geothermal energy can have in supermarkets. Three facilities are analysed in Germany, Portugal and Turkey. German installation employed shallow geothermal technology for heating and cooling the supermarket. Portuguese installation consisted of the application of ground source heat pumps to replace traditional air conditioning systems. Turkish installation was the first application in Turkey which took advange of the storage of thermal energy in an aquifer integrated into a system of air conditioning and ventilation. The use of geothermal energy led to save 45% in energy consumption in the German case, 30% in the Portuguese case and 36% in the Turkish installation. There was a reduction of 28% in CO_2 emissions in the German case, 30% in the Portuguese case and 36% in the Turkish installation. The payback period in geothermal energy range from 15 to 16 years and depend on the geological area of implantation and the type of installation. When geothermal energy is used for supermarket air conditioning, the savings in electricity consumption vary between 28-36% and increase to 30-45% when combined with commercial cooling.

Highlights

- Supermarkets are the commercial models with the highest growth and energy consumption.
- Supermarkets are economically forced to be more energy efficient.
- Geothermal energy is a viable renewable energy in supermarkets.
- Savings are obtained by using geothermal energy for air conditioning.
- Savings improve when geothermal energy is combined with commercial cooling.

Keywords

Geothermal energy; Efficient facilities in supermarkets; Geothermal fluids; Reduction of greenhouse gas emissions; Ground source heat pump; Aquifer thermal energy storage.

Abbreviations

ASHRAE: American Society of Heating and Air-Conditioning Engineers.
ASTM: American Society for Testing and Materials.
ATES: Aquifer Thermal Energy Storage.
BHE: Borehole Heat Exchanger.
cm^2: square centimetre.

COP: Coefficient of Performance.
CO_2: carbon dioxide.
CU: arbitrary currency units.
EACI: Executive Agency for Competitiveness & Innovation of the European Commission.
EED: Earth Energy Designer.
EER: Energy Efficiency Ratio.
EV: arbitrary energy values for heating/cooling work (instead of MWh).
GHG: Greenhouse Gases.
GSHP: Ground Source Heat Pump.
HVAC: Heating, Ventilation and Air Conditioning.
IEE: Intelligent Energy for Europe.
IGEIA: Integration of Geothermal Energy into Industrial Application.
K: degree Kelvin.
kcal: kilocalorie.
Kg: kilogram.
kW: kilowatt.
kWh: kilowatt hour.
l: litres.
m: meter.
$MtCO_2$: million tonnes of CO_2.
MWh: megawatt hour.
P: Pascal.
PU: arbitrary power unit for heating/cooling capacity (instead of kW).
s: second.
EU: arbitrary emission values for heating/cooling work (instead of kg CO_2).
USA: United States.
W: watt.
WoS: Web of Science.
€: euro.
ʎ: thermal conductivity of the ground.
ºC: degree centigrade.

1. Introduction

Supermarkets are the main retail channel, a consolidated and growing model. They are large energy users, consuming 3% of the total electric energy in developed countries [17]. Within the commercial sector, the entire supermarket type establishments have one of the highest rates of energy consumption per square meter in all commercial and industrial sectors [13].
These establishments consume energy for long periods of time in many ways: heating, cooling, ventilation, lighting, commercial cooling and so on and generate a large amount of greenhouse gas emissions associated with energy consumption. In the United Kingdom, emissions from retail food outlets amounted to 4 $MtCO_2$, which represented 1% of total greenhouse gas emissions (GHG) to the atmosphere [16], these emissions are the causes of climate change. The inherent problems of climate change caused by GHG have led to a change in the sensitivity of energy issues and a growing global concern, which has resulted in international and regulatory agreements aimed at avoiding the generation of GHG. Sustainable development calls for the use of sustainable energy systems [15]. Geothermal, a domestic source of sustainable and renewable energy, can replace other forms of energy use, especially fossil fuels. For many countries, geothermal energy leads to a reduction in their dependence on imported fuel, and for all countries, it means the elimination of

pollutants such as particulates and greenhouse gases [7]. The application of geothermal energy as a source of energy efficiency improvement, reduction of energy consumption and reduction of pollutant emissions to the atmosphere is very attractive in the commercial sector of supermarkets, due to the high-energy consumption, the low implementation of renewable energies and the need to reduce pollutant emissions. Geothermal systems do not pollute the environment because they operate from earth's natural energy and do not alter chemical compounds [10]. The number of geothermal installations has been continuously rising for the past 15 years [2] [5] [7] [8] [12]. Sustainable development requires the use of sustainable energy systems. Therefore, the use of geothermal energy has a triple interest: social, environmental and economical. It constitutes an opportunity to modernise the sector with more efficient equipment, to increase the environmental commitment of the companies, meaning a competitive advantage and differentiation of the same and an opportunity to increase the economic benefit due to the savings in energy consumption [14]. In this article, three cases of geothermal energy use in European supermarkets were analysed, revealing an interesting source of energy. Pretending to serve as a reference to the implementation of renewable energy sources in supermarkets, where related technologies such as aerothermal applied to the production of hot water is being used, but the geothermal energy has not just implemented.

Direct-use of geothermal energy is one of the oldest, most versatile and common forms of utilising geothermal energy 3]. However, only a small fraction of the potential of this energy has been developed, and there is a great capacity for the development of this renewable energy source both for the generation of electricity and for direct applications, among those used in supermarkets, related to heating, cooling and commercial refrigeration.

2. Material and case presentation

A systematic review of the existing literature in different databases for the period 2004-2017 was carried out. The first database used in the December 2016 search was the Web of Science (WoS), including Medline, SciELO Citation Index, KCI-Korean Journal Database, Current Contents Connect, Derwent Innovations Index and Russian Science Citation Index. The searches were conducted using as descriptors, in the subject file, the term "geothermal" AND "supermarket", one article was found. Then, the terms were changed using "geothermal" AND "retail", ten articles were found. The search terms were changed again, using "ground heat pump" AND "supermarket" and the result was four articles. Finally, the terms "aquifer thermal energy storage" and "supermarket" were used, and two articles were obtained. In January 2016, the Scopus database was used to perform a new search, using the same terms used in WoS. With the descriptors "geothermal" AND "supermarket" three articles were found. Applying "geothermal" AND "retail" twenty seven articles were shown. By using "ground heat pump" AND "supermarket" seven results were obtained. And with "aquifer thermal energy storage" AND "supermarket" two articles. From these documents, a choice was carried out in which research, based on the following inclusion criteria was selected: 1º) studies whose objective was the application of geothermal energy in supermarkets; 2º) written in English or Spanish; 3º) that access to the full text of the article was available. We have also analysed a paper published in the European Geothermal Congress 2016, which describes the "economic and technical feasibility of geothermal applications in specific industrial sites such as a supermarket with the support of Intelligent Energy Europe". A total of 2 articles were identified with the inclusion and exclusion criteria discussed.

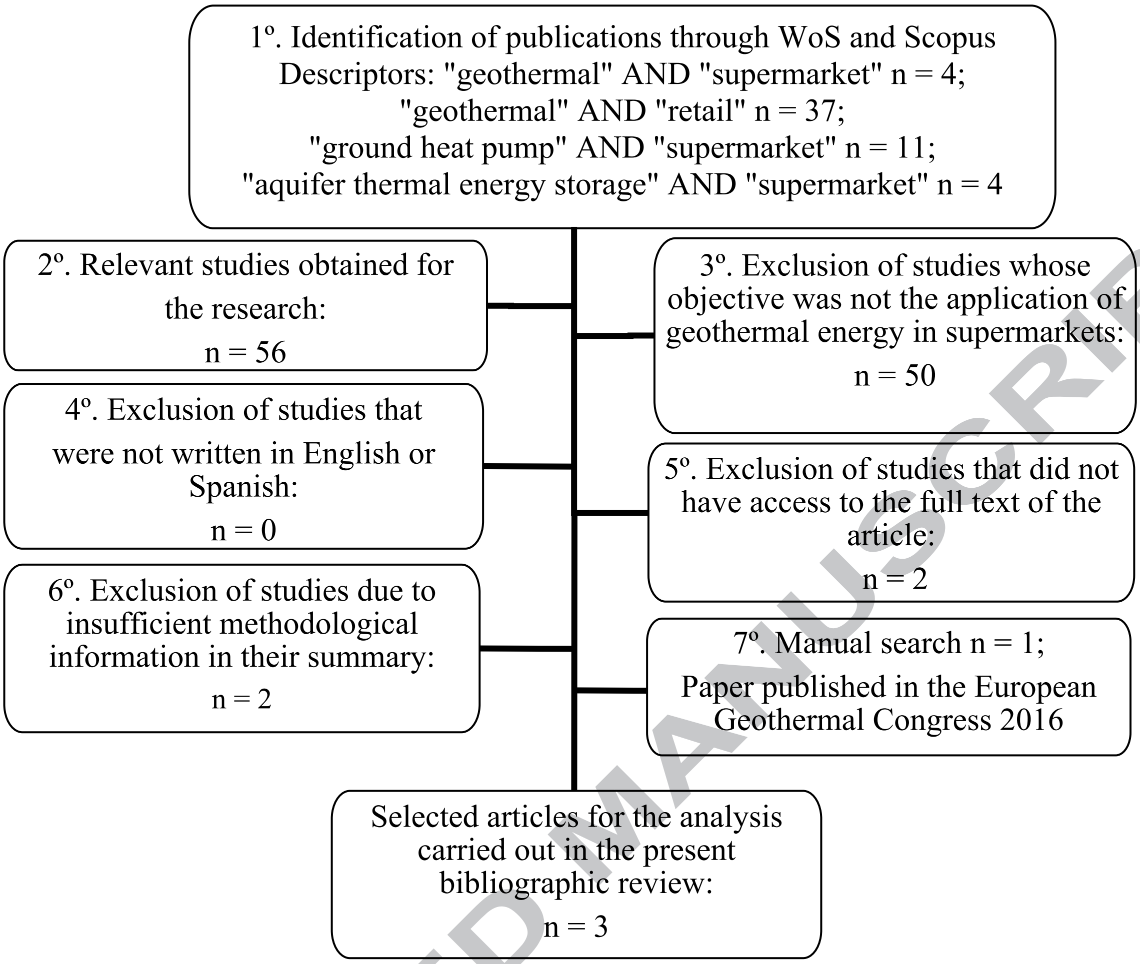

Figure 1. Process of bibliographic review.

2.1. Installation of geothermal energy in a supermarket in Germany

The installation took place in the south of Frankfurt-Germany in 2009, as part of the European Project "Integration of Geothermal Energy into Industrial Application - IGEIA" program under EC EIE/06/001, with the support of the Intelligent Energy for Europe (IEE), Executive Agency for Competitiveness & Innovation (EACI) of the European Commission.
The geology of the terrain consisted of thick layers of gravel, sand and sludge from the quaternary and late tertiary. The thermal conductivity of the ground was estimated on the basis of geology with $\lambda = 2$ W/m·K, value later confirmed using a thermal response test [9].

HVAC needs of the supermarket were calculated as a starting point for dimensioning the geothermal system, choosing a Borehole Heat Exchanger (BHE) installation. It was a system of geothermal probes as heat collectors in an upright position, located inside perforations made in the ground at a depth not exceeding 150 meters [9]. The system is shown in figure 2.

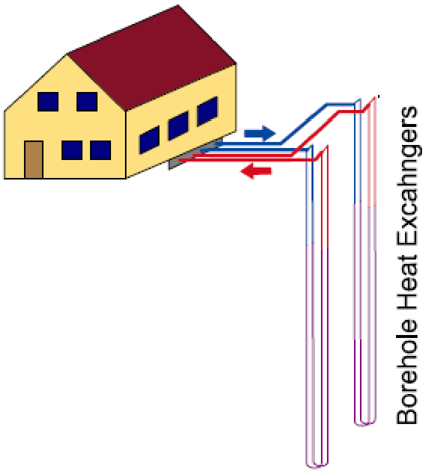

Figure 2. Shallow Geothermal System with Borehole Heat Exchangers (BHE) [9].

This was intended to cover the heating and cooling needs of the supermarket. In order to carry this out, all the heat sources of the establishment (air conditioning and commercial refrigeration) were connected to an intermediate circuit coupled to the heat exchangers of the well.

The heat and cold needs of the supermarket using natural gas for heating and electric energy for cooling are detailed in table 1 and the thermal energy needs of the supermarket using geothermal energy are detailed in table 2. Arbitrary energy values EV for heating/cooling work (instead of kWh or MWh) and arbitrary power units PU for heating/cooling capacity (instead of kW) were used for air conditioning capacity [9].

Table 1. Summary of thermal energy need from the German supermarket [9].

	Annual work (EV per year)	Power (PU)
Space heating requirement	14,690	13.8
Natural gas for space heating	15,460	14.6
Space cooling requirement	942	6.9
Electricity for space cooling	314	2.3
Food cooling, storage, freezing	73,370 EV	18.1
Electricity for food cooling etc.	24,260 EV	6.0

Table 2. Summary of thermal energy need; resulting energy flows from and towards earth (and air cooler) [9].

	Annual work (EV per year)
Space heating requirement	14,690
Heat of the earth (BHE)	10,820
Space cooling requirement	942
Heat into the earth (BHE)	1,130
Food cooling, storage, freezing	73,370
Condenser waste heat (into earth and air)	98,090

2.2. Installation of geothermal energy in a supermarket in Portugal

The installation took place in a 8308 m^2 supermarket located in the Oporto region, on the north coast of Portugal, forming part of the European Project "Integration of Geothermal Energy into Industrial Application - IGEIA", program under EC EIE/06/001, with the support of IEE, Executive Agency for Competitiveness & Innovation of the European Commission.
The geological structure of Porto is the Hesperian Massif with Cambrian material and granites. The supermarket's thermal energy demand depended on the average temperature and solar radiation of the area. In the case of Oporto, the average temperature is between 12.5 °C and 15 °C and solar radiation between 140 kcal/cm^2 and 145 kcal/cm^2 [4].
In order to find out the incidence of the use of geothermal energy in the air conditioning of the supermarket, firstly the heating and cooling needs were calculated using an ASHRAE (American Society of Heating and Air-Conditioning Engineers) certified software: 140-2004 [1]. The results obtained were compared by using a traditional system, consisting of natural gas boilers for heating and a water-cooled air conditioning system complemented by ice benches with the results from the ground source heat pumps system. To estimate the number of perforations, the Earth Energy Designer (EED) software was used and an average value of 60 W/m of extracted heat from the boreholes (75 W/m of heating deliverable into the building). The cooling capacity in summer was covered by the geothermal heat pumps (GSHP) and partly with the traditional air-conditioning system cooled by water and supplemented with ice banks. The number of wells reflected in table 3 was obtained along with the drilling cost of the wells [4].

Table 3. Number of boreholes and total deep results in the Portuguese supermarket [4].

Heating capacity (kW)	256
Delivered power (kW/m)	0.075
Boreholes total depth (approximately) (m)	3,413
Borehole depth (approximately) (m)	150
Number of boreholes	23
Perforation cost (€/m)	35
Total cost of boreholes heat exchangers (€)	120,750

2.3. Installation of geothermal energy in a supermarket in Turkey

The installation took place in a supermarket of 1800 m^2 in 2001, located in the city of Mersin, on the southern Mediterranean coast of Turkey. This was the first application in Turkey that took advantage of Aquifer Thermal Energy Storage (ATES) integrated into an air conditioning system.
The geological structure of the Mersin area entirely belongs to the quaternary period, presenting alluvial detrital material such as sand, gravel, clays and limes.
The climatic conditions of the zone presented a daily average fluctuation at a temperature of 7.4 ºC and conditions for the calculation of the heat loads of 35 ºC of dry bulb and 29 ºC of wet bulb in summer and 3 ºC of temperature of dry bulb in winter. A computer program was used to calculate the maximum demand of air conditioning of the establishment, obtaining the values 195 kW of cooling in summer and 74 kW of heating in winter [11].

Table 4. Turkish heating and cooling needs depending on the type of thermal loads [11].

Type of thermal load	Cooling load (W)	Heating load (W)
Building Components	36,800	34,800

Lighting	18,500	-
People	13,800	-
Ventilation	102,700	47,700
Others	23,200	- 8,500
Total	195,000	74,000

The air conditioning and ventilation system (HVAC) with ATES used the groundwater of the aquifer to cool the condenser of the HVAC system and at the same time, stored the residual heat from the air conditioning process in the aquifer to recover this heat when needed in winter. The total energy that could be stored in this operation was 0.4 MWh [11]. Cooling with groundwater at a temperature of 18 °C instead of air from outside the supermarket, which during the summer could reach 35 °C, meant a significant saving in the energy consumption of the HVAC system. The ATES system presented two groups of wells connected to HVAC system of the supermarket. Each group contained a well with a depth of 100 meters and a shell diameter of 150 millimetres. The distance between the wells was 75 meters. The groundwater was withdrawn from the wells by submersible pumps placed over them. The ATES system was designed to use 4 kg/s of groundwater with an average pump efficiency of 50% and a consumption of 3 kW of electrical energy [11]. The HVAC system used four Scroll compressors connected in parallel to form a refrigerant circuit with several protection devices to avoid overheating and overloading the electric motor. For the operation of the heat pump, each compressor was attached to a reversing valve, subsequently modified to only one larger ball valve to decrease the pressure drop across the valve. The capacity of the system was controlled by the return air thermostat and the high and low pressure sensors. The air handling unit had a double entry curved air fan which was connected to an electric motor of 7.5 kW electric motor. The volume of air was 5500 l/s to 600 Pa of external static pressure [11]. The direct expansion heat exchanger was made of aluminium fins and copper tubes. The total area of heat transfer was 200 m^2 and the front or entrance velocity was 1.6 m/s. The unit could handle 2000 l/s of fresh air, the exhaust unit had the same type of fan connected to a 1.5 kW electric motor. The air volume was from 2000 l/s to 350 Pa of external static pressure. The condenser was a plate heat exchanger with 50 ASTM and 316 stainless steel plates. The total condensation capacity was 200 kW at 35 °C condensing temperature and 4 kg/s water at 20 °C [11].

Table 5 compares the main characteristics of the three geothermal facilities presented.

Table 5. Main characteristics of the three analysed uses of geothermal energy in real supermarkets.

Location	Frankfurt (Germany)	Oporto (Portugal)	Mersin (Turkey)
Geological characteristics of the ground	Gravel, sand and mud Quaternary and Tertiary	Granites Cambrian Hesperian Massif.	Sands, gravels, clays and silts Quaternary
Type of geothermal installation	Closed vertical geothermal with heat pump	Closed vertical geothermal with heat pump	Exploitation of thermal energy from an aquifer
Application of		Heating and cooling	Heating and cooling

geothermal energy	Heating, cooling and commercial refrigeration		
Conventional installations replaced by geothermal energy	Natural gas boiler for heating Cooling air chillers	Natural gas boiler for Heating Partially to the water chillers and ice banks	Air condensation of the HVAC Partly heating with reversible air-to-air heat pump
Data of the geothermal installation	Well depth: 100 m Number of wells: 16	Well depth: 150 m Number of wells: 23	Well depth: 100 m Number of wells: 2

The technologies used in the three cases analysed are still updated.

3. Results

3.1. German supermarket

The commercial cooling system, used to keep perishable foods in perfect condition, generated large amounts of residual heat. In summer part of this heat returned to the ground to recharge the wells and in winter a part could be used in the heating system together with the thermal energy of the land. However, the volume of heat was so large that a part had to be removed by using condensation that used the air from outside the supermarket.
Three possible scenarios with injections of this residual heat in the field were studied, in percentages between 15-65%, obtaining the shortest time of return of the investment when 70% of this residual heat using the ambient air was rejected. Resulting the type of installation of a plant of 16 wells, with a depth of 100 meters each, 2 lines in parallel and double tube U. The results are detailed in table 6. Values estimated are based on generic data for geothermal heat pump systems [9] and can be assimilated to a real currency (euro).

Table 6. Incremental investment cost and annual savings for each percentage of waste heat utilization through geothermal energy.

% Geothermal utilization of residual heat from commercial refrigeration	Incremental investment cost (€)	Annual operation cost savings (€/year)	Payback time (years)
65	140,000	6,000	23
30	80,000	5,000	16
15	35,000	2,000	18

Table 7 shows the comparison between the energy required to satisfy thermal energy needs of the supermarket using geothermal energy and the traditional systems that use electric energy and gas. Arbitrary energy values EV used for heating/cooling work have been assimilated to MWh. The system of geothermal energy had a COP = 4, for cooling and heating, obtaining an energy consumption saving of 45%.

Table 7. Comparison of both conventional and geothermal energy input required to satisfy thermal energy needs of German supermarket [9].

	Annual work	Final energy input conventional (MWh per year)	Final energy input geothermal (MWh per year)
Space heating requirement	14.690	15.460	3.673
Space cooling requirement	0.942	0.314	0.047
Food cooling, storage, freezing	73.370	24.260	18.343
Total	89.002	40.034	22.062
Reduction			45%

Table 8 shows the CO_2 emissions. Arbitrary emission values EU for heating/cooling work have been assimilated to $kgCO_2$. The units are based on the CO_2 emissions for natural gas (0.254) and electric power (0.641) [9]. The values were taken from the guidelines for granting of economic aid from the State of Baden-Württemberg, where they are compulsory for the calculation of CO_2 emissions.

Table 8. Comparison of CO_2 emissions generated using a conventional energy system with a system using geothermal energy for the German supermarket [9].

	CO_2 emissions using a conventional system ($kgCO_2$ per year)	CO_2 emissions using a geothermal system ($kgCO_2$ per year)
Space heating requirement	3,927	2,354
Space cooling requirement	201	30
Food cooling, storage freezing	15,551	11,758
Total	19,679	14,142
Reduction		28%

3.2. Portuguese supermarket

Annual costs by using a geothermal pump with COP = 5, EER = 4 were estimated and compared to the annual costs of the traditional HVAC installation, obtaining the results that are reflected in table 9.

Table 9. Annual energy costs of traditional air conditioning system by using geothermal energy. Savings and payback period using geothermal energy in the Portuguese supermarket [4].

	Air conditioning with geothermal energy	Natural gas boiler and water cooling (chillers)	Annual Savings using geothermal energy
Heating costs (€/year)	3,078	9,415	6,337
Cooling costs (€/year)	4,873	6,362	1,489
Total costs of the geothermal system (€)	120,750		

Payback (years)	15.4	

Table 10 shows the comparison between the energy required to satisfy thermal energy needs of the supermarket using geothermal energy and the traditional air conditioning system using natural gas boiler and water cooling (chillers).

Table 10. Energy required comparison of traditional air conditioning system using natural gas boiler and water cooling (chillers) and using geothermal energy of Portuguese supermarket.

	Natural gas boiler and water cooling (Chillers) (MWh per year)	Air conditioning with geothermal energy (MWh per year)
Space heating requirement	39.013	23.677
Space cooling requirement	48.938	37.485
Total	88.011	61.162
Reduction		30%

Table 11 shows the CO_2 emissions. The units are based on the CO_2 emissions for electric power in Portugal (0.369).

Table 11. Comparison of CO_2 emissions generated using natural gas boiler and water cooling (chillers) with a system using geothermal energy for the Portuguese supermarket.

	CO_2 emissions using natural gas boiler and water cooling (chillers) ($kgCO_2$ per year)	CO_2 emissions using air conditioning with geothermal energy ($kgCO_2$ per year)
Space heating requirement	14,395.80	8,736.44
Space cooling requirement	18,058.12	13,831.96
Total	32,453.92	22,568.41
Reduction		30%

3.3. Turkish supermarket

The conventional HVAC system used an air-cooled condenser with a cooling capacity of 31.8 kW at an outdoor temperature of 35 °C, consuming 898.4 kWh/day to meet the cooling needs of the supermarket in August [11]. The amount of energy consumed was directly proportional to the air temperature outside the supermarket. The higher this temperature the greater the energy consumption for cooling in summer and the lower the temperature in the outside the greater the energy consumption for heating in winter. The HVAC system with ATES used groundwater that was at an average and stable temperature of 18 ºC to reduce the energy consumption needed for supermarket cooling. Obtaining ATES an EER = 4.18, compared to EER = 2.67 obtained with a traditional HVAC system [11].

Table 12. Comparison of a conventional HVAC system and one combined with ATES in the Turkish supermarket [11].

Cooling load (kWh/day)	Energy consumption (kWh/day)	EER

	HVAC	HVAC with ATES	HVAC	HVAC with ATES
2401.5	898.4	574.2	2.67	4.18

Table 13. Annual energy costs of a conventional HVAC system and one combined with ATES. Savings using geothermal energy in the Turkish supermarket.

	HVAC with ATES	HVAC	Annual Savings using geothermal energy
Heating costs (€/year)	11,796.46	6,570.20	5,226.26
Cooling costs (€/year)	17,694.04	11,308.83	6,385.21

Table 14 shows the comparison between the energy required to satisfy thermal energy needs of the supermarket using traditional HVAC system and using HVAC with ATES.

Table 14. Energy required comparison of traditional HVAC system and using HVAC with ATES of Turkish supermarket.

	HVAC (MWh per year)	HVAC with ATES (MWh per year)
Space heating requirement	90.742	57.140
Space cooling requirement	136.108	86.991
Total	226.848	144.131
Reduction		36%

Table 15 shows the CO_2 emissions. The units are based on the CO_2 emissions for electric power in Turkey (0.49).

Table 15. Comparison of CO_2 emissions generated using a conventional HVAC system with a system using conventional HVAC with ATES for the Turkish supermarket.

	CO_2 emissions using HVAC ($kgCO_2$ per year)	CO_2 emissions using HVAC with ATES ($kgCO_2$ per year)
Space heating requirement	44,463.58	27,998.60
Space cooling requirement	66,692.92	42,625.59
Total	111,156.50	70,624.19
Reduction		36%

4. Discussion

The savings in energy consumptions obtained with the analysed geothermal installations are detailed in table 16. In the Turkish supermarket, the savings would have been greater if the generated savings by using the energy stored in the aquifer had been considered. This energy stored could be used for the heating of the establishment through the HVAC system, hence, the energy consumption in winter would be reduced.

Table 16. Percentage of savings in the energy consumptions obtained with geothermal energy in the analysed supermarkets [4] [9] [11].

Supermarket	Savings in energy consumptions (%)
German	45
Turkish	36
Portuguese	30

Energy savings translate into significant savings of CO_2 emissions. These savings are detailed in the following table.

Table 17. Percentage of savings of CO_2 obtained with geothermal energy in the analysed supermarkets [4] [9] [11].

Supermarket	Savings of CO_2 emissions (%)
Turkish	36
Portuguese	30
German	28

Geothermal projects require significant initial economic investment, including wells, pipelines, heat exchangers and so on, their maintenance costs are as traditional systems. However, the costs of geothermal fluids are stable unlike the price of fossil fuels or the price of electric power used in traditional systems.
The return times of the investment are high, due to the higher costs of the geothermal installation compared to a conventional installation of air conditioning and commercial cooling, being between 15 and 16 years. The probable increase in the price of electric energy, the consolidation of geothermal technology since the cost is expected to decrease as its implementation increases. In the present scenario, where legal constraints force the reduction of GHG emissions, it certainly improves the prospect meaning the installation is advisable. The direct uses of geothermal heat with geothermal heat pumps, have a great capacity of growth at world-wide level as shown in table 18, there is also the advantage of being used at normal temperatures of the soil or groundwater (between 5 and 30 °C), therefore its implantation is possible all over the world.

Table 18. Probable growth scenario for direct use of geothermal from 2005 to 2050 [6].

Year	Average annual growth rate from 2005 (%)
2005	--
2010	22
2020	16
2030	12.5
2040	10
2050	9

5. Conclusions

The results obtained in the three cases presented, allow us to obtain the following conclusions about the implementation of geothermal energy in supermarkets:

1. The payback period in geothermal energy vary between 15 and 16 years and depend both on the geological zone of implantation and the type of installation. This period can be significantly reduced in the case of public subsidies for the use of renewable energy, for the expected increase in

the price of energy and for the reduction of the cost of geothermal technology by increasing its implementation.
2. When geothermal energy is used for the air conditioning in supermarkets, the savings in electricity consumption vary between 28% and 36%.
3. Its application is more interesting when the use of this energy source, for the air conditioning in the supermarket, is combined with the commercial cooling, this reduces energy consumption between 30% and 45%.
4. Its use reduces the generation of greenhouse gases resulting from non-industrial energy combustion, with a reduction of CO_2 emissions between 28% and 36%. Its implementation is very interesting to achieve the environmental commitments of reducing GHG emissions that States are obliged to comply with.
5. The use of this energy increases the energy efficiency of the supermarket by reducing energy consumption while maintaining the same levels of comfort of the facilities.
6. It is an established technology which provides high performance in both heating and cooling.
7. The COP of the geothermal facilities in supermarkets analysed is between 4 and 5, always surpassing the more restrictive case established by the current regulations that obligate a COP > 2.95 to be considered as a renewable energy.
8. It satisfies, with normative requirements set in the norms of building for new constructions, as much in the use of renewable energies as in energy efficiency.
9. It has the advantage of being a stable renewable energy that does not depend on the climatic conditions, therefore it is interesting to combine it with other renewable energies that are only available intermittently.
10. The direct use of geothermal energy, using geothermal heat pumps, does not require specific geological conditions and can be used anywhere in the world.
11. Increases the environmental commitment of companies, becoming a competitive advantage and a quality for the consumer.
12. Only a small fraction of the geothermal potential has been developed so far. An increase in the use of geothermal energy for direct use is anticipated, with applications such as those presented in this article for use in supermarkets.

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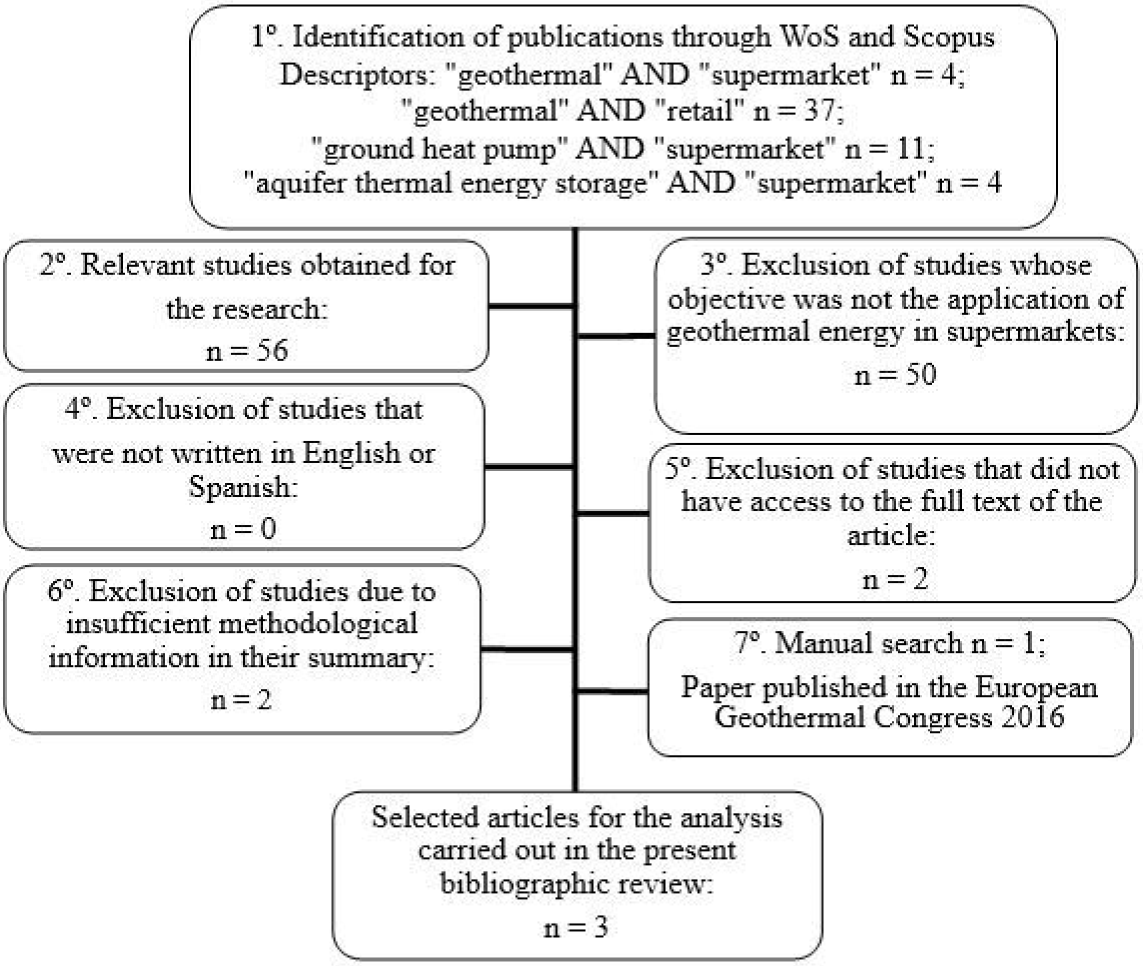

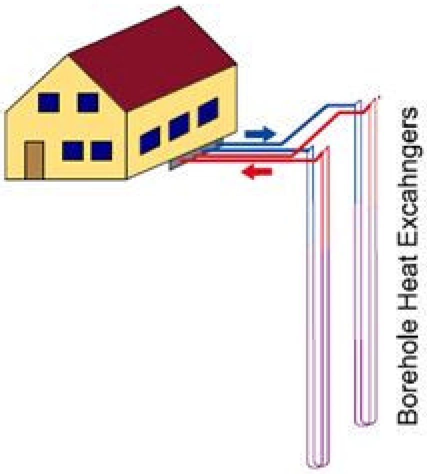

Highlights

- Supermarkets are the commercial models with the highest growth and energy consumption.
- Supermarkets are economically forced to be more energy efficient.
- Geothermal energy is a viable renewable energy in supermarkets.
- Savings are obtained by using geothermal energy for air conditioning.
- Savings improve when geothermal energy is combined with commercial cooling.