Ground Source Heat Pumps in Europe: An analysis of the Geothermal Heat Pumps market

Deliverable D2.1

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GeoBOOST

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Abbreviations

1U, 2U – configuration of heat exchanger with one respectively two loops made of polypropylene pipe.

ATES Aquifer Thermal Energy Storage

BHE – borehole heat exchanger

BTES – Borehole Thermal Energy Storage

CAGR – compound annual growth rate

CAPEX – Capital Expenditure

DTH – down the hole drilling technique

EaaS – Energy as a Service

EG – ethylene glycol

EHPA European Heat Pump Association

ESCO – Energy Service Company

EU European Union

GeoBOOST – Project that promote geothermal heating and cooling

GHP – geothermal heat pump

GHE Ground Heat Exchangers

GSHP – ground source heat pump

MPG – monopropylene glycol

NGO – non-governmental organization

PV – photovoltaic

BWP – Bundesverband Wärmepumpe

SGU – Swedish Geological Survey

SKVP – Svenska Kyl&Värmepumpsföreningen,

Introduction

European countries have emerged as leaders in the utilization of renewable energy, playing a crucial role in mitigating CO_2 emissions and combating the greenhouse gas effect. Over the past two decades, the adoption of renewable energy sources has experienced exponential growth, with geothermal energy being a significant contributor.

In particular, the market for geothermal heat pumps (GHPs) has witnessed a boom, driven by factors such as phasing out natural gas and other fossil fuels. While some countries are actively providing financial support for the establishment of new geothermal installations, others have been slower to do so. The Russian invasion of Ukraine prompted European nations to seek for even greater independence from Russian gas supplies, leading to increased private investments in geothermal infrastructure in east European countries especially during the first year of war.

In order to tackle these questions, two surveys submitted to the GeoBOOST partners are used to assess firstly the possibilities what data are necessary and could be acquired in different countries and secondly to determine the maximum available data about the Ground Source Heat Pump (GSHP) market.

The surveys also monitor the state of the art of the new actors and business models in the shallow geothermal energy. The possibilities for future business models will be published during the task 5.1. of the GeoBOOST project.

It is worth noting that member states that offer financial assistance usually gain access to valuable data related to GHPs, such as underground temperature, geological profiles and heat capacity and conductivity of the geological basement, which can further help to build regional energy strategies.

Methodology

Demographic and geographic scope

The main scope is the comparison of the national habits and future possibilities. the main differences in the applications of GSHPs in different countries is related to varying climatic condition and energy demand profiles as well as differences in underground geological conditions. Important factors are also heating / cooling demand dependent on geographical region.

Differences in geological conditions in European countries result in the presence of different rock types and varying requirements for the selection of different drilling methods to successfully complete GSHP projects. In the case of complex sedimentary successions, the requirements for protection of shallow aquifers necessitate the use of casing to seal off potable aquifers and prevent the collapse of borehole conditions prior to completion of the geothermal collector. This represents a greater challenge to the completion of GSHP systems. In the case of harder rock formations or where groundwater aquifers are less frequent, the completion times are reduced with often the use of drilling methods with faster penetration rates.

People in the different countries might have different earnings, very important is the quality of the buildings, such as highly insulated, low temperature heating, high temperature cooling etc.. Also the different states offer different subsidies.

The primary focus of Deliverable 2.1 is the comprehensive comparison of national practices and prospective opportunities. This analysis delves into variations among countries, encompassing varying climatic conditions/energy demand profiles and the varying geology.

Beyond geological variances, economic disparities among nations contribute to the multifaceted landscape. Divergent income levels among the population and distinct subsidy offerings from respective states add another layer of complexity to the overall analysis. Recognizing these complex factors is important for a nuanced understanding of national drilling practices and potential advancements in the diverse customs under consideration.

Data acquisition

There are notable differences among European countries when it comes to data acquisition and registration of ground source heat pumps. Partner countries such as Finland, the Netherlands, and Sweden have implemented comprehensive systems to register all GSHP installations within their territories. This enables them to gather valuable data and insights related to geothermal energy usage.

However, other countries, including Ireland, Germany, Spain, Poland, and Austria, currently do not have robust mechanisms in place to collect such data. Consequently, the availability of information regarding GSHP installations in these countries is limited.

In most European countries, the installation of new boreholes for geothermal energy exchange requires permission from either local or national authorities. The specific rules and regulations governing the approval process for boreholes vary among different countries. For detailed information on these regulations in each country, please refer to Appendix 1.

Data for the deployment of geothermal energy systems per capita of population was developed as part of this analysis. Population data was obtained from Wikipedia for the year 2023, and the validity of the data was checked in the Worldometers.info database.

Main types of geothermal heat pump system

All the different geothermal heat pump settings are discussed in the technology review D5.1. The deliverable D2.1 deals only with the three main settings

i) vertical close loop,
ii) horizontal loop, and
iii) open loop system.

Among the various types of geothermal systems, the closed loop system is by far the most widely adopted. This system utilizes a closed circuit of pipes containing a heat transfer fluid to extract and transfer geothermal energy. Its popularity stems from its versatility, efficiency, and relatively low maintenance requirements.

On the other hand, open loop systems are less commonly installed. They are typically employed in larger buildings such as offices, large apartment complexes, hospitals, and schools. Open loop systems utilize groundwater as a direct heat source or sink. Although they serve specific purposes for larger energy demands, their installation frequency is comparatively lower.

It is important to note that horizontal loop system, which is the easiest, cheapest and the least efficient type of geothermal system, are often not accounted for in registration processes, resulting in incomplete statistics. From the available information provided by individual countries, the utilization of horizontal loop systems is generally negligible across most nations.

However, it is worth emphasizing that despite their limited representation in statistics, horizontal loop systems may still hold significance in certain localized contexts.

The main end-users and investors

In the dynamic world of GSHPs, diverse end-users and investors play pivotal roles in driving the adoption and expansion of this sustainable heating technology. The market segmentation reveals a nuanced distribution, with small GSHPs predominantly catering to residential structures, while larger-scale installations find prominence in commercial buildings. Below are listed the most important end-users and investors shaping the trajectory of the GSHP market:

Homeowners

Residential GSHP systems are gaining recognition among homeowners seeking efficient and eco-friendly heating solutions. The appeal lies in the cost-effectiveness and environmental sustainability offered by these systems, aligning with the growing awareness of responsible energy consumption among residential consumers. However, most people prefer ASHPs because their cheaper CAPEX are more attractive in residential settings. However, large scale adaptation in housing for ASHP is limited due to electrical load on the network, while GSHP have 2x smaller impact on grid. The developers of the new buildings often choose the free cooling with GSHP, which is much more efficient.

Commercial Building Owners

The scope of GSHP applications extends seamlessly to commercial buildings, where owners recognize the economic and environmental benefits of incorporating these systems. From reduced operational costs to meeting sustainability benchmarks, GSHPs are becoming integral to the heating infrastructure of commercial properties.

Local and State Governments

Governments at various levels are emerging as key stakeholders in the GSHP market. The commitment to sustainable energy practices has encouraged local and state authorities to subsidize the adoption of GSHP systems in their buildings. Through regulatory support and financial incentives, governments are fostering an environment conducive to the widespread integration of geothermal heat pumps in buildings in their cities and regions. On the other hand, local governments also often limit implementation due to environmental concerns installing boreholes.

Energy Service Companies

Energy service companies are actively investing in and promoting GSHP technologies as part of their comprehensive energy efficiency solutions. By incorporating GSHPs into their portfolios, ESCOs are not only meeting the demand for sustainable energy solutions but they also profit from long term extremely high costs contracts for the end user. There are many technical issues in maintenance and operation which can make the heating/cooling network uneconomical.

Utilities

Forward-thinking utilities are playing a crucial role in advancing the GSHP market. Some utilities have proactively implemented programs aimed at encouraging the adoption of GSHP systems, with a particular focus on residential customers. These initiatives not only promote energy efficiency but also position utilities as leaders in the transition towards sustainable heating practices.

The diverse range of end-users and investors in the GSHP market emphasizes the technology's versatility and widespread applicability. As residential and commercial stakeholders, along with government entities and energy-focused companies, continue to invest in geothermal heat pumps, the overall market is self-adjusted for sustained growth and a more sustainable future in heating solutions.

On the other hand, the long term contacts limits the diversity of energy supply on the market, which can lead in increase of the energy prices.

New actors

The shallow geothermal energy is experiencing worldwide exponential growth with the emergence of diverse actors, each contributing to the sector's growth and innovation. Traditional oil and gas industry is increasingly venturing into shallow geothermal projects, leveraging their expertise in (deep) subsurface technologies.

New investors

Many companies and private investors found GSHP industry rising and funding bigger project. Many house owners investing individual, small GSHPs to heat and cool their property. Commercial banks profit from loans that are offered to other investors.

New energy suppliers

Energy suppliers are recognizing the potential of shallow geothermal energy as an exploitable and sustainable source. New projects are cropping up, driven by a combination of technological advancements and a growing awareness of the environmental benefits of geothermal systems. Investors, both traditional and new to the field, are recognizing the economic feasibility of shallow geothermal energy, injecting capital into innovative projects.

Energy companies are diversifying their portfolios by incorporating shallow GSHP systems, emphasizing a commitment to cleaner energy alternatives. Academic institutions are actively engaged in research and development, fostering the knowledge base and technological advancements in shallow geothermal applications.

PV groups

Interest of photovoltaic (PV) groups in geothermal systems as an energy storage is evident. Both institutional and private investors, are increasingly attracted to the promising yields and sustainability aspects of shallow geothermal projects.

The PV-geothermal hybridization might be supported by PV panels to the HPs, thermal panels to the domestic hot water production and the ground heat exchange collector. This combination requires smaller ground source heat exchangers, which reduces the initial capital outlay of the system and increases versatility and efficiency of the installation by balancing the amount of re-injecting heat into the ground during the summer with the energy demand.

Non-Governmental Organizations

Many NGOs are playing an essential role in advocating for sustainable practices, influencing policies, and supporting initiatives that promote steady growth within the shallow geothermal energy sector.

Every year, other NGOs organize demonstrations against the CO_2 production, because the CO_2 emission is the major reason for the visible climate changes and air pollution. GSHPs in combination with other renewable energy sources helps to mitigate (or slow down) climate change.

During the air-source heat pump boom in the city centres, the outside units were installed in backyards surrounded by solid walls resulting in increased noise levels often above the accepted background[1] for day time and night time levels[2]. The noise reaches higher levels than health limits allow. As a result of this problem, an increasing number of neighbours, local communities or NGOs are opposed to the installation of ASHPs and thus they also indirectly support GSHPs.

Oil and gas industry

The traditional major oil and gas industry players are taking part in energy transition. They promote their expertise with directional and horizontal drilling, reservoir engineering techniques. They might be more efficient in the field of deep drilling over the classical water well drillers. However, these modern methods are more expensive and the classical drilling companies dominates the market with the drilling for the depth at least up to 500 metres.

Services companies and equipments manufacturers in oil and gas are also providing services (design) and furnitures (pumps, pipes, fluids) for geothermal systems.

IT companies and artificial intelligence

All the data centres of IT companies such as Google, Amazon or Microsoft are extremely energy-intensive for running and cooling the servers, which have huge impact on electricity

[1] https://www.umweltbundesamt.de/en/press/pressinformation/heat-pumps-the-like-low-frequency-hum-annoys-a

[2] https://sorama.eu/air-conditioners-and-heat-pumps-can-cause-noise-pollution

grid. To combat these problems Google invested vast amount of money into the renewable energy and became a player in the development of deep geothermal energy.

Artificial intelligence is becoming as a new player among geothermal energy sources. It can play major role in the state scale in order to equilibrate the demand by switching on and off the earth- or air-sourced heat pump, with intermittent renewable sources (such as solar and wind) and the peaking power plant such as gas and modern geothermal powerplants.

Traditional industry

The classical industrial companies are becoming invest in production of geothermal systems. One of the leaders on the market is the Flygt (Xylem) pump factory in Emmaboda (Sweden) that is the biggest producer of waste water pumps, this factory currently focus on the pumps for geothermal energy. Other examples include Siemens or Viessmann that produce high quality brine-water or water-water heat pumps.

Academic institutions and R & D

Many geologist and geophysicist focusing on geothermal energy, they are dealing with projects on evaluation of the geothermal potential. They are modelling geological situation in 3D view, so the drilling companies would not drill into the collectors with artesian water, salt or anhydrite diapirs. They also study the chemistry of different water collectors, because the possible precipitation of newly form minerals due to water mixing especially during the open loop system.

Investment trends in EU

Investment trends in the EU for ground source heat pumps are reflecting a broader interest in clean energy alternatives and efficient space heating technologies. In 2023, the European heat pump market was valued at EUR 15.9 billion and is projected to grow at a compound annual growth rate of 18% between 2024 and 2032[3]. This growth is driven by increasing demands for energy-efficient units in residential and commercial sectors and the ongoing replacement of existing heating systems to reduce carbon emissions. Despite a slight downturn in heat pump sales by around 5% in 2023 due to high interest rates, expensive electricity, and changing national policies, the market is expected to rebound. The European Heat Pump Association (EHPA) emphasizes the importance of rapid publication of the delayed EU Heat Pump Action Plan and adjustment of taxes and levies on energy to ensure continued growth in the sector.

These trends underscore the EU's commitment to transitioning towards clean energy alternatives and reducing its carbon footprint. Key manufacturers and stakeholders in the heat pump market are actively investing in new technologies and expanding manufacturing capacities to meet the growing demand for efficient, eco-friendly heating and cooling solutions.

Renewable energy systems

Investment trends in ground source heat pumps across the EU are increasingly aligning with the region's commitment to renewable energy systems, showing a robust move towards cost-saving and environmentally friendly heating solutions. Ground source heat pumps, recognized for their efficiency in harnessing the earth's stable temperatures, are becoming a keystone of sustainable energy strategies.

Energy Service Companies

ESCOs, established by a coalition of investors, utilities, and local action groups of homeowners, are playing an essential role. These entities not only facilitate the transition to energy-efficient solutions but also oversee the implementation of comprehensive energy projects, including the installation of ground source heat pumps.

[3] https://www.gminsights.com/industry-analysis/europe-heat-pump-market

Heat pump replacements

The market dynamics reveal a preference for new installations over replacements, indicative of a growing awareness and adoption rate. For instance in Sweden, according to Swedish Refrigeration & Heat Pump Association, approximately 70% of the installations are new and 30% are the replacements for older installations.. This shift underscores a broader acceptance and integration of ground source heat pumps in new building projects, attributing to their long-term benefits over conventional heating systems. Also, modern heat pump system can achieve higher temperatures and therefore are more suited for retrofit.

Move to large installations

Countries like Austria are witnessing a trend towards larger installations, which involve deeper boreholes and more extensive borehole heat exchanger fields than seen in previous years. This evolution points towards an ambition not only to meet the current demand for renewable heating solutions, but to anticipate for future requirements. The integration of low temperature grids is becoming common, enhancing the efficiency and applicability of ground source heat pump systems in a variety of settings.

Hybridisation

Another trend is the coupling of geothermal heat pumps with other renewable energy sources, such as solar thermal or photovoltaic (PV) systems. This hybrid approach maximizes energy efficiency and sustainability, offering a versatile solution that adapts to different energy needs and conditions. Even that hybridisation is still a leading trend in some countries, in the countries with mature market such as Netherland the combination of different methods is the declining, and the geothermal heating and cooling is the best solution on its own.

The main market drivers

The main market drivers for GSHP systems are deeply rooted in energy efficiency and environmental sustainability, reflecting a growing consensus on the urgent need for cleaner, more sustainable heating and cooling solutions. At the forefront, the superior energy efficiency of GSHP systems, makes them a compelling choice for both new constructions and building retrofits, aiming to significantly reduce energy consumption and operational costs. Environmental concerns, particularly those related to climate change, air pollution, and the transition towards low-carbon technologies, further accelerate the adoption of GSHPs, aligning with global efforts to mitigate environmental impacts.

Building regulations across the EU increasingly mandate higher energy efficiency standards, compelling the integration of technologies like GSHPs into both new and existing structures. Government incentives play a critical role in the market, with various forms of financial support—such as subsidies, tax credits, and low-interest loans—making GSHP installations more accessible and appealing to a broader range of users.

GHE and GSHP are the best solutions for cooling, passive cooling and storage of thermal energy from summer to winter. Only GSHP and shallow GHE can be used so efficiently for house climatization and no other technology can be used at the same scale!

The pursuit for independence from Russian gas, especially pronounced in Central European countries, has emerged as a significant market driver, underscoring the strategic importance of diversifying energy sources to enhance energy security. While South-Western European countries exhibit less dependency on Russian gas, the push for GSHPs in these regions still aligns with broader energy efficiency and environmental goals. Additionally, GSHPs are favoured for their lower impact on the electrical grid compared to air-source HP equivalents, presenting a more grid-friendly alternative that complements the EU's overarching energy strategy.

To sum up, the market consists of these drivers:

1. Energy efficiency of the GSHP systems
2. The extreme efficiency in cooling, including the passive cooling
3. The cheapest energy storage on the yearly basis
4. Environmental concerns: Climate change, air pollution and a low-carbon technology
5. Building codes and regulations are increasingly requiring higher energy efficiency standards for new construction and building retrofits.
6. Government incentives: e.g., financial incentives for GSHP installations, including subsidies, tax credits, and low-interest loans.

7. Independence of Russian gas
8. Lower impact on electrical grid than air-source equipment.

Market models

Ground Source Heat Pumps (GSHPs) are at the forefront of sustainable heating and cooling solutions, garnering attention across diverse sectors. This deliverable presents a comprehensive market model, encapsulating the intricate dynamics influencing the GSHP industry. Key influencers include business demand, private investors, district heating, city planning, environmental and state regulations. The technology is shaped by ongoing research and development, innovation, best practices, employee training, and an overarching focus on energy efficiency. Financial considerations, encompassing risk mitigation, state incentives, savings, bank loans, and mortgages, are pivotal in determining the viability and scalability of GSHP projects. Furthermore, industry players, ranging from installation companies to heat pump manufacturers, contribute to the ecosystem's growth and innovation as presented in Figure 1.

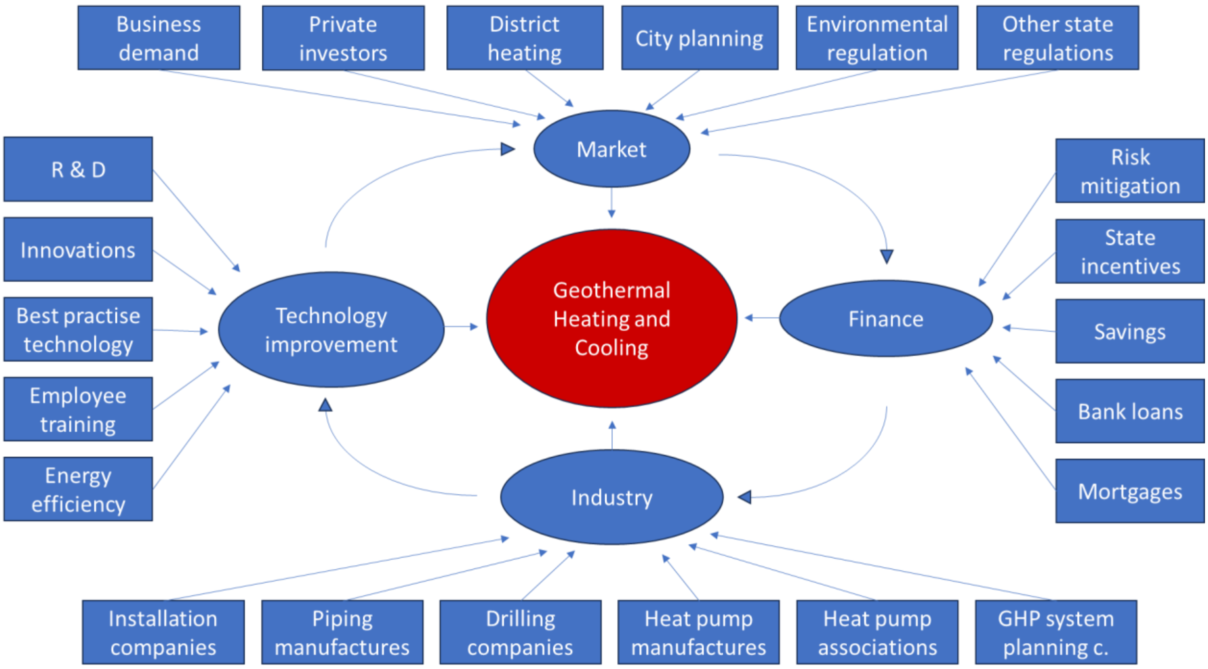

Figure 1.Market model for GSHP *with the main players and processes*

Financial entities such as private investors, banks, investment companies, and funds, along with communities, cities, and local energy suppliers, form a crucial support network. Private investors play a decentralized role, contributing individually to GSHP projects, while banks offer financial products and loans for system development. Investment companies and funds facilitate large-scale initiatives, and communities, cities, and local energy suppliers collectively invest in and support GSHP projects. Energy providers, ranging from single installations to main energy suppliers and integrated heating and cooling grids, ensure the broader integration of GSHPs into diverse energy portfolios. The end users, including private consumers and companies, benefit from the sustainability and cost-effectiveness of GSHPs, emphasizing their role in shaping the energy landscape as depicted in Figure 2.

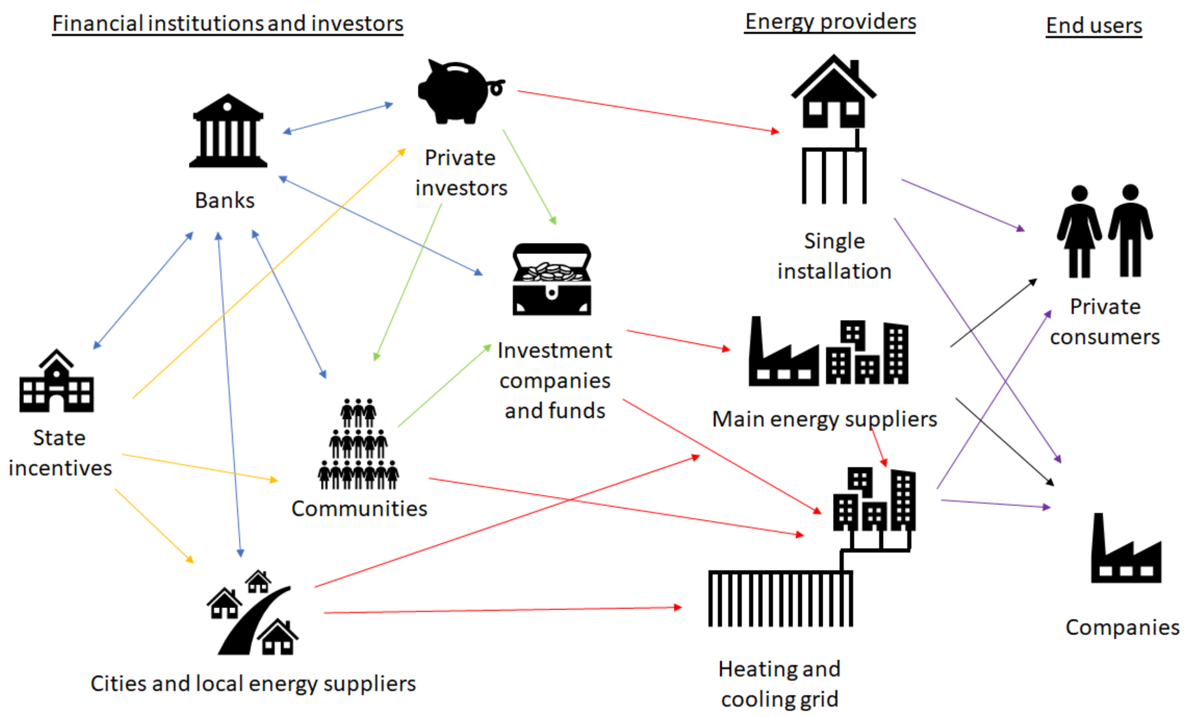

Figure 2. Relation between the market players

Performance-Based Contracts and ESCO Models: These companies offer performance-based contracts or very similar pay-as-you-save model, where they install, operate, and maintain ground source heat pump systems for clients. The payment should be based on the actual energy savings achieved, providing an incentive for the provider to optimize system performance. However, in many cases the providers are making the profit, while the house owners can not change the technology, or the energy company.

Smart Technologies Integration: The methods involving integration of smart technologies and data analytics into ground source heat pump systems are developed in university of Bergen in Norway. These methods could include predictive maintenance services, optimizing energy consumption, and enhancing overall system efficiency, which are set on the municipal level.

Financing and Leasing Models: Offering financing options or leasing arrangements for the installation of ground source heat pump systems can make them more accessible to a broader range of customers. This model allows clients to avoid high acquisition costs and pay for the system over time.

Community-Based Projects: Collaborative projects within communities, neighbourhoods, or business districts can be developed, where all the partners benefit from a centralized ground source heat pump system. This can be particularly effective in urban planning and large-scale developments. Community-Based Projects business model is commonly used in Denmark.

Energy as a Service (EaaS): Several companies are providing thermal energy rather than selling equipment. They offer a complete package, including design, installation, maintenance, and energy supply, and charge customers based on the delivered thermal energy.

Government Incentive Programs: Businesses may often use models with government incentive programs for renewable energy installations. This can include leveraging tax credits, subsidies, or other incentives to make the implementation of ground source heat pump systems more attractive.

Closed loop systems (including piles)

Average depth of Borehole Heat Exchangers

In the majority of countries, the average depth of borehole heat exchangers (BHEs) closes the maximum permissible length, even in the countries where are special permits for longer boreholes, majority of drilling companies prefer the shorter bore holes with easier approval procedure. Consequently, the prevalent average depth across many nations is around 100-300 meters. Notably, in countries such as the Netherlands, Sweden or Switzerland, where regulatory limits are higher, the average depth extend significantly, reaching up to 200 meters to meet the real demands of geothermal applications. In Germany, for the boreholes deeper than 100m is necessary to apply according more complicated mining law is average depth much lower. However, the rules in Germany will be changed during the year 2024, which offer much easier planning possibilities for deeper wells, as seen in figure 3. The graph shows average length of ground sources heat exchanger.

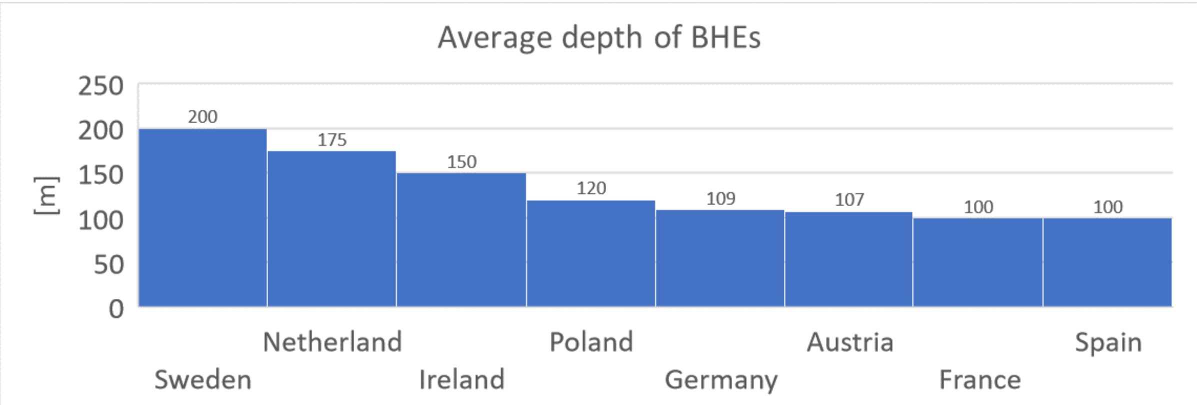

Figure 3. Average depths of BHEs

Number of heat pumps among the selected countries

The prevalence of Ground Source Heat Pump (GSHP) installations per 1000 people exhibits significant disparities across countries. The most mature market in adopting GSHP technology are in the Scandinavian countries, where the ratio stands at an impressive 50 installations per 1000 people. This suggests a remarkable trend, with approximately a five percent of the population actively harnessing geothermal energy through these systems.

The graph in figure 4 shows that Sweden has significantly more mature market with GSHP installations than any other country.

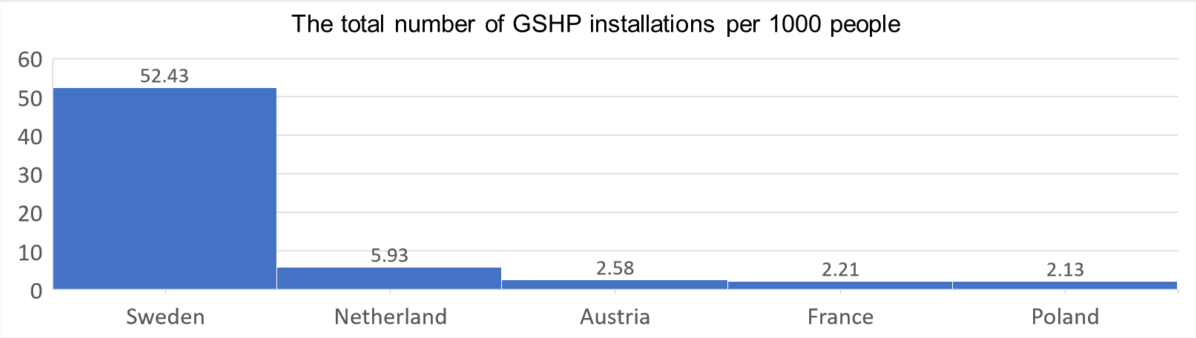

Figure 4. Total number of GSHP installations per 1000 people

In contrast, France and Poland lag behind in GSHP adoption. France's lower installation numbers may be attributed to its predominantly mild climate, with some residents without heating altogether, while others, facing only occasional heating needs, resort to small electric radiators. Poland, on the other hand, is still in the early stages of embracing renewable energy, making it a less mature market in this regard. Other reason for not implementing geothermal energy in these countries is low price of electricity, that is produce by nuclear or old coal powerplants, respectively. The problem is also a pure quality of house insulation, which disable the use of low temperature heating system. Furthermore, the absence of legislative requirements in Poland regarding information on newly installed heat pumps contributes to the slower uptake of GSHP technology.

The vast differences in GSHP adoption rates among countries underscores the influence of climate, cultural practices, and regulatory frameworks on the implementation of sustainable energy solutions. As the global landscape evolves, these variations highlight the need for targeted strategies and policies to promote the widespread integration of environmentally friendly technologies like GSHP systems.

Major types of circulation media (anti-freezing liquids) being used (estimation)

In Central Europe, the prevalent choice for circulation liquid in geothermal heat pump systems is often a 25% or 33% solution of ethylene glycol. However, Sweden use ethyl alcohol, because it has lower viscosity than MEG and MPG solutions, especially at higher concentrations. In the Netherlands both MPG and MEG are common.

Conversely, Spain, characterized by generally higher ground temperatures compared to other parts of Europe, adopts a nuanced strategy based on local climate conditions. In areas where ground temperatures range between 15-20°C, the use of anti-freezing agents is often omitted, and regular water serves as the circulation medium. However, the GHE with only water without antifreeze agents need to be designed for higher temperatures and to have a proper balance between heating and cooling.

However, in colder regions of Spain, where ground temperatures fall below 15 degrees, the inclusion of anti-freeze becomes recommended to ensure the effective and reliable operation of geothermal heat pump systems. This tailored approach underscores the significance of adapting system components to the unique climatic characteristics of each geographic region, promoting both efficiency and sustainability in the utilization of geothermal energy.

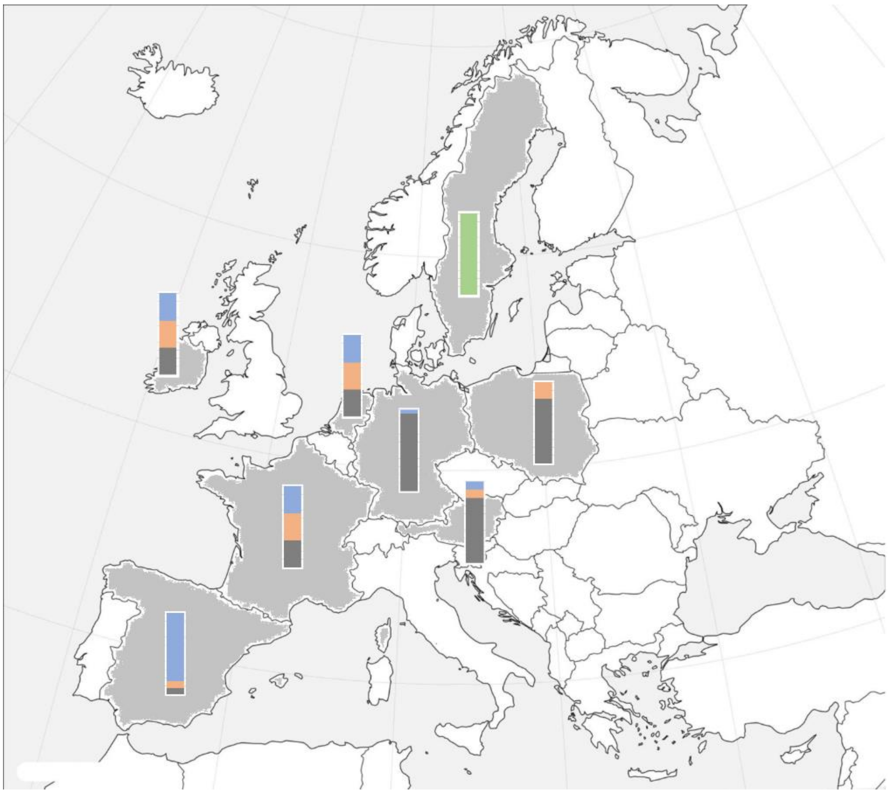

Figure 5. Circulation media among different countries.

In Figure 5, the colours refer to:

red - propylene glycol water solution, grey - ethylene glycol water solution, green - ethyl alcohol water solution in bio-quality, blue - pure water.

The data was acquired during a survey among the GeoBOOST members.

Typical borehole diameter

The borehole diameter for geothermal systems primarily depends on the rock type, borehole depth, and local or national regulations regarding grouting thickness. In igneous and metamorphic rocks, the drilling diameter can be smaller due to the strength of these rock walls, which are capable of maintaining structural integrity. Conversely, sedimentary rocks often require a wider borehole to accommodate casing that prevents wall collapse. The upper section of deeper boreholes typically needs to be wider to fit the casing installed for technological reasons, whereas the lower part may be narrower, especially when a single U configuration of polypropylene tube heat exchangers is used. The thickness of the grout applied around the heat exchanger significantly affects the overall borehole diameter. Regulatory practices vary by country; for example, in Sweden, grouting is not mandatory, allowing for narrower boreholes that simply need to accommodate the heat exchanger. In contrast, Germany mandates a minimum of 30mm of grouting around the heat exchanger, necessitating a borehole diameter at least 38mm larger than that in Sweden.

Table of typical borehole diameter in different countries, and presented in graph figure 6.:

Austria	- 152 and 168 mm
France	- 145 or 165 mm
Germany	- 152 to 168 for igneous
	- 178 and more for sedimentary rocks
Ireland	- 152 mm
Netherlands	- 140 – 180 mm
Poland	- 110 for DTH
	- 136-142 (1U) and 162-186 (2U) for sediments
Spain	- 110-150 mm
Sweden	- 114 mm most common, sometimes 139 mm

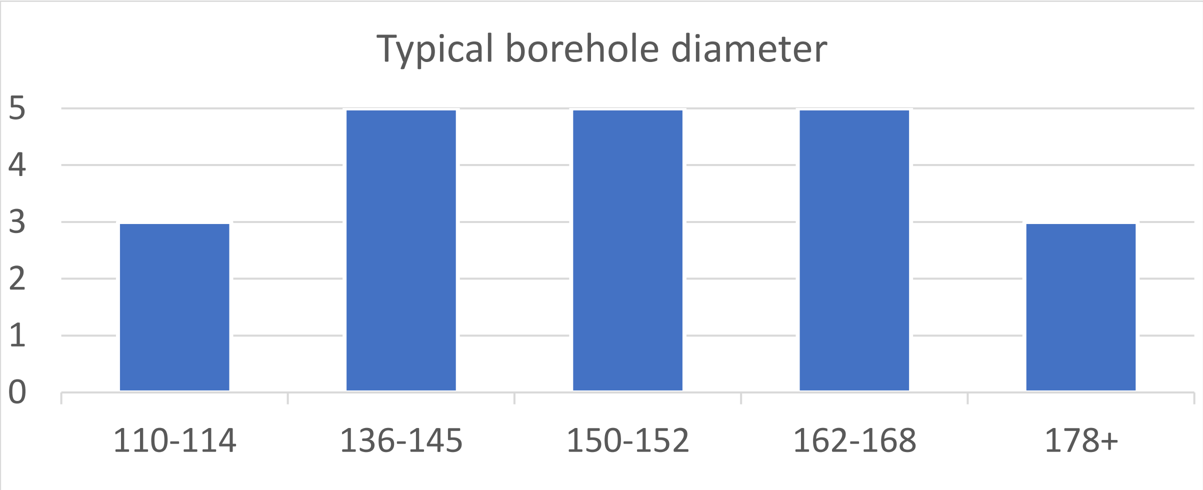

Figure 6. Typical borehole diameter among studied countries.

Different columns represent the range of borehole diameter. The vertical axis represents the number of GeoBOOST countries that use these diameters.

General cost of the installation per meter (EUR/m).

The price of drilling depends on the borehole diameter, drilling type, automation or number of workers necessary for the operating of the drilling machine and also average wages in the country. The borehole backfilling requirements are also very important. But one of the most important factor is state of the market itself (current supply versus demand).

The lowest prices are in the Netherlands, where is the highest automation. The second lowest prices are in Sweden, where are generally narrower boreholes are used during the drilling and completion process. The third lowest prices are in Poland, where the human power is cheaper than in more other GeoBOOST countries. The most expensive prices are in Germany and France.

The cost of drilling depends on several factors: the borehole diameter, the type of drilling, the level of automation, the number of workers required to operate the drilling machine, and the average wages in the country. The lowest prices can be found in the Netherlands, which has the highest level of automation. The second lowest prices are in Sweden, where boreholes are generally narrower. The third lowest prices are in Poland, where labour costs are lower compared to most other GeoBOOST countries. The highest prices are observed in Germany and France, where the boreholes are wider, the labour price is the higher and the competition between the drilling companies is not so high.

The price of drilling and installation costs of one-meter Geothermal Heat Exchanger in different countries:

Austria	**70 – 80** for singular family homes (lower costs for bigger installations)
France	**100**
Germany	**90 – 130** (drilling, probe and grouting)
Ireland	**56 – 62** (drilling probe and grouting)
Netherlands	**25 – 35**
Poland	**35** (drilling, grouting, probe and glycol)
Spain	**75 – 85** borehole complete (borehole, probe and backfill) (without lost casing)
Sweden	**30 – 32** for drilling (collector, ground install, digging not included)

Average cost of installation is highest in France and Germany, while lowest in Sweden and the Netherlands as shown in figure 7:

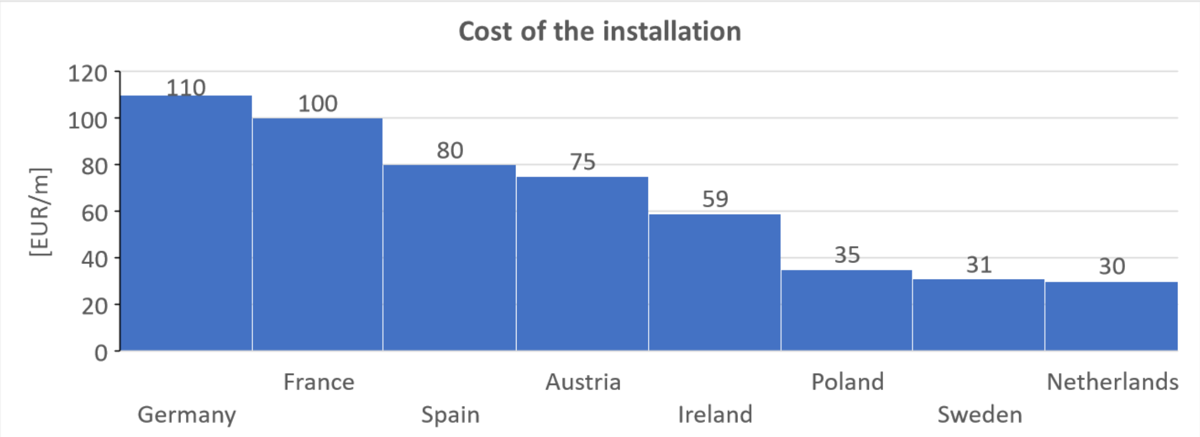

Figure 7. Average cost of installation

Databases of the installations

All GeoBOOST countries has some official registries for boreholes or geothermal heat pumps. Often the databases are not complete. Very often there is a special registry for each federal state or municipality. The best databases are in Sweden and the Netherlands, while the poorest databases are in Poland & Ireland, where reporting of newly drilled of GHE is not obligatory in majority of cases.

- **Austria** - Water Registries in most of separate states
- **France** - Installations which need a regulatory existence
- **Germany** - Some states have database
- **Ireland** - Only database Geothermal Association of Ireland for Commercial Systems
- **Netherlands** - All, registration required by law since 2013
- **Poland** - Around 5% of all installations are saved in the National Geological Archive
- **Sweden** - SGU Brunnsarkivet, only the Boreholes. It is possible to obtain data on all installations, since it is public, but it's necessary to check around 250 municipalities and request data

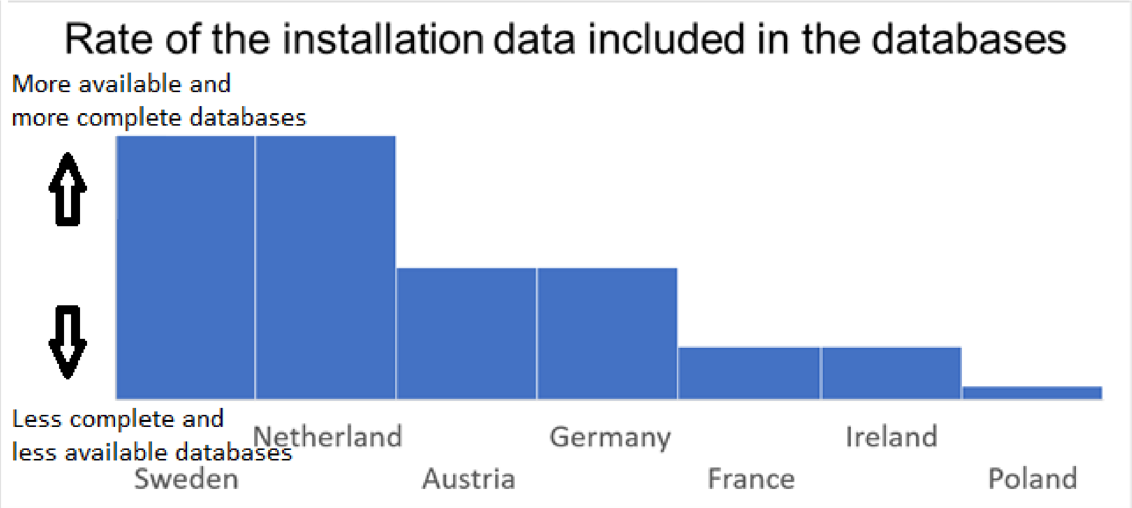

Figure 8. Availability of the data about the installation of the GSHP installations.

The graph 8 is based on the questionary. The value of the column represents the quality of the statistical data available in database about GSHP installations.

Heat exchanger diameters

Countries Austria, Germany, France and Spain prefer the heat exchanger mostly in double U configuration. On the other hand, in Ireland, the Netherlands, Poland and Sweden the use single U configurations is more common. When the double U configuration is used the pipe diameter is 32mm. While the single U configuration is installed the pipe diameter ranges between 32 and 50 mm, the most common diameter is 40mm. When deeper probes are installed, the diameter is almost always between 40 and 50 mm.

Main types of probes	Austria	France	Germany	Ireland	Netherland	Poland	Spain	Sweden
Type of probe is being commonly used	Double U32	Double U32	Double U32	PE100 - single U 40mm	Single U probes dia. 32 – 40 mm - mainly PE-RC	Single U probes Ø40 mm - mainly PE-RC	Double U32	Most common simple-U, 40, 45 and 50 mm, sometimes Double-U 32 mm
Type of probe is being used, for deeper BHE (125m).	Double U32mm x 2,9 mm	Double U32	Double U40	PE100 - single U 40mm	Single U probes dia. 32 mm - mainly PE-RC	Single U probes Ø40 mm - 45 mm, mainly PE-RC	Double U32	Most common simple-U, 40, 45 and 50 mm, sometimes Double-U 32 mm
Type of probe is being used, for deeper BHE (200m).	Double U40mm x 3,7mm, double U50mm for down to 400 m	Double U40	Single U40 or U50	As above - but PEX probes occasionally used	Single U probes dia. 32 mm - mainly PE-RC	Double U Ø40 mm - PE-RC or PE-Xa, Single U Ø45 mm - PE-RC	Not used in Spain	40 mm up to 250 m, 45 mm up to 320, after that 50 mm

Table 1. Summary of the preferred heat exchanger design.

Open loop systems

France leads in the number of open-loop geothermal heat pump systems, leveraging its substantial geothermal resources (figure 9). However, Austria and the Netherlands boast the highest per capita deployment of heat pumps (figure 10), attributed to their geological advantages. In these countries, the majority of the population resides in areas with sediment-rich terrain near lakes or seas, which facilitates the efficient use of geothermal heat pumps for sustainable heating and cooling solutions, reflecting their commitment to green energy and environmental sustainability.

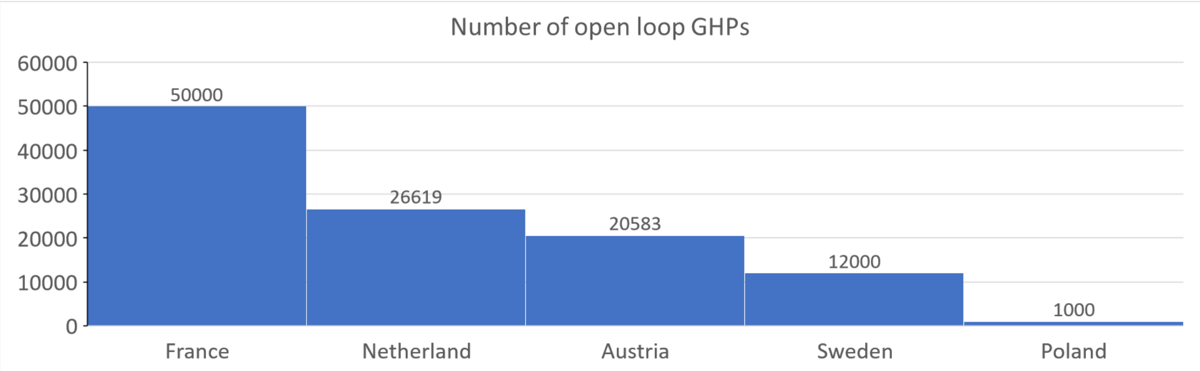

Figure 9. The total amount of open loop systems in different states

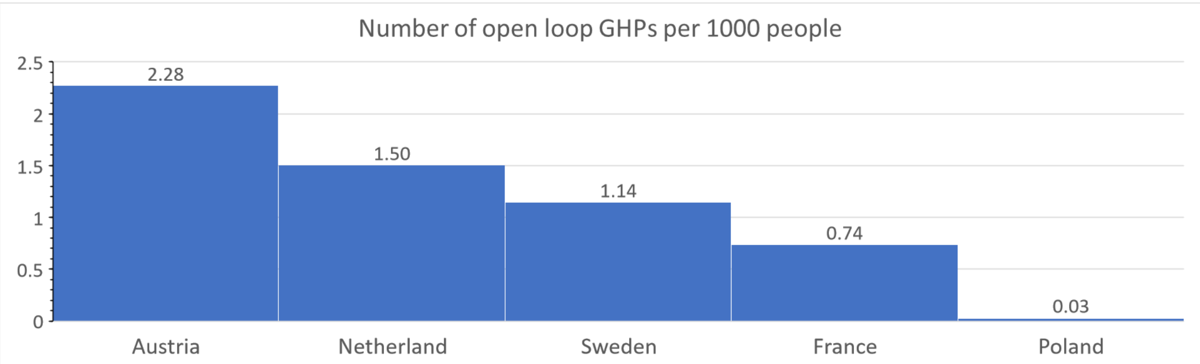

Figure 10. Number of open loop systems per 1000 inhabitants in different Member States

Open-loop systems are predominantly utilized in large-scale installations, such as those found in commercial buildings or industrial applications. These systems offer a practical solution for managing temperature control and energy efficiency on a bigger scale. In contrast, single-family residences seldom use open-loop systems, mainly because the open loop system is not economical for single family houses even in collective systems. Also considering the risk, lots of maintenance and shorter lifespan compared to closed loop. one of the exceptions is Bavaria, where local regulations or environmental concerns limit deep drilling activities. These legal and ecological requirements often influence the choice of heating and cooling systems, pushing homeowners towards alternatives that comply with local guidelines while still meeting their energy needs. Figure 9 shows an approximation of the predominant users of open loop system.

Average number of inlet and outlet wells

Open loop systems, often used in a doublet (reversible extraction and injection well) for seasonal heating and cooling need to keep the wells hydraulically/thermally separated to avoid thermal interaction. Poland, however, often adopts a more extensive setup for its larger installations, using two pairs of doublets. The need for one or two doublets is governed by the energy demand of the system, and the pairing of the aquifer properties with the requirements of the HP flow rates on the primary side. This means that higher productivity sedimentary aquifers require (but not always) a lower number of doublet pairs to achieve the desired flow rate, whilst lower productivity aquifers will require several pairs.. The Netherlands stands out for incorporating an additional spare borehole to its standard one inlet and one outlet setup. This innovative approach ensures operational continuity during maintenance and allows for selection flexibility based on thermal performance, thereby optimizing the system's overall effectiveness.

The number of inlet and outlet wells of the open loop system is presented in figure 11:

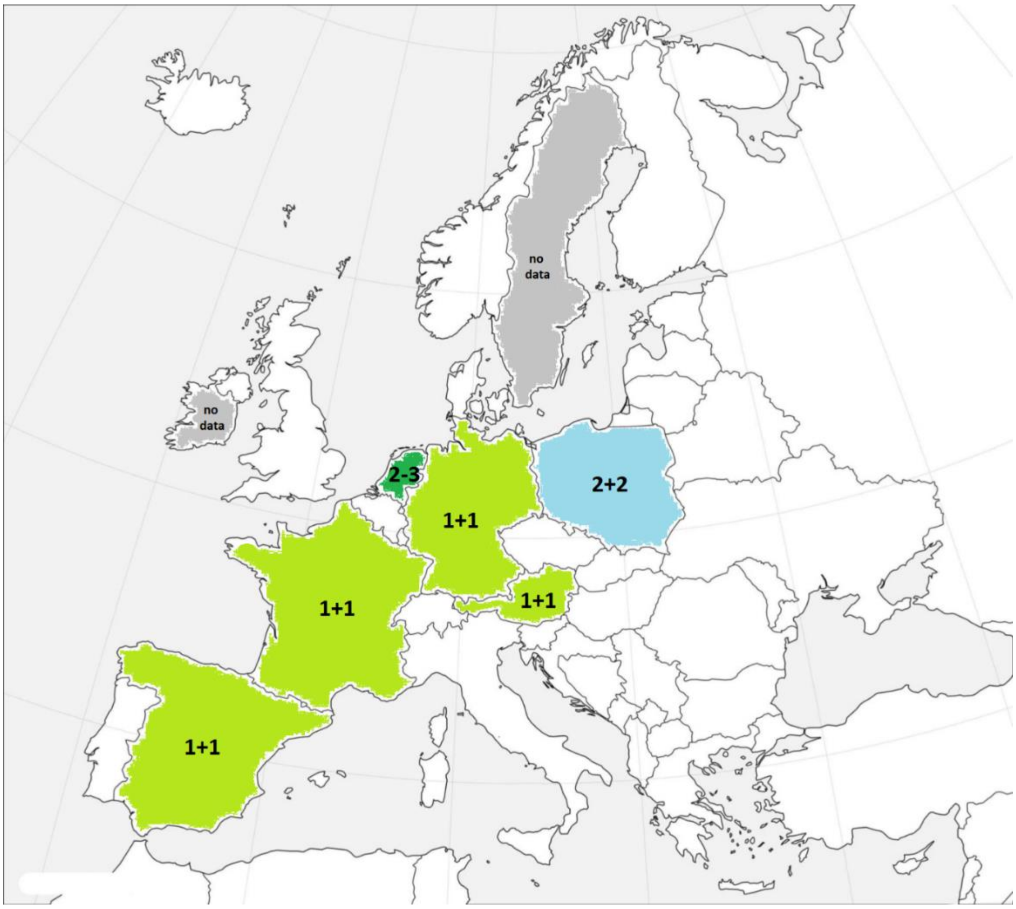

Figure 11. The number of inlet and outlet wells of the open loop system.

Databases dealing with open loop systems

Across numerous countries, databases documenting hydrogeological boreholes exist, yet they commonly exhibit incomplete information and frequently operate only on a regional scale. The intricacy lies in the fact that boreholes specifically designated for geothermal energy extraction often lack distinct differentiation from conventional water wells. This complicates the task of accurately cataloguing geothermal resources and also underscores the need for enhanced data integration and standardized documentation. The challenge extends beyond mere availability to encompass the classification and identification of geothermal-specific boreholes within the broader spectrum of water wells. Addressing this issue is pivotal for optimizing the utilization of geothermal energy resources and facilitating comprehensive, nationwide assessments that can inform sustainable energy strategies. Efforts to refine and expand these databases are essential to harnessing the full potential of geothermal energy while providing invaluable insights for policymakers, researchers, and industry stakeholders.

Horizontal loop systems

Installation area

Horizontal collectors require very careful design the soil type, moisture content (and/or presence of shallow groundwater) and thermal conductivity properties are extremely important at defining the size of any horizontal array configuration. However, the average area for one family house might be calculated using the old method as twice time the area of the heated space, which is around 200 m^2. The most common types are slinky loops, a bit less common are horizontal exchanger made of parallel tubes. The least common type are the basket shaped exchangers.

The type of collector

The primary configurations for horizontal GSHP collectors include the slinky loop system, which is efficiently installed in trenches. Another prevalent design is the classical horizontal plane layout. Conversely, basket configurations are the least common due to their unique installation requirements and design specifications. The use of these diverse possibilities helps to find the best solution to varying spatial and geological conditions, optimizing the extraction of geothermal heat for sustainable energy solutions.

Database

In most European countries it is not necessary to obtain permission for the horizontal loop system GSHP, so the data about these types of installations are not available. The only country monitoring the horizontal loop systems is Austria, however there is no comprehensive database for the whole country, and the data are stored at the municipal level.

The legislation about acquiring new statistical data for market analysis

Austria

In the case of new installations, these need a license or permission through a "water right", which is under the responsibility of a district authority. Usually, the authorities of the districts forward this information to a countywide organized "water registry". Only in some counties, the authority on county level collects this information from the district authorities. Usually, closed loop systems are registered in the "Baugrundkataster", which is the registry of all drillings in a county, but this is not the case for all counties unfortunately.

In counties, where you do not have to have a permission for ground heat exchangers, it is not treated as "water right" and therefore usually does not end up in the "water registry". For these cases, there is no information about the installations. All open loop systems are considered a "water right" and need a license, hence they are included in the water registry, this is the case for all of Austria.

- "Water registry" of each county in Austria
- "Baugrundkataster" - the registry of all drillings in separate counties in Austria

Finland

Acquiring new statistical data for market analysis in the context of geothermal energy projects, involves legislative considerations. Specifically, individuals or entities looking to drill boreholes for geothermal purposes must obtain a permit from the relevant local municipality. This regulatory step ensures that drilling activities comply with environmental and safety standards. Additionally, the Finnish Heat Pump Association plays a critical role by collecting and publishing statistics on the sale of heat pumps across the country.

- The Finnish Heat Pump Association SULPU cares about the interests of heat pump operators and promote cooperation between them.

Ireland

The regulatory and legislative situation in Ireland are due to change by the end of 2024. Registration will be expected for small scale systems (up to 25kW) with a licensing system required for larger shallow geothermal and deep geothermal systems in commercial applications. There will be a requirement to submit annual monitoring data for larger closed and open loop systems. Open Loop systems where a water abstraction greater than $25m^3$/day is planned currently require an abstraction license and re-injection >$5m^3$/day currently requires a license from Irish Water and/or local authorities. The open loop regulations (although currently not specific to geothermal system but to groundwater abstraction) are already in place. Larger systems are expected to require and EIA to be completed (capacity/scale of abstraction not yet defined). The main sources of data on GSHPs in Ireland are:

- the Sustainable Energy Authority of Ireland for grant subsidised systems
- Heat Pump Association of Ireland for general HP unit sales (excludes the subsurface element of the system)
- The Geothermal Association of Ireland – collection of mostly large-scale commercial systems by type, installed capacity, and estimated energy produced
- GeoScience Regulatory Office (GSRO) – will be mandated with data collection and statistics under the new upcoming licensing and regulatory framework

Germany

All open vertical loop systems and BHEs need a permit, but horizontal loop system do not require this.

The geological data (drilling report, etc.) needs to be sent to the geological survey, and the data about BHE installation are written in the permit application. The application process varies between the federal states (some are still in non-readable pdf files and the information which needs to be provided differs), also the interpretation of the Federal Laws varies between the states.

- Geological surveys and Water authorities in Germany
- Bundesverband Wärmepumpe (BWP) in Germany
- Waermepumpen Angebotsvergleich in Germany
- Manufacturers for the HP, e.g. Vaillant, also non-European companies (China)

The Netherlands

ATES of all sizes and BTES > 70 kW load on the ground, require permitting. BTES below 70 kW load on the ground require notification only. ATES permit requires design document containing all relevant data. BTES data (with limited information) needs to be provided when giving the notification.

ATES systems are regulated through the provincial authorities. BTES systems are regulated via the municipal authorities. As a standard all regulations are harmonised throughout the country, however a local shallow geothermal energy plan (tailored to local requirements) may have a few (site specific) requirements, such as maximum drilling depth.

- The Netherlands Central Buro of Statistics (CBS)

Poland

There is no obligation to register GSHPs in the National Geological Archive. However, the bigger projects are registered by submitting 'other geological documentation', so consequently there is about 3-4% registered GSHPs projects.

In Poland, regulations related to drilling for ground heat are consistent across the country. Drillings up to 30 m is not subjected to any permission. The geological works project is approved at county level (314 counties and 66 cities with county rights), and is needed for drilling above 30 metres. In addition, there is an obligation to submit project for mining plant operations in every mining area above 30 m, as the next step - an approval decision must be issued at the District Mining Office, of which there are 11. The list of submitted geological works projects and, much less, the as-built geological documentation, is the only source of data on drilling for ground heat exchangers. There is no formal reporting obligation in Poland for ground source heat pump installed.

- Polska Organizacja Rozwoju Technologii Pomp Ciepła (PORT PC)
- Stowarzyszenie Producentów i Importerów Urządzeń Grzewczych (SPIUG) in Poland
- Polish Geological Institute - National Research Institute (PIG-PIB) is in charge of the database ‘’Other geological documentation’’.
- The all works in Poland can be identified by the Geological Works Project, which in most cases stays in the Municipalities.

Spain

In Spain, the legislative landscape for acquiring statistical data for market analysis varies significantly across different regions. We focus on the legislative framework in Madrid. Unlike some countries that maintain a public database for geothermal installations, Spain lacks a centralized, publicly accessible repository for records of geothermal installations. This absence of a unified database presents challenges for market analysis, requiring stakeholders to navigate a diverse array of administrative processes specific to each region. The decentralized nature of this legislative environment underscores the need for a more coordinated approach to data collection and sharing to support the growth and sustainability of Spain's geothermal energy sector.

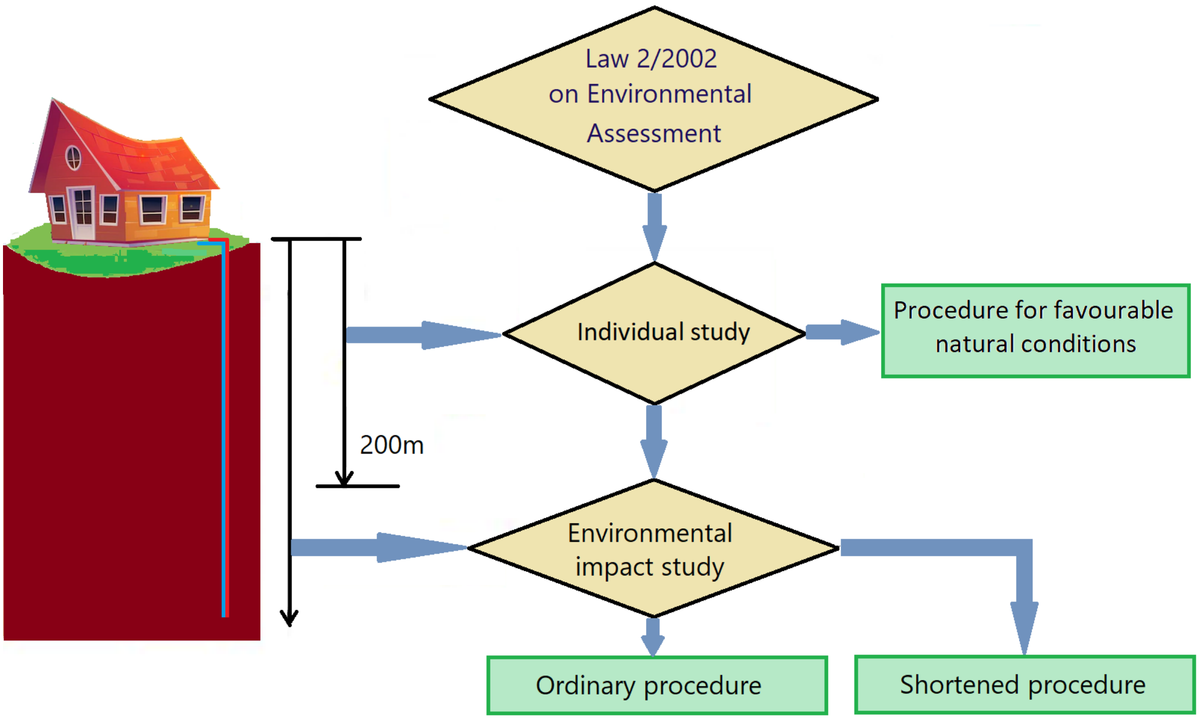

Figure 12: Procedure by Law 2/2002 on Environmental Assessment in Madrid

- l Instituto para la Diversificación y Ahorro de la Energía (IDAE) de Españaes
- The Spanish Geothermal Technology Platform (*GEOPLAT)*

Sweden

The legislative framework in Sweden, governing the acquisition of statistical data for market analysis in the geothermal sector mandates that every borehole drilled for geothermal purposes has to be reported to the Swedish Geological Survey (SGU). This ensures a systematic collection of relevant data, promotion transparency and accessibility. The SGU's website, Brunnsarkivet, is a public platform where this data is readily available, serving as a critical resource for stakeholders in the geothermal industry. Key organizations involved in this process include SGU, Svenska Kyl & Värmepumpsföreningen (SKVP), and partly Rototec, with Svenskt Geoenergicentrum, a part of the drillers association Borrföretagen, playing a significant role in advocating for and disseminating information about geothermal energy. These entities work collaboratively to promote the sustainable development and utilization of geothermal resources, underpinning the market's growth with robust, data-driven insights.

- Svenska Kyl&Värmepumpsföreningen, (SKVP) and partly Rototec.
- Svenskt Geoenergicentrum a part of drillers association Borrföretagen

Conclusions

The deliverable offers a comprehensive overview of the GHP market across Europe on the examples of GeoBOOST countries (Austria, Finland, Ireland, Germany, The Netherlands, Poland, Spain, and Sweden) including France. The report investigates the main types of geothermal heat pump systems, identifying the principal end-users and investors, alongside emerging new actors within the market. Significant emphasis is placed on investment trends across the European Union, highlighting the main market drivers that are driving the industry forward. A market model is presented, with on a geothermal heating and cooling.

Specific focus is on the close loop GSHP system and its details, such as the summary of average depth of Borehole Heat Exchangers, and the number of boreholes and heat pumps installed in various nations. It also estimates the major types of circulation media (anti-freezing liquids) used and outlines the typical borehole and heat exchanger diameters. The report includes a section on databases of installations,

The major parameters of open-loop systems are stated, including the average number of inlet and outlet wells. Main properties of horizontal loop system are described. Finaly a report into legislative aspects of acquiring new statistical data for market analysis is presented.

This analysis is crucial for stakeholders within the GHP market, offering valuable insights into current trends, legislative challenges, and future opportunities within the European geothermal heat pump industry.