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1. PUBLISHABLE EXECUTIVE SUMMARY

The present deliverable reports the activities related to the Task 7.2 - Market Assessment – aiming to carry out a preliminary assessment of the European market for the developed GEOTeCH solutions.

A detailed and complete analysis has been performed investigating first the most used conventional solutions for heating and cooling of buildings in Europe. It has been found out that the conventional heating and cooling market is very heterogeneous, composed by many different technologies, and characterized by a low level of efficiency for the installed stock: hence there is a relevant need for modernisation of existing conventional heating and cooling systems.

In this context, geothermal represents a renewable energy source with a very important potential of energy savings (up to 70%), addressing the main EU targets and goals for carbon emissions reduction. An overview of the geothermal solutions currently used for heating/cooling of buildings has been provided: shallow geothermal is the largest type (63%) of geothermal energy used in Europe, but many differences between Member States still exist about actual state of deployment of such renewable energy, mainly due to the availability of incentives and financial support schemes.

The more mature markets of geothermal installations are Sweden, Germany, France, Switzerland and Norway, which account for around 70% of all installed capacity of the continent.

In order to identify the most profitable countries for application of GEOTeCH solutions, the market potential for geothermal heat production has been investigated through ground parameters (geotechnical/geomechanical and thermal properties of the shallow underground), climate and geothermal heat flow data: for each EU country the ‘neutral zone’, as optimal depth to reach when installing BHEs thus to exploit the maximum amount of energy, has been calculated. Profitable markets have been identified with The Netherlands, Denmark, Poland, Belgium, the UK and Germany for their large percentages of territory suitable for application of GEOTeCH drilling technology.

The competitor analysis outlines that some companies present in the EU market are starting to offer innovative products for geothermal applications, but the innovation brought from the dry drilling technology developed within the project is actually beyond the state of the art.

In every Member State it is envisaged that GSHPs can play an important role for heating/cooling of residential and commercial buildings, reducing requirements for primary energy and carbon emissions. However strong competition exists with ASHPs, more commercialized in the market due to their easiness of installation, lower price and less space occupancy, although GSHPs provide higher efficiencies.

Market requirements, opportunities and barriers, plus financial models have been deeply analyzed for application of geothermal systems: the main barriers, as lack of available space in built urban environment for installation, different regulations and permits, lack of appropriate financing schemes, high cost of GSHPs and needed certifications respect to alternatives, lack of awareness and knowledge about geothermal systems, can be overcome exploiting opportunities in the market and leveraging on the key success factors of GEOTeCH solutions, identifiable in the main following points:

- less capital-intensive compact equipment
- reduction of environmental risks, complexity and costs
- better integration between heat exchange elements during installation
- maximum use of the foundation structures
- optimized hybrid solutions integrating the different geothermal systems
- cost-effective geothermal systems
- safety enhancement

2. INTRODUCTION

2.1 Purpose and target group

Main goal of the GEOTeCH project consists on stimulating and promoting greater utilization of renewable heating and cooling using shallow geothermal GSHP systems through advancement of innovative drilling and ground heat exchanger technologies which are significantly more cost-effective, affordable and efficient than current technology.

The need for rapid growth of the application of geothermal heating and cooling technology in most Member States represents a challenge in terms of market development, meeting cost and quality expectations in order to encourage new SMEs to join the GSHP installation industry.

In fact, GEOTeCH project intends not only to develop and innovate drilling and ground heat exchanger technologies but also to develop hybrid heat pump technologies so that efficient replicable “plug and play” whole systems can be offered to the housing and small building market sectors. For the large tertiary building sector instead, the aim is to improve the uptake of foundation heat exchanger technology through better design, robust control systems, optimal hybridization and integration as well as improved life-cycle cost effectiveness.

In the framework of WP7 - Market analysis, Business modelling e Business planning – the main objectives are related to the assessment of the market opportunities and to the definition of the exploitation strategies needed for a future successful commercial exploitation of the key results of the project.

In particular, the present deliverable reports the activities related to the Task 7.2 - Market Assessment – aiming at performing a preliminary assessment of the European market for the developed GEOTeCH solutions, investigating actual market requirements, competing technologies, barriers and opportunities.

Specifically, activities performed within this deliverable have reached the following purposes:

- Overview and trend of the most used conventional heating/cooling solutions (**Chapter 3**)
- Comprehensive analysis of the geothermal systems existing in the market (**Chapter 4**)
- Study and investigation of the market potential for geothermal heat production in order to classify countries holding more exploitable energy. Specific focus has been provided for demo sites' countries (**Chapter 5**)
- Provision of market requirements/standards related to the technologies developed in GEOTeCH (**Chapter 6**)
- Competitor analysis focused on competitive shallow geothermal solutions commercialized in Europe (**Chapter 7**)
- Analysis of the key success factors of GEOTeCH technologies (**Chapter 8**)
- Analysis of the framework market conditions identifying financing models for potential buyers, potential market entry barriers and opportunities (**Chapter 9 and 10**)

The current deliverable D7.1 is public and it addresses the whole GEOTeCH Consortium, providing partners with a detailed analysis of the most suitable markets for deployment of developed solutions, as well as external stakeholders interested in entering the field of shallow geothermal systems for renewable heating and cooling.

2.2 Contributions of partners

D'Appolonia is the workpackage leader as well as leader of Task 7.2.

All partners, based on their expertise and knowledge, contributed to carry out activities needed for a detailed and complete document which is the D7.1 - Market Assessment.

Contributions from other related tasks mainly derive from Task 7.1 - Mapping and Risk assessment (leader is UNIBO) - where preliminary data of the mapping activity of geo-thermal parameters have been used to investigate the potential for geothermal heat production at European level.

2.3 Baseline

For the preparation of this deliverable a state-of-the-art for the technologies developed within GEOTeCH has been performed, analysing the current markets and the available systems.

The assessment of the market have been focused on: drilling technologies, borehole heat exchangers, ground source heat pumps, foundation heat exchangers and integration of geothermal systems in buildings.

2.4 Relations to other activities

- Inputs: main inputs are provided by Task 7.1, concerning the mapping activity used for market potential study, plus contributions provided by all Consortium partners
- Outputs: activities related to this deliverable will represent the basis to carry out Task 7.3 (business models and business plans activities) and Tasks 7.4, 7.5 concerning the exploitation and IPR management of the knowledge developed within GEOTeCH.

3. BRIEF OVERVIEW ON THE MOST USED CONVENTIONAL SOLUTIONS FOR HEATING/COOLING OF BUILDINGS IN EUROPE

Energy consumption intended for heating and cooling in the European Union represents half of total consumption. Looking at how such energy is distributed among the individual sectors, the percentages are shared as follows: 45% residential sector, 37% industry and 18% services¹.

In 2007, 48% of the final energy consumption in EU-27 took the form of heat and, specifically, heat accounted for 86% of the final energy consumption in households, 76% in commerce, services and agriculture and 55% in industry².

There is a trend of significant reduction in the heating demand in the EU whereas the cooling demand is growing exponentially. However, it is difficult to accurately estimate the impact on energy consumption of cooling demand, because it's hidden in data for the electricity demand of the residential and service sectors. An estimation of the expected evolution for the next years has been made and it is shown in Figure 1³:

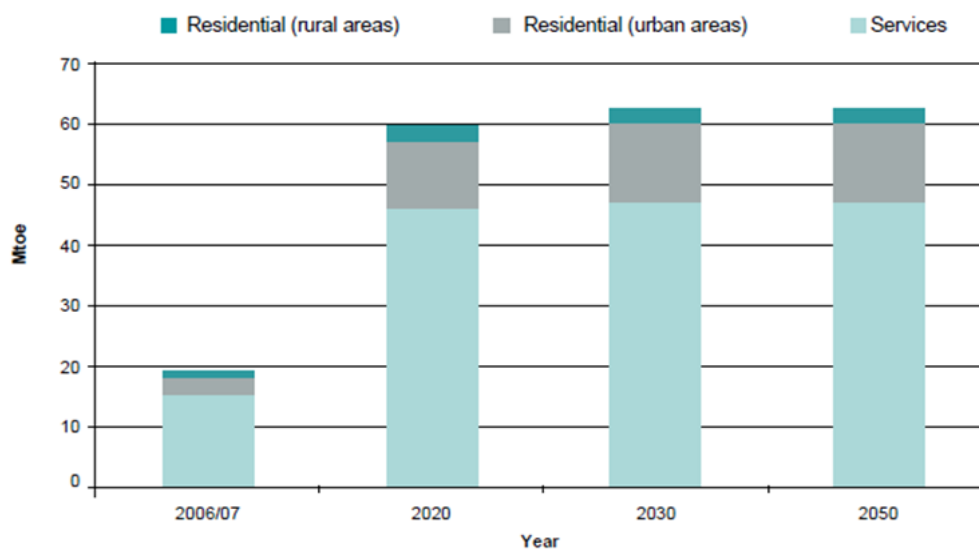


Figure 1. Expected evolution of cooling demand in UE

The following subchapters provide an overview of the existing and most used technologies for heating and cooling in buildings in the EU Member States, according to the EU Strategy for Heating and Cooling report presented to the European Commission in 2016.

Technologies for heating reach from small decentralised applications to large-scale industrial boilers and furnaces and large centralised generation units in district heating networks. Small decentralised technologies include gas and biomass boilers, heat-pumps, individual solar thermal panels and micro-small cogeneration units. Similarly, cooling can be produced in decentralised applications using technologies from small air-conditioning units to large chillers and heat pumps. The capacity used for thermal energy generation ranges from 1 kW or below to several hundred MW units.¹

The heating and cooling market is fragmented and no single sector has so far emerged either nationally or EU-wide. In its place, heat markets are local markets composed by many different

¹ EU Strategy for Heating and Cooling. Brussels, 2016

² Common vision for the Renewable Heating&Cooling sector in Europe. 2020-30-50. RHC Platform.Brussels, 2011

³ Common vision for the Renewable Heating&Cooling sector in Europe. 2020-30-50. RHC Platform.Brussels, 2011. (fig6)

technologies and economic agents (suppliers, installers and builders, engineering companies and energy advisors, energy utilities and energy service companies) selling the heat and cool as a commodity or service, often combined with other services, such as facility management, water and sewage and waste treatment.

Heating and cooling are closely linked with other energy markets, in particular fuel and electricity, but also with non-energy markets like, for example, water, waste and technology.

3.1 Technologies supplying heating and cooling in buildings

3.1.1 Heating technologies

A wide range of technologies are used in the EU Member States to supply heat. The most used technologies are listed below:

BOILERS

They are the most commonly used technology. They can be operated on natural gas, oil, coal and bioenergy. Boilers can be characterised with different efficiencies. The currently most widely used standard boilers have an efficiency of 40-80%, while modern condensing boilers can reach efficiencies above 100% and they are typically more than 90% efficient.

INDIVIDUAL STOVES AND FURNACES

They are an important current technology. Stoves are fueled by gas, oil, coal and biomass and furnaces using coal, biomass and waste.

DIRECT ELECTRIC HEATING

Another option widely used in some Member States, where electricity is a cheap energy vector (ex: France) or when the heating loads are modest (ex: Southern Regions of Italy, Greece and Spain).

COGENERATION

Cogeneration technologies constitute an important family of heating technologies, which include combined cycle and steam turbines and engines operated on gas, coal or biomass, internal combustion engines using gas, and emerging technologies, such as fuel cells, Stirling engines and Organic Rankine Cycle. While cogeneration is usually applied in large capacities up to 150 MW and above, micro-CHP is emerging in the residential sector supplying individual buildings and even apartments.

In addition, there are a number of new technologies emerging, e.g. fuel cells, to complete the existing established heat technology families. At the same time, there are emerging alternative fuels, such as biogases, synthetic gases and hydrogen or recovered waste heat, which expand the available range of energy carriers and sources for heating.

Lastly, modern heating systems include other technologies that are complementary to boilers and are often used to provide more comfort to the users depending on specific needs; these complementary technologies are listed below:

- Heat storage and domestic hot water;
- Intelligent thermal control and communication instruments;
- Radiators and heat exchangers;
- Surface (floor) heating (and cooling);
- Passive heating (and cooling) elements;

- Smart metering and smart homes integrating heating (and cooling) with the wider;
- Technical systems of buildings.

Figure 2 shows the most common categories employed in the **residential sector** for heating supply, including the technology employed and the energy carriers used⁴.

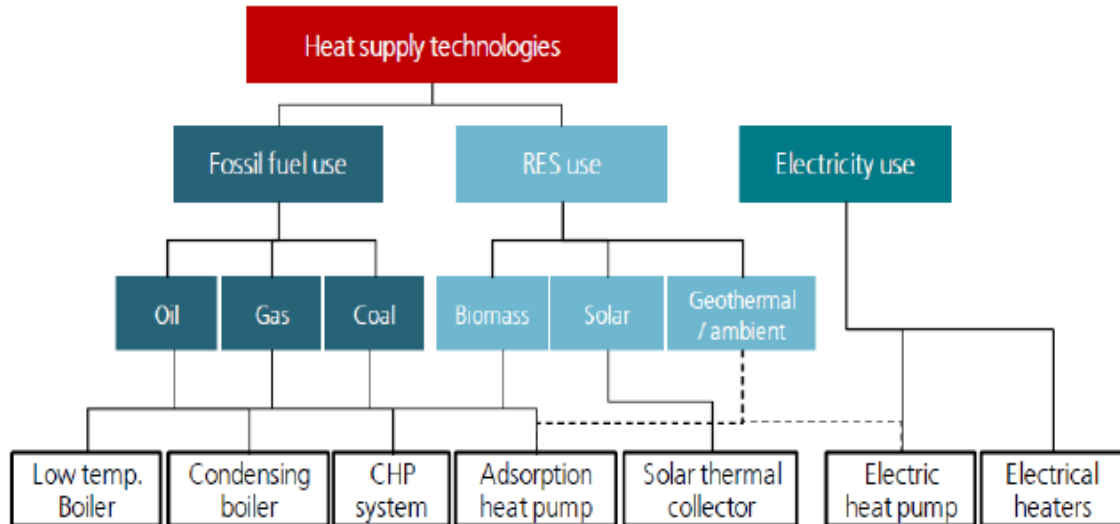


Figure 2. Categories of heating supply technologies in the residential sector (Fraunhofer Institute)

3.1.2 Heating & Cooling Technologies

Several technologies supplying heating and cooling are available in the EU Member States as:

HEAT PUMPS

There are many types of heat pumps such as air source, ground source and water source using electricity or gas. A more detailed explanation about heat pumps is presented in next chapter.

SOLAR THERMAL

These technologies have been gaining ground. They can be either with flat plate or vacuum tube collectors.

GEO THERMAL ENERGY

This technology also provides heat and cool and it is usually applied in larger district heating systems. In the next chapter an overview of geothermal solutions for heating and cooling systems is described more detailed.

⁴ Fraunhofer 2015. EU Strategy for Heating and Cooling. Brussels.

3.1.3 Heating Market statistics

European Heating Industry (EHI) statistics provide an overview of the stock and the annual sales for the different heating categories.

According to the corresponding 2010 statistics, 89% of the installed stock of central space heaters was composed of inefficient low temperature gas and oil boilers, while the 10% consisted in more efficient condensing boilers and the residual 1% based on heat pumps and mini-micro-combined heat and power (CHP) devices (less than 0.1%).

Data available from EHI in 2012, in EU-25, shows the following percentages:

- 64% of the installed space heating systems were non-condensing boilers;
- Condensing boilers represented 26%;
- The residual shares were represented by biomass boilers (6%), heat pumps, and other technologies (e.g. micro-CHP)⁵.

Almost half of the EU buildings have individual boilers installed before 1992, with efficiency of 60% or less. Furthermore, 22% of individual gas boilers, 34% of direct electric heaters, 47% of oil boilers and 58% of coal boilers are older than their technical lifetime⁶.

These data show that the **level of efficiency of the installed stock is low** (around 60% below the nominal efficiencies of these appliances of between 78% and 85%) as operational performance deteriorates over time and, even more so, because regular maintenance is not followed up. Hence, the modernisation of heating and cooling systems, even only about condensing boiler levels, could bring significant energy efficiency gains.

Significant differences exist across countries as we can see in the following Table 1. In the UK, for example, the share of condensing boilers is much higher than the average, thanks to regulatory pull and incentives towards condensing boilers. Instead, in Sweden, heat pumps are the most diffused technology reaching 46% of the installed capacity.

Table 1. Space heater in EU-25,2012 (European Heating Industry – EHI)

	EU25 (Thousands)	Italy	UK	Germany	France	Sweden
Non-condensing boilers	(75.784) 64%	87%	44%	71%	80%	12%
Condensing boilers	(31.092) 26%	12%	56%	22%	12%	1%
Biomass boilers	(7.030) 6%	1%	<1%	4%	3%	18%
Heat pumps	(2.712) 2%	<1%	<1%	3%	5%	46%
Other	(1.083) 2%	<1%	<1%	1%	1%	22%

Table 1 does not reflect the particularity of France, where there is a high deployment of electric heaters which are not collected in EHI statistics. Around 6.5 million electric appliances for space heating and warm water production are sold annually in France⁷.

⁵ EHI Statistics. EU Strategy for Heating and Cooling. Brussels, 2016

⁶ Fraunhofer 2015. EU Strategy for Heating and Cooling. Brussels, 2016

⁷ EHI Statistics. EU Strategy for Heating and Cooling. Brussels, 2016

3.1.4 Cooling technologies

The cooling sector is quite heterogeneous regarding its technologies and actors.

Cooling shows a strong interconnection with the electricity sector because, on the one hand, electricity is used as secondary energy in order to produce cooling (e.g. compression methods) or to satisfy the heat demand (e.g. heat pumps). On the other hand, there is an interaction of cooling with heating. One example of this occurs when heat is used to drive heat driven chillers for the generation of cooling (e.g. tri-generation applications), or when cooling is produced from the waste heat generated in electricity production or industrial processes.

Moreover, it is also possible to recover the heat rejected in compression chillers for instance for the pre-heating of hot water.

Cooling is mostly supplied from electric devices removing heat/moisture from air.

Conventional cooling technologies include:

- Individual ventilation and air conditioning units: these are the individual room ventilation units, usually called RAC (room air conditioners). The UE defines as air conditioning systems those units with less than 12 kW of cooling capacity;
- Central air-conditioning units (CAC) which can be distinguished as follows:
 - *Packaged air conditioning equipment (PAC)*: it includes all direct expansion (DX) systems. PAC are standardised products, with a packaged central unit containing the heat exchanger and compressor – and sometimes the evaporator and condenser as well – all in one cabinet, usually placed on a roof. Multiple split systems, ducted packaged systems and roof-tops are also defined as packaged plants;
 - *Central plant air conditioning equipment*: these are usually larger systems based on Chillers. One or more chillers, either water- or air-cooled, are located in a central place and produce cold water. This cold water can be piped either to air handling units, which distribute the cold air within the building through the ventilation system, and/or to individual fan coils, inductor or beams located throughout the building.

Thermally driven "adsorption or absorption" chillers (using fossil fuels, solar thermal, waste energy, biomass, etc.) are a mature technology and use a similar cycle to that of conventional air conditioners. Their efficiencies are lower than electrically driven heat pumps (with coefficients of performance typically in the range 0.7-1.2).

Instead, high-efficiency absorption chillers, which use mixtures of water and ammonia (or lithium bromide) with natural gas or cogenerated heat sources, could replace traditional electric chillers in buildings with a high demand for cooling and/or heating and air conditioning.

Therefore, the **European market is dominated by electric cooling machines**. However, thermal cooling machines operated with district heating and cooling or waste heat are also present to a limited extent in the high performance, large-scale classes.

Regarding district cooling technologies, some important information are provided below.

District cooling

This technology allows using locally available sources. Often district cooling uses the direct thermal energy, converting heat into cool using waste heat from industry and waste incineration (often via tri-generation) to produce cooling, using heat driven sorption chillers and heat pumps. Electric compression chillers represent also a large portion of many of the existing systems.

The so-called *free cooling*, whereby cold from rivers, lakes and seas is transported directly, or enhanced with heat pumps through pipes, to the end-users (mainly tertiary and public buildings sectors) has been in use since the early nineties and, using ATES (Aquifer Thermal Energy Systems), it is the standard cooling technology used in the Netherland and also in other countries

with suitable aquifers (UK, Germany, France) for large scale applications such as airports, hospitals, large offices, etc. (currently district heating is under consideration). Free cooling is best established in Finland, France, Sweden and Spain. District cooling still represents a small portion with a total installed capacity of only 2.4 GW, which is less than 1% of the total installed district heating capacity of 301.5 GW in EU-28⁸.

3.1.5 Trend of Heating & Cooling technologies

Costs and performance vary widely among heating and cooling technologies and also for each individual technology, because of differences in equipment prices, installation and running costs, different end-use applications, climate, technology specifications, user requirements and building occupation profiles.

The old heating (using coal, oil and wood) and cooling (electrical) equipment installed raise concerns for the air quality and associated health problems that it can cause. In fact, in some parts of Europe, up to three quarters of outdoor fine particulate matter pollution is attributable to household heating with solid fuels (including coal and biomass)⁹.

To overcome such problem, Ecodesign and energy labelling requirements for space and water heaters came into application in 2015 and the sale of inefficient boilers is now banned. Moreover, consumers can be informed about efficiency ratings, both for single technologies and for packages that include the use of renewables.

The new Regulation 517/2014 on fluorinated greenhouse gases will also accelerate the refurbishment of heating and cooling technologies, pushing towards the use of alternative refrigerants. Indeed, climate-friendly refrigerants offer great energy saving potentials, even though they require, for some applications, an update of the existing standards to ensure their safe use.

A good time to replace an old heating system is when a building is refurbished: transformation to an efficient building makes it possible to shift to heat pumps, solar or geothermal heating or waste heat. These appliances save costs.

In addition, there is a number of innovative highly efficient technologies that quickly approach market-readiness, such as stationary fuel cells.

Hence, a wide range of renewable heating and cooling solutions is available and scaling-up the market would reduce their price. The Energy Labelling Directive (2010/30/EU) states that Member State incentives for products, such as heaters, need to reach the highest performance levels.

Cooling comes mostly from electric devices, although there are promising innovative low energy cooling technologies. A recently adopted Ecodesign regulation covering cooling products completes the set of requirements for heating and cooling and it will bring fuel savings of 5 Mtoe per year in 2030, corresponding to 9 million tonnes of CO₂¹⁰.

⁸ Fraunhofer 2015. EU Strategy for Heating and Cooling. Brussels, 2016

⁹ An Eu Strategy on Heating and Cooling. Brussels, 2016. European Commission. Final Report

¹⁰ An Eu Strategy on Heating and Cooling. Brussels, 2016. European Commission. Final Report

4. OVERVIEW OF GEOTHERMAL SOLUTIONS FOR HEATING AND COOLING SYSTEMS IN EUROPEAN BUILDINGS

4.1 Introduction

As it was briefly mentioned before, heating and cooling represents the largest share of final energy demand in EU-27. Heat represents almost half of the energy needs in Europe: for example, in 2010, heat energy use represented the 48% of energy usage in the EU¹¹.



Figure 3. Final energy use in EU-27 by type of energy

The majority (81%) of this energy is generated by burning fossil fuels. This is the reason why current systems generally used in Europe are not only boosting costly imports of fossil fuels, such as oil into Europe, but they are also major contributors to the overall EU's greenhouse gas emissions. Another general characteristic of the European landscape is that the heating and cooling sector is very heterogeneous in its structure, in terms of technologies, actors, demand, sources, costs, etc.

In this context, **geothermal** represents a **renewable energy source** with a **very important potential of energy savings** which can concern the air conditioning of different kind of buildings such as residential, commercial or industrial.

Shallow geothermal energy has the potential to save up to 70% of energy in comparison with the traditional heat and cool (H&C) systems that use oil and gas, thus it is a technology that can be in charge for decarbonising the overall heating sector. Furthermore, shallow geothermal systems can also cover the cooling demands, such as in commercial buildings all over the EU. However, this sector is currently facing important challenges, such as regulatory barriers at different levels, which are able to affect the implementation of those systems in Europe.

It has to be noted that the EU is committed to achieve the following goals by the year 2020¹²:

- A reduction of at least 20% in greenhouse gas (GHG) emissions compared to 1990 levels;
- 20% of the final energy consumption needs to come from renewable sources;
- An improvement of energy efficiency by 20%

¹¹ Strategic Research and Innovation Agenda for Renewable Heating and Cooling

¹² Horizon 2020

Addressing these objectives, Shallow Geothermal Energy (SGE) represents a Renewable Energy Source (RES) with a large potential of energy savings and GHG emissions reduction.

This is the reason why SGE will be a key technology in order to contribute to achieve all major objectives of the EU's energy policy.

Additional **benefits** provided by using shallow geothermal energy technologies are:

- Reducing import dependency of fossil fuels and increasing security of energy supply
- Increasing local added value and creating jobs
- Potential integration of shallow geothermal technology in local existing businesses, especially SME
- Bringing innovation to the building/installation sector
- Zero pollution systems, when using clean electricity
- Empowering consumers and contributing to provide affordable energy as it is immune (buffers) from price volatility typical of fossil fuels
- Suited for European-wide geology, hydrogeology, and climate
- Suitable for a variety of small as well as large applications
- High energy savings potential for both heating and cooling
- Integration through (thermal) storage potential as controllable load into smart electrical grids of small and large scale
- Practical implementation on large scale (proven technology with good track record)

In this context, it is important to provide the definition of Geothermal Energy given by the EU in Article 2 of Directive 2009/28/EC: “*Geothermal Energy means energy stored in the form of heat beneath the surface of solid earth*”¹³. It is also relevant to specify that the limits of SGE technologies are not very clear but, by common understanding, the deep geothermal starts at about 400 m of depth.

Shallow geothermal systems are in use throughout Europe to meet ambitious energy savings targets, whilst at the same time achieving high comfort levels through the inherent heating and cooling capacity. The relatively high efficiency achievable with Ground Source Heat Pump (GSHP) systems means that they can play a particularly important role in carbon emission reductions.

This is shown in the National Renewable Energy Action Plans (NREAPs) that Member States produced in order to indicate pathways able to reach 2020 targets for carbon emission reductions. These plans show that exploitation of shallow geothermal energy should grow significantly in this time frame and will also become increasingly important after 2020. For example, in the UK, production of geothermal heat from shallow resources is expected to grow from 120 ktoe (kilotonnes of oil equivalent) in 2010 to 953 ktoe in 2020.

In the north of Europe, heating is usually the dominant mode because of the weather there; in the middle latitudes both heating and cooling are used, while in Southern Europe, in countries such as Spain or Italy, cooling is dominant in tertiary buildings, although heating is also required in the cooler periods as well as for the production of domestic hot water (DHW).

Regarding the installed capacity and talking about the number of installations, **shallow geothermal is the largest type of geothermal energy used in Europe**. The number of heat pump systems of this kind is growing and represents a renewable, sustainable, and reliable energy technology. Related applications range from small houses and apartments, with small systems which can provide 3-10 kW_{th} in capacity, to commercial public buildings with installations able to provide up to 1 MW_{th}.

¹³ Article 2 of Directive 2009/28/EC

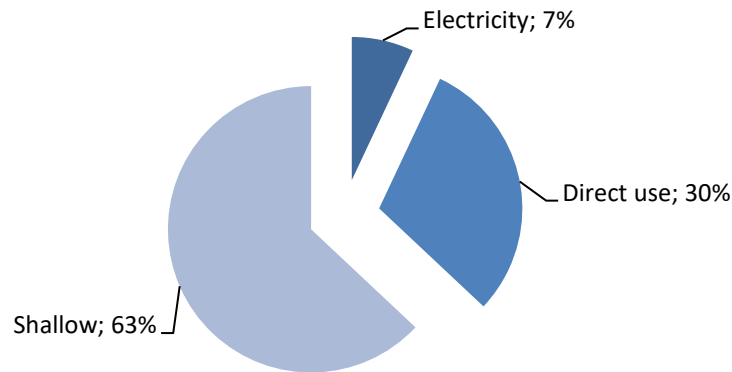


Figure 4. Share of installed capacity in the three geothermal sector in Europe¹⁴

In 2007, the installed thermal capacity (including geothermal heat pumps) amounted to ca. 10,000 MW_{th} (MegaWatt thermal) in EU-27 and 15,000 MW_{th} for all Europe. The target of this sector, for all Europe, is to reach over 40,000 MW_{th} in 2020 and 80,000 MW_{th} in 2030.

In the following Figure 5, the white paper expectations for 1995 and 2010 are represented, as well as the objectives of the National Renewable Energy Action Plans for 2015 and 2020; these objectives are compared with the current trend, in order to observe the evolution of the shallow geothermal energy.

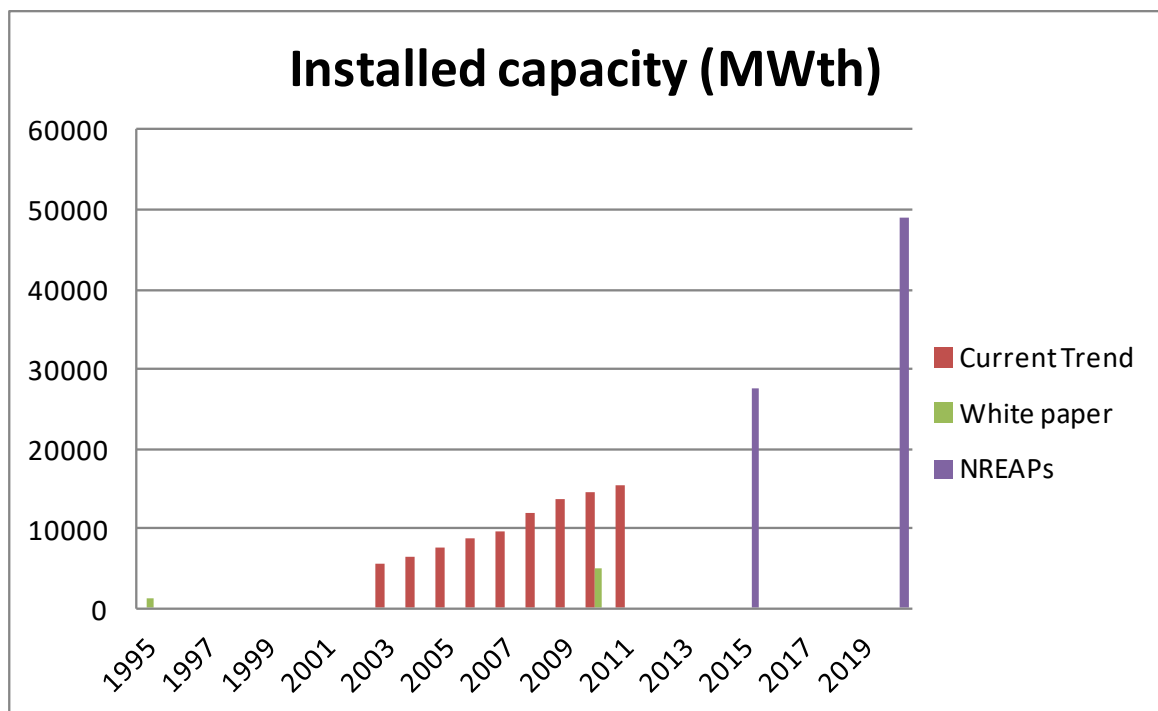


Figure 5. Installed Capacity of GSHP in Europe

In the EU, the current state of shallow geothermal energy is very heterogeneous across Member States. In order to be able to reach the targets set for uptake of shallow geothermal energy technology, an important growth of industries in many Member States is necessary and several economic, technical and socio-technical challenges have to be accomplished.

¹⁴ Antics, M., Bertani, R. & Sanner, B. (2013): Summary of EGC 2013 Country Update Reports on Geothermal Energy in Europe. - Proc. EGC 2013, paper keynote-1, 18 p., Pisa

The GEOTeCH project aims to address key challenges by improving the development of shallow geothermal technologies and new system solutions, besides demonstrating their effectiveness.

The countries with the **highest number of geothermal heat pumps** are **Sweden, Germany, France and Switzerland**. These four countries, alone, account for **64% of all installed capacity for shallow geothermal energy in Europe**. Hence, such technology is much implemented in these countries, while major developments are needed in other countries.

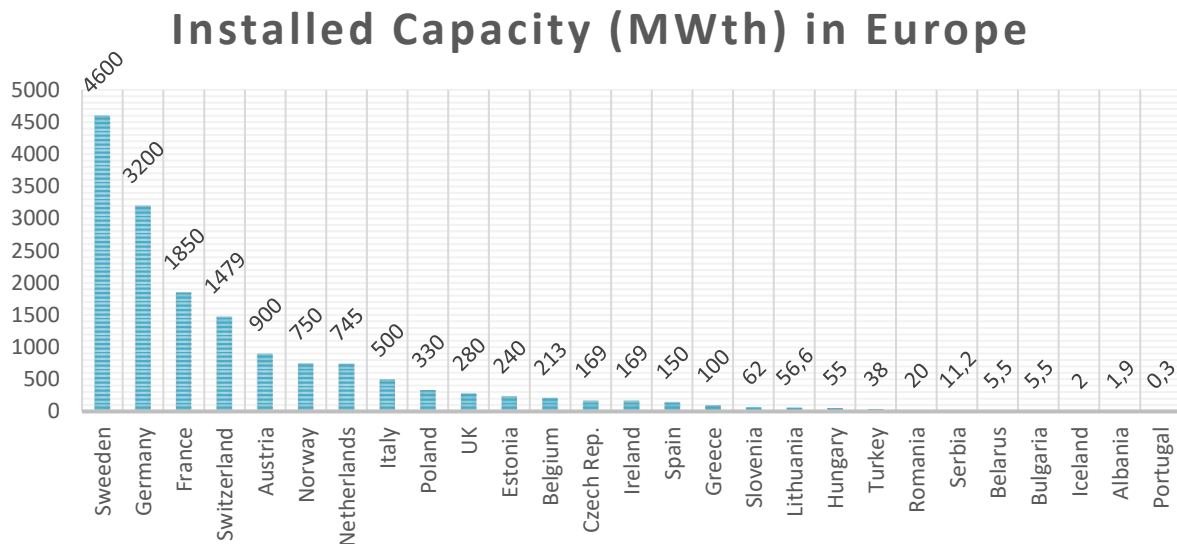


Figure 6. Shallow geothermal installed capacity in Europe 2012

4.1.1 Research priorities

The Shallow Geothermal Research Priorities are intended to identify technical, environmental and economic topics that will enhance the deployment of shallow geothermal systems (ground source heat pump and underground thermal energy storage UTES) in the European context. The topics have been selected with an emphasis on the potential for further deployment and contribution to the improvement of the overall market potential of shallow geothermal systems.

Shallow geothermal systems not only use heat pumps but also other components in common with conventional HVAC (Heating, Ventilation & Air-Conditioning) systems.

The SRA (Strategic Research Agenda) focuses on the components, issues and processes that are unique and relevant to the geothermal applications and that, following the consultation of the geothermal community, indicate the largest potential for improvement.

In this document, the following areas have been identified as those which the R&D projects will be focused:

Table 2. Summary list of shallow geothermal research priorities and targets¹⁵

	Short terms (2020)	Medium term (post 2020)
Basic research	Improvement to BHE materials	New (plastic) materials for BHE with enhanced thermal conductivity
	Improvement to antifreeze agents	New environmentally benign heat transfer fluids with low freezing point, low viscosity and high specific heat capacity
	Better understanding of thermal impact on building elements used as ground heat exchanger	
	Environmental impact of shallow geothermal applications	
	Short term (2020)	
Applied research & development	Improvement of BHE design and construction	
	Improved grouting materials (sealing, thermal conductivity)	
	Mechanised and optimised drilling and installation technologies (incl. mechanised grouting, quality monitoring, etc.)	
	Standardised installation technology for building elements as ground heat exchangers	
	Further development of heat pipes as BHE	
	For open systems, improved well construction and completion, injection wells control, water treatment.	
	Improved methods for determining underground parameters	
	Integrated design and modelling tools	
	Effect of open systems on hydrochemistry and microbiological composition of the subsurface	
Demonstration	GSHP and UTES plants with improved efficiency in different climate and geology, including improved control strategies	
	Hybrid applications with integrated planning and operation control	
	Use of storage function of the ground in the framework of smart electricity grids and smart thermal grids	
	Collect and provide ground design data for closed and open systems in easily accessible geographical databases	

¹⁵ Strategic Research Priorities for Geothermal Technology – European Technology Platform on Renewable Heating and Cooling

4.2 Geothermal Technology

The following is a description of the different systems which compose a geothermal facility: the exchange with the ground, the heat pump, and at last, the hybridisation of the production system with other back-up technologies.

4.2.1 Exchange with the ground

The heat exchange with the ground depends on the different temperatures and underground depth and also on the different typologies of heat exchanger used (vertical, horizontal, or foundations).

The distinction between shallow and deep geothermal is not fixed. In general, shallow geothermal systems can be considered as those not pursuing the higher temperatures, typically found only at greater depth, but instead applying technical solutions to make use of the relatively low temperatures offered in the uppermost 100 to 200 m or more of the Earth's crust¹⁶.

The Spanish Geothermal Technology Platform (GEOPLAT) classifies the geothermal resources depending on the temperature level in the ground. The most important characteristics of each one are listed below:

- **High-Temperature Geothermal Resources**, with temperatures above 150 °C, used fundamentally for electricity generation and found at highly variable depths but frequently between 1,500 and 3,000 m
- **Medium-Temperature Geothermal Resources**, with temperatures between 100 °C and 150 °C, usually used in power generation plants but also used for district heating and other thermal purposes. This type of geothermal resources can be found at depths lower than 1,000 m in areas with high geothermal gradient or at depths between 2,000 and 4,000 m in sedimentary basins
- **Low-Temperature Geothermal Resources**, with temperatures between 30 °C and 100 °C, mainly used for thermal purpose in HVAC, found in areas with normal geothermal gradient at depths between 1,500 and 2,500 m or at depths lower than 1,000 meters in areas with high geothermal gradient
- **Shallow or Very Low-Temperature Geothermal Resources**, with the energy stored in the Earth or in groundwater at temperatures lower than 30 °C and used for thermal uses

The Shallow Geothermal Resources use the geothermal energy stored in:

- The shallow subsurface, normally less than 250 m, including heat captured that is associated with construction elements in building projects
- Groundwater, including the one originating from mining and drainage activities associated with civil construction work, which is non-consumptive and is used exclusively for energetic purposes.

Italy categorises geothermal energy in the Legislative Decree of 11th February 2010 n.22 where Shallow Geothermal Energy (SGE) is considered as geothermal energy with low temperature and it is classified as **low heat content** when geothermal fluid has a temperature lower than 90 °C. The other categories are **high heat content** with temperature higher than 150 °C and **medium heat content** with temperature between 90 °C and 150 °C.

¹⁶ Geotrainet Training Manual for designers of shallow geothermal systems. GEOTRAINET. Brussels, 2011

In brief, we can say that **SGE in Europe always refers to depths of less than 500 m**; even less in several countries¹⁷. For shallow geothermal, the undisturbed ground temperature, that forms the basis of heat extraction or heat injection, varies between $<2\text{ }^{\circ}\text{C}$ and $>20\text{ }^{\circ}\text{C}$, depending upon the climatic condition of the region and the depth of the borehole¹⁸.

In order to use the constant low temperature of the ground, two options are available:

- Increase or decrease the temperature of geothermal heat to a usable level using heat pumps (**Ground Source Heat Pumps, GSHP**)
- Increase or decrease the temperature in the ground by storing heat or cold (**Underground Thermal Energy Storage, UTES**).

The Netherlands regulative framework defines in the Decree of Shallow Geothermal Energy Systems the following SGE systems:

- **Borehole Thermal Energy Storage (BTES)**: “installation that uses the subsurface for the supply of heat and cold for the purpose of heating and cooling of spaces in buildings, by means of a closed circuit of piping in the subsurface, including the above ground part of the installation”;
- **Aquifer Thermal Energy Storage (ATES)**: “installation that uses the subsurface for the supply of heat and cold for the purpose of heating and cooling of spaces in buildings, by means of the extraction of groundwater that is re-infiltrated into the subsurface after use, including the above ground part of the installation”.

To sum up, all these SGE technologies can be classified in two main types:

- **Open circuits**, where water is pumped from an aquifer, having a heat exchanger above ground
- **Closed circuits**, where a heat exchanger is installed inside the ground to exploit the energy resource.

The various shallow geothermal methods to transfer heat out of or into the ground comprise:

- Horizontal ground heat exchangers (horizontal loops): 1.2 – 2.0 m depth
- Borehole heat exchanger (vertical loops - BHE): 10 - 250 m depth
- Energy piles (foundation heat exchanger): 5 - 45 m depth
- Screen walls (foundation heat exchanger)
- Basket systems: 2 – 6 m depth
- Ground water wells
- Water from mines and tunnels

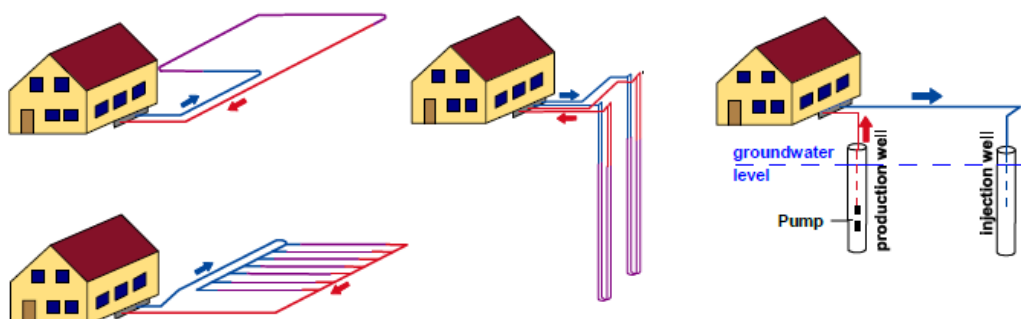


Figure 7. Schematic diagram of the most common ground-coupling methods (from left): horizontal loops, BHE, groundwater wells

¹⁷ General Report of the current situation of the regulative framework for the SGE Systems. REGEOCITIES. September 2013

¹⁸ Geotrained Training Manual for designers of shallow geothermal systems. GEOTRAINNET. Brussels, 2011

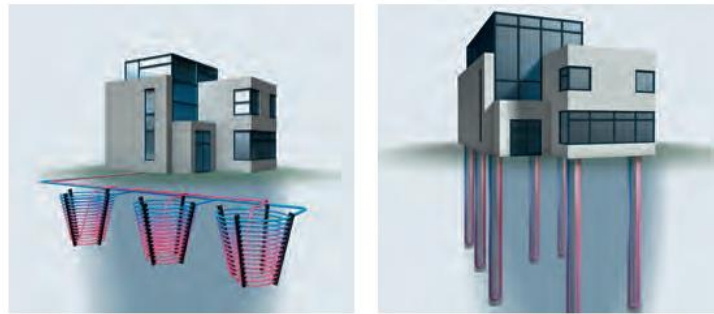


Figure 8. Basket systems (left); Energy piles (right) (Source: UPONOR)

4.2.2 Heat Pump

In the current market a lot of types of heat pumps exist, depending on their source of energy, application and coupled end-unit.

Heat pumps can be categorised according to¹⁹:

- **Function:** heating, cooling, domestic hot water, ventilation, drying, heat recovery
- **Heat source:** ground, ground-water, air, exhaust air
- **Working fluids:** (heat source/heat distribution) brine/water, water/water, direct-expansion/water, air/water, air/air, water/air
- **Unit construction:** compact or split, installation location (indoor/outdoor), compression heat pump, absorption heat pump, drive power (electric, gas), number of compression stage

Once the different categories of heat pumps have been described, it is important to clear out that **Ground Source Heat Pumps (GSHPs) are the type that uses as heat source, as indicated by the name itself, ground.** However, their other sub-category are Water Source Heat Pumps (WSHPs) that use as source ground water, aquifers, ponds, lakes, seas, etc. They are usually not differentiated due to the fact that they are based on the same technology and obtain similar performance results. Many times the terminology as geo-exchange, ground-coupled, geothermal, earth-coupled, ground water source and well water heat pumps refers to GSHPs. This diversified nomenclature is sometimes used to describe more accurately the specific application, however more often all of them work as synonyms for GSHPs.

4.2.2.1 Technology and application

Typical geothermal heat extraction systems coupled with ground source heat pumps are shown in Figure 9. The working fluid functioning as heat source is water or brine (heat transfer medium that has a freezing point depressed relative zero to water – antifreeze mixture).

¹⁹ Karl Ochner, *Geothermal Heat Pumps. A guide for Planning and Installing*, Earthscan, UK 2007

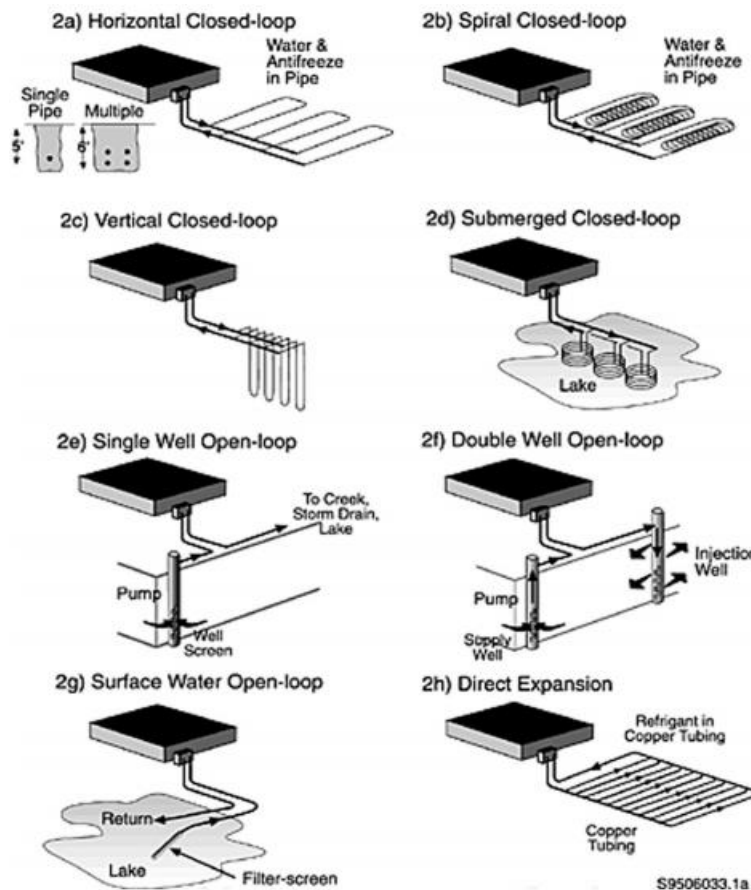


Figure 9. Ground-coupling system types²⁰

As it comes to delivery media, there are two different ones: water and air. By applying one or another, different kind of terminal units can be used and different operating temperatures are required. **In general, the GSHPs can be applied for heating, cooling and domestic hot water purposes of the building.** The major difficulties in functionality are encountered in water-based heating systems due to their inherent high operating temperatures. In the Table 3, exemplary distribution systems for heating and their needed temperatures are shown:

Table 3. Operational temperatures for different distribution systems for heating

Distribution system for heating	Delivery temperature (°C)
Underfloor heating	30 - 45
Low temperature radiators	45 - 55
Conventional radiators	60 - 90
Air	30 - 50
Domestic hot water heating	60 - 65

²⁰ Federal Energy Management Programme, Ground Source Heat Pumps Applied to Federal Facilities - Second edition, March 2011, US Department of Energy

Hence, the maximum operational temperature achievable for distribution systems for heating is 65 °C²¹. Nevertheless, it is only theoretically possible to achieve such high temperatures. In the Table 4 studied Seasonal Performance Factors (SPF) for heating in eight European countries for multi-family houses as well as for office buildings are shown. The SPF value is an average of COP (Coefficient of Performance) value obtained during the heating season. The COP is an indicator of efficiency of heat pump for heating purposes. It is expressed as:

$$COP = \frac{\text{space heating demand [W]}}{\text{power input [W]}}$$

The study was done by ECOFYS under the European Heat Pump Association²². The countries taken into account are Austria, Belgium, France, Germany, Italy, Spain, Sweden and United Kingdom. Analysis took place in capital cities of these countries, with an exception of Germany, where the reference building was located in Würzburg.

Table 4. SPF values in eight EU countries for ground and water source heat pumps applications for space heating and domestic hot water in residential buildings and space heating for non-residential

Country	AT	BE	FR	DE	IT	ES	SE ¹	UK
Multi-family houses								
Space heating 55 °C design temperature								
Brine heat pump	3.9	4.1	4.2	4.1	4.6	4.3	3.7	4.1
Water heat pump	4.0	4.2	4.3	4.2	4.8	4.5		4.2
Space heating 35 °C design temperature								
Brine heat pump	4.8	5.0	5.1	5.0	5.5	5.3	4.5	5.0
Water heat pump	5.1	5.3	5.4	5.7	5.8	5.7		5.3
Domestic Hot Water 60 °C								
Brine heat pump	2.6	2.6	2.6	2.6	2.7	2.7	2.5	2.6
Water heat pump	2.5	2.5	2.5	2.8	2.7	2.7		2.5
Office building ²								
Space heating 55 °C design temperature								
Brine heat pump	3.8	4.0	4.1	3.9	4.4	4.2	3.6	4.0
Water heat pump	3.9	4.1	4.2	4.0	4.6	4.4		4.2
Space heating 35 °C design temperature								
Brine heat pump	4.8	4.9	5.0	4.8	5.4	5.3	4.5	4.9
Water heat pump	5.1	5.2	5.3	5.6	5.6	5.7		5.2

(1) Sweden is an exception in terms of the water heat pump as the temperature of the groundwater is so low that it would freeze during operation. That is why the water heat pump is not investigated.

(2) For the non-residential building there is no considerable amount of domestic hot water energy need, therefore it is not taken into account.

²¹ Domestic Ground Source Heat Pumps: Design and installation of closed-loop systems (2007 edition)

²² ECOFYS, Heat Pump Implementation Scenarios until 2030, October 2013, EHPA

The first observation can be done with respect to operating temperatures: the lower they are, the higher the SPF values. However, these lower temperatures mean that the size of heat distributors must be increased (20 °C lower temperature increases the size of equipment about 30 - 40 %). In general, this is another aspect that must be taken into account while designing the system. In order to achieve the best performance of GSHPs, it is necessary to evaluate the building demand for space heating with precision. Even though the final energy needed to produce usable heat is low, heat pumps are an expensive technology and the payback period is coupled with performance.

Considering cooling, in the above presented studies, only countries like Spain and Italy have indicated demand for cooling for the residential part. In the Table 5 results of energy demand for typical residential and non-residential constructions in aforementioned countries are presented.

Table 5. Space heating and cooling demand for Single-Family House, Multi-Family House and Office building in eight EU countries

	AT	BR	FR	DE	IT	ES	SE	UK
Space Heating Demand								
Single-Family House	61.2	75.9	97.6	82.2	40.2	57.3	60.7	58.7
Multi-Family House	80.7	90.5	90.4	104.3	35.2	64.2	49.9	73.8
Office	45.8	53.8	56.5	39.8	18.6	39.9	37.1	48.2
Space Cooling Demand								
Single-Family House	0.0	0.0	0.0	0.0	11.2	10.5	0.0	0.0
Multi-Family House	0.0	0.0	0.0	0.0	25.3	26.1	0.0	0.0
Office	14.3	4.5	6.6	2.5	32.6	28.0	6.8	4.0

Using closed loop systems a limited amount of free cooling (using the circulation pump) is available, depending on the temperature of the circulation medium and the surrounding ground. When the free cooling is no longer capable of providing the cooling capacity and/or the temperature becomes too high, the mechanical cooling of the heat pump can be used.

In cooling applications, same as in heating, the operating temperature depends on delivery media. For water the inlet flow is around 5 – 7 °C with thermal rise of 5 °C. The terminal units for such systems are air handlers or cooling panels. Usage of air as energy distribution allows to impulse it directly into air ducts with temperatures around 15 °C. These temperatures are achieved easily by ground source heat pumps, due to stabilised underground temperature oscillating in between 10 – 20 °C. This small temperature difference between heat source and delivery media is favourable in terms of energy transfer, contributing to lower electricity consumption, hence higher performance. Moreover, it is possible to run GSHPs with compressor turned off during the cooling season, obtaining the effect of ‘free-cooling’. For cooling systems the efficiency is defined as Energy Efficiency Ratio and it is obtained similarly to COP, with difference in value of numerator.

$$EER = \frac{\text{space cooling demand [W]}}{\text{power input [W]}}$$

The cooling seasonal performance is reaching a value of 4 to 5, which will be shown below. Compared to other heat pumps applications available on the market, this is the best performance.

It is stated, though, that ground source heat pumps still have not achieved the maximum in terms of efficiency²³, hence it is possible to achieve more promising results, as shown in Figure 10. The thermodynamic efficiency of heat pump is defined by Carnot Cycle and its maximum is assessed to reach values 7 to 9. Therefore, by year 2020 the prognostic of seasonal performance of GSHP will reach around 60% of Carnot-efficiency, which constitutes an increase of 10% considering actual technology. The following Figure represents the evolution of the efficiency over the years, the graphic compares the geothermal shallow heat pumps and borehole heat exchangers.

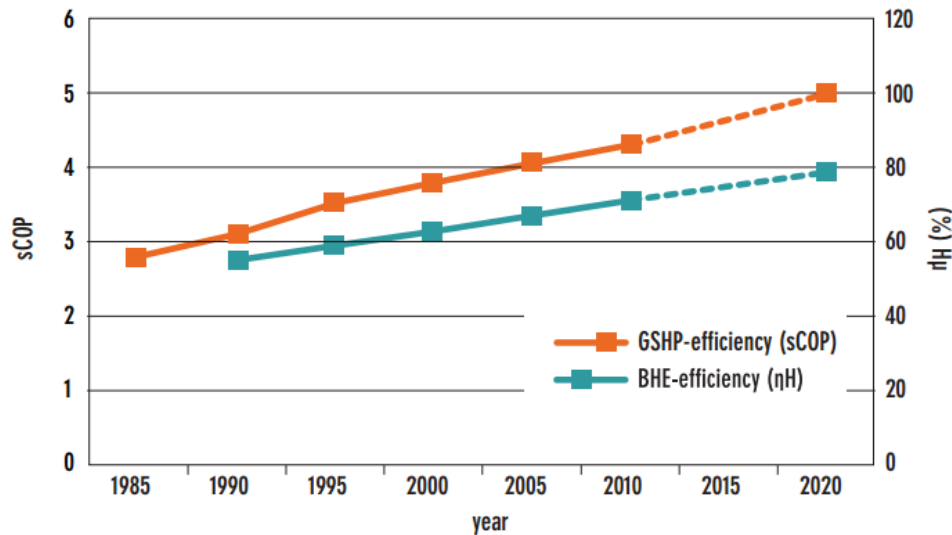


Figure 10. Prognostic of seasonal efficiency increase of state-of-the-art geothermal heat pumps (orange) and efficiency increase in state-of-the-art borehole heat exchanger (blue)

4.2.2.2 Heating vs cooling

In 1997 study done by Kavanaugh and Rafferty on GSHPs, estimated typical values for COP and EER resulted 3.3 and 4.2, respectively²⁴. In addition to this, the study carried out by GeoCool²⁵ in 2001 proves these performance values. In Figure 11, results of this study are shown. The seasonal performance for water-to-water heat pump during the cooling season reached 4.36, while in heating mode was 3.46. There is also included comparison to air-to water heat pump performance, about which it will be written later.

²³ European Technology Platform on Renewable Heating and Cooling, *Strategic Research and Innovation Agenda for Renewable Heating & Cooling*, 2013

²⁴ Kavanaugh, S. P. and K. Rafferty, 1997. "Ground-Source Heat Pumps", ASHRAE, Atlanta, Georgia, 167 p.

²⁵ Conference Cámara de Comercio Alemana para España, I+D+I en Geotermia: Un campo de oportunidades para la cooperación transnacional, Madrid, 2016

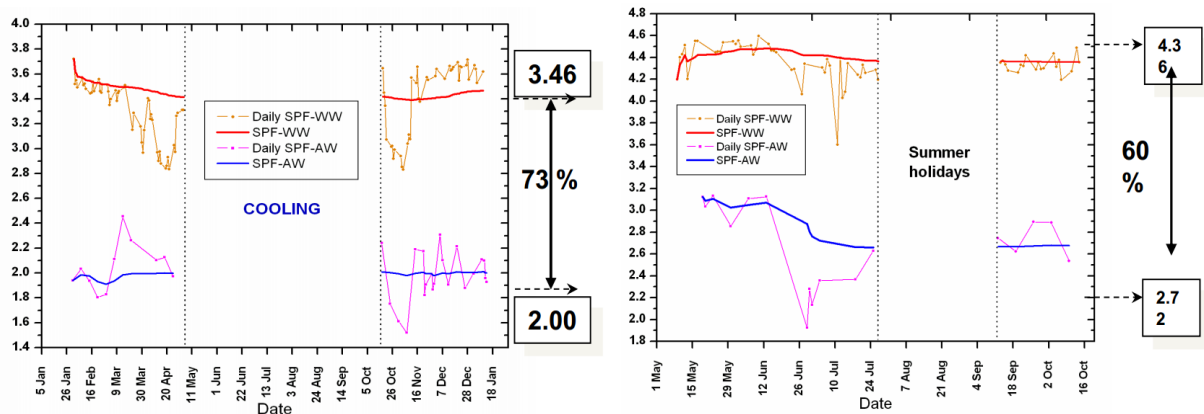


Figure 11. Performance of water-to-water heat pump (GSHP) and air-to-water heat pump (ASHP) in the GeoCool study plant (Spain) for heating (right) and cooling (left) mode

Regarding the previously presented studies by ECOFYS, it should be noted that performance of GSHPs for heating mode increased. It is mainly due to technology advances, like the design of compressor, implementation of two compressing stages when working with high temperature fluids, improvement of thermal storage systems and building construction. Nevertheless, as it comes to space cooling, there have not been noticed any specific improvements. It is mainly due to the fact that demand for space cooling in Europe is not as high as for heating. Therefore, the energy sector strongly focuses on reducing the primary energy usage for heating purposes. As it comes to domestic hot water energy needs, implementing this system is not profitable and it still requires improvements.

4.2.2.3 Recovery

In order to fully use the potential of ground source heat pump, one of the well-known recovery methods is the implementation of reversible valve that allows production of heating and cooling at the same time, provoking a so-called reverse cycle. In Figure 12, it is shown the refrigerant flow while applying the recovery for heating and cooling mode.

The reversing valve allows the use of a heat pump for heating and cooling purposes (it reverses the refrigerant cycle) and the evaporator becomes the condenser and vice versa. It does not allow simultaneous heating and cooling operation (however there are systems that will allow simultaneous heating and cooling on the same compressor input).

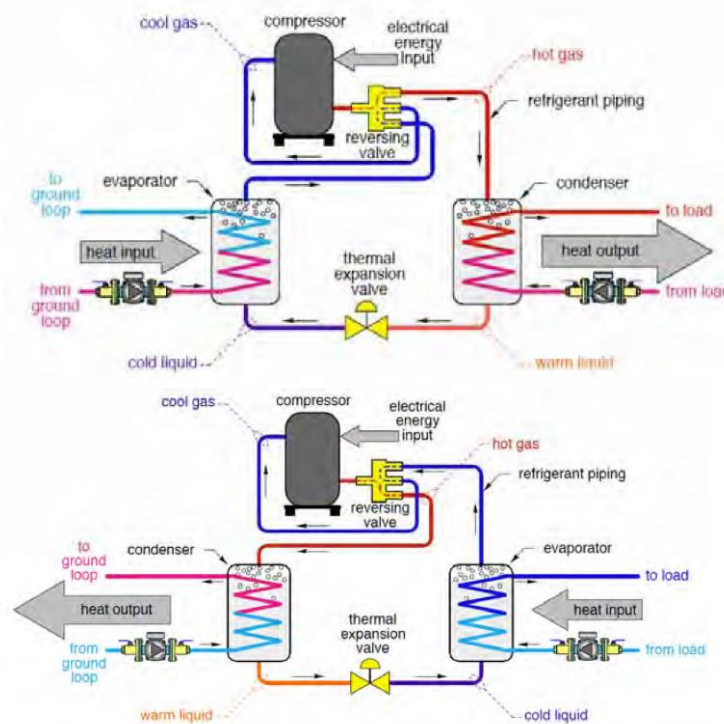


Figure 12. Reverse cycle application for cooling (on the right) and heating (on the left) mode²⁶

This kind of application allows transferring heat between units, injecting it to units that require this heat. The performance of the heat pump, under these circumstances, changes and is defined as the following formula:

$$\text{COP}_{\text{HR}} = \frac{\text{Heating capacity [kW]} + \text{Cooling capacity [kW]}}{\text{Required Work Input [kW]}}$$

It is estimated that implementation of recovery system increases the performance and exceeds the value of 5 (COP)²⁷. Nevertheless, it strongly depends on operating conditions and it cannot be taken as a rule.

Furthermore, it is possible to add another system that recovers the heat for domestic hot water purposes, namely desuperheater. When the refrigerant is compressed it heats up and converts in the so-called hot refrigerant, leaving the compressor with a temperature above the saturation point. This temperature difference can be called superheat or waste heat and it is later on transferred to condenser. The desuperheater function consists on recovering superheat before it enters the condenser. However, implementing this technology is twofold:

- In the cooling mode, the superheat extraction has positive impact on the system. This energy surplus that enters the condenser is not being further utilised by the system, hence its extraction reduces the heat losses
- In the heating mode, this superheat is used by the system in order to maintain high operating temperatures. Hence, while applying desuperheater, this heat cannot be used further by the system and brings about more operating difficulties

²⁶ ClimateMaster, *Applications of Water-to-Water heat pumps*

²⁷ Heating, Ventilation & Air-Conditioning High Efficiency Systems Strategy, *Heat Pump and Heat Recovery Technologies Factsheets*, September 2013

The desuperheater circuit is composed by: (1) heat exchanger (desuperheater) positioned between the compressor exit and the condenser entrance\reverse valve; (2) storage tank and (3) bronze circulator that transfers the water to heat; as shown in Figure 13.

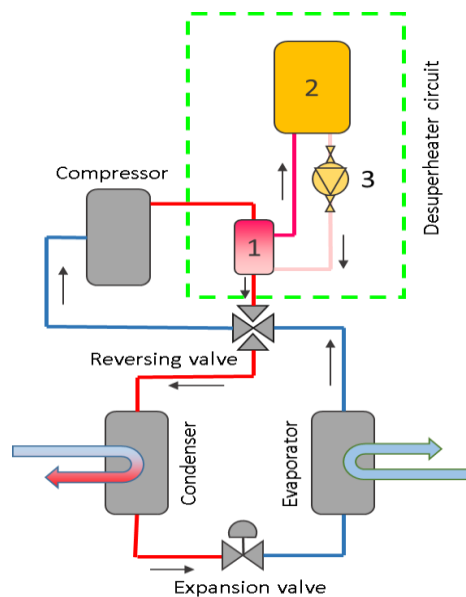


Figure 13. Desuperheater circuit where (1) desuperheater, (2) storage tank and (3) bronze circulator. By applying the desuperheater and a reversible valve, the system obtained is multi-functional, covering space heat, cooling and domestic hot water demand. Its operation was already proven in United States for residential application²⁸. Nevertheless, there are certain restrictions when it comes to its market volume, cost and operation: in fact, this system is not optimised yet and it requires further research.

4.2.2.4 Market outlook

The main market competitor for Ground Source Heat Pump is Air Source Heat Pump (ASHP). These pumps are more commercialised in the market due to their easiness of installation, lower price and less space occupancy. However, in terms of performance, the GSHPs are proven to reduce energy consumption by approximately 25% to 50%, due to less operation and maintenance difficulties and because they provide higher efficiencies, especially for heating loads when outside temperatures are very low. In general, GSHPs work in more stable conditions than ASHP. Furthermore air source heat pumps have acoustic (noise) issues.

Table 6. Heat pump global market properties

Regions		North America	China & India	OECD Pacific	OECD Europe
Typical size (kW)		2-19	1.5-4	2.2-10	2-15
Economic life (year)		15-20	15-20	8-30	7-30
Installed cost (USD/kW)	A-to-A*	360-326	180-225	400-536	558-1,430
	ASHP*	475-650	300-400	560-1,333	607-3,187
	GSHP*	500-850	439-600	1,000-4,000	1,170-2,267

²⁸ Mark Modera et al., *One Machine for Heating Cooling & Domestic Hot Water: Multi-Function Heat Pumps to Enable Zero Net Energy Homes*, ©2014 ACEEE Summer Study on Energy Efficiency in Buildings

*A-to-A refers to air-to-air heat pump, while ASHP is considered as air to water heat pump. Both are air source, but the delivery media change.

GSHP refers to brine/water to water heat pump.

In Table 6, global prices, typical size and economic life of installation for residential application are shown²⁹. These big price differences between the regions are the result of diversified incentive policies, among other reasons. As it can be observed, the most expensive installation cost is related to ground source heat pumps.

Concentrating strictly on the European market, in Figure 14 shown the number of units installed per country is shown.

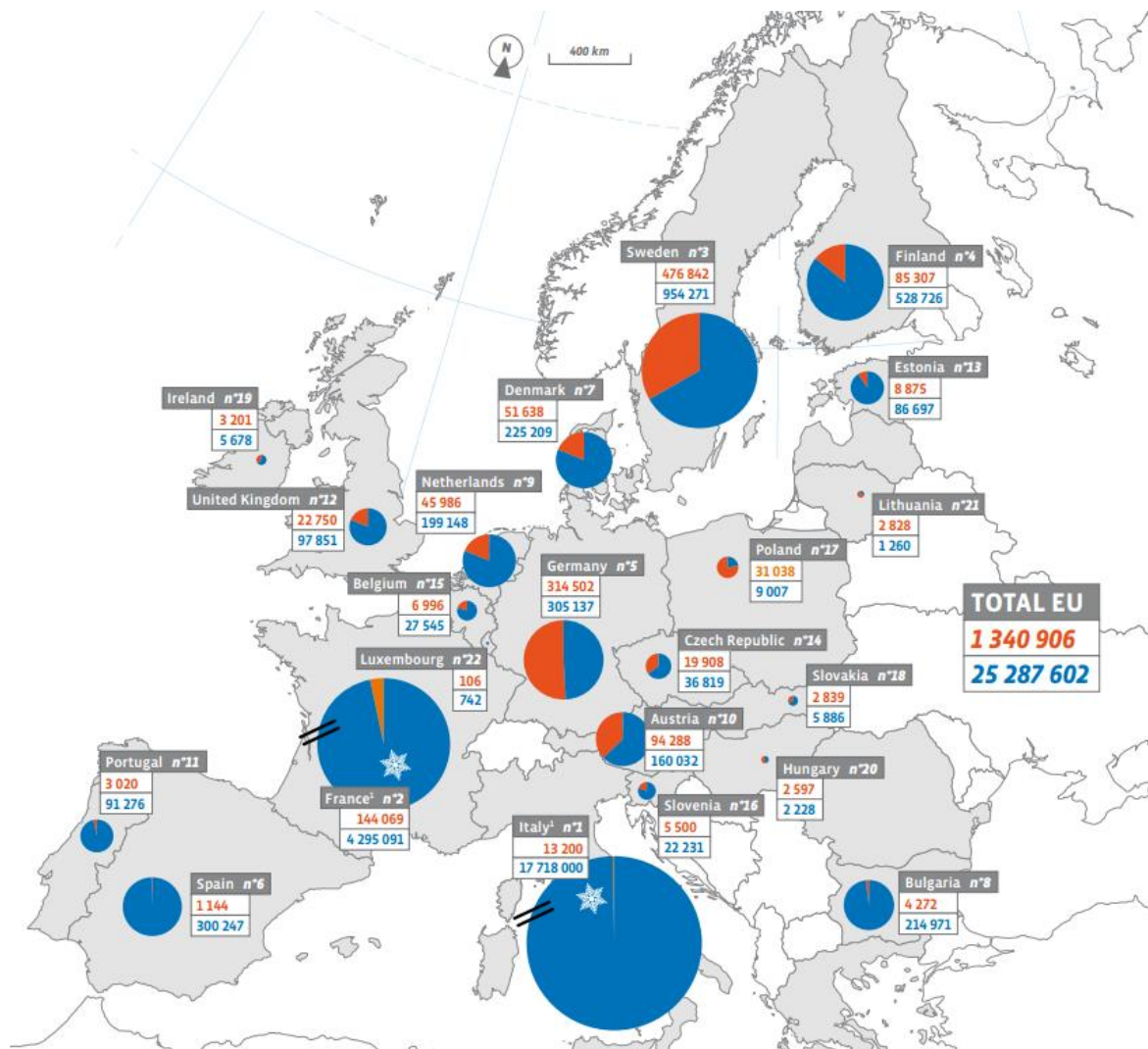


Figure 14. Installed ASHP (blue) and GSHP (orange) units in Europe for 2014

Geothermal technology can be applied in residential, non-residential and industrial sectors. Currently, the most popular application of GSHP refers to large commercial buildings, usually combined with thermal storage technologies, covering the needs for heating and cooling. The market diversifies from small-scale applications, starting with power of 2.8 kW, to large-scale applications, reaching the maximum of 1,000 kW.

²⁹ IEA-ETSAP and IRENA© Technology Brief E12 – January 2013

The **biggest and most stable market for GSHP systems** is **Sweden** due to favourable policies, offering around 5,000 € incentive for new built residential segment. It is estimated that every second family home uses heat pumps as a source for heating system. The **second most interesting market** is **Germany**, even though it is not stable (in 2014, a drop in sales of GSHPs systems was noticed). In spite of this, the most recognised distributors of geothermal heat pumps are mostly found in Germany, with companies as Viessmann Group, Buderus, Stiebel Eltron, Waterkotte and Wolf Heiztechnik and brands as Alpha Innotec, Vaillant, Rotex, Bosch therrmotechnology, Brötje. Other representative companies are BDR Thermea, IVT Industries (Sweden), Daikin Europe, Danfoss, Nibe, Vaillant Group, Oschner Wärmepumpe (Austria)³⁰.

4.2.3 Hybridisation of the production system

The most common type of HVAC systems using GSHP are the water-to-water system and the water-to-air system. Unlike air-to-air and air-to-water systems, these do not include an air-handling unit, and ventilation is effectuated independently through air vents. As for the terminal unit, fan coils, conventional radiators and radiating surfaces can be used, depending on the delivery media.

Regarding fan coil units, they consist of a heat exchanger (coil) and a distributing fan (there are 2-pipe-units and 4-pipe-units). The former can only provide heating or cooling depending on the season, while the latter can provide both heating and cooling simultaneously by means of two separated circuits.

According to the Eurovent data analyses, 2-pipe-units account for three quarters of the total fan coil units in the European market, whereas 4-pipe-units represent the remaining quarter and they are even the prevailing type in Ireland and the United Kingdom, in spite of their significant larger energetic expenditure.

The building's energy efficiency is improved when GSHPs are combined with low-temperature heating and high temperature cooling systems like radiant floors or ceilings. Radiant surfaces require a small thermal gap to function, thereby offering better heat pump efficiency.

Foundation heat exchangers can provide direct or indirect hybridisation with HVAC systems. Direct applications can be found on heating and cooling thermal collectors with several inputs and outputs. Heat transfer water from the pump as well as water from heat generators such as boilers arrives at the collector, from which it is distributed through the many outlets by a simple control system.

Sometimes it is convenient to pre-heat the water from the pump because it does not reach the temperature of the other input fluids. In this case, the heat transfer water goes through a heat generator along with the network water, which results in a water output from the boiler whose temperature will be adequate for the thermal collector and its applications. This pre-treatment improves the efficiency of the pump because of the lower thermal gap between the input and output heat carrier fluid. However, as additional non-thermal energy is used, it might not be worth doing if the energy expenditure of the heat generator is higher than the savings from the heat pump.

Indirect applications, as Thermally Active Building Systems (TABS), are less common but much more energy efficient, although do not usually match the building's demand in energy and they are therefore a complimentary heating and cooling technology. The heat transfer fluid is distributed through a loop system embedded in the central concrete core of a building's construction, meaning floors and, occasionally, walls. This technology utilises the heat storage capacity of the concrete and increases the thermal capacity of the building to neutralise peak loads. It works as follows: energy is produced at night, when the price of electricity is lower, and then stored in the structure of

³⁰ EurObserv'ER, *Heat pumps barometer*, 2015

the building. During the day, energy is dissipated through the floor and ceiling. Conventional heating or cooling systems will only perform if the heat capacity of the heat pump system is not enough to provide the room temperature requirements for optimal comfort. This system is particularly suitable for buildings with temporal occupancy such as office buildings, universities and shopping centres, which have a very specific and stable energy demand. Comfort is warranted thanks to the optimal and stable temperatures offered by quiet equipment without air circulation, which means that air currents and fouling factor caused by dust are avoided.

4.2.4 Opportunities for reducing cost

Minimising the overall cost of the technology is always a priority. While ground source heat pumps already represent a big difference in energy expenditure in terms of electricity use with respect to other more conventional HVAC systems, the installation costs are higher and vary depending on the building energy requirements, soil conditions, system configuration, site accessibility and amount of digging and drilling required. Improvements can be made in order to make this technology cheaper while maintaining its high efficiency.

The type of loop used in GSHP systems is a decisive factor in the installation cost. Horizontal closed-loops are cheaper to implement than vertical closed-loops, but they require more open space (the choice will also affect the design and efficiency of the system). The cheaper closed-loop option is represented by submerged closed-loops, which draw heat from water (if this is allowed by local legislation and ecological consequences) instead of the ground, though the need for a nearby pond or lake makes it a very limited option, especially in urban sites.

An **improved and convenient application of GSHP for HVAC systems** can be found in **Foundation Heat Exchangers (FHX)**, which consist of the insertion of a heat exchanger, such as the aforementioned loop, inside the reinforced concrete foundations of the building (e.g. piles, panels). These structural elements are usually not located deep enough in the ground, where the conditions for heat exchange are adequate like in the case of the previously cited closed loops, and provide a considerable (usually limited) contact surface with the soil for optimal energy exchange without requiring any additional space. The main advantage of FHX is that its implementation takes place during construction and, in spite of signifying a bigger initial investment, the high costs of later additional drilling are thereby eliminated or vastly reduced. However, foundation heat exchangers can be used successfully only in a limited number of applications. Usually they can only contribute to a relatively small amount of “renewable” energy to the total building demand, so they are almost always part of a hybrid solution (additional gas boilers, chillers etc.): this requires high quality integration. In practice, foundation heat exchangers require a lot of effort to install and the soil condition in which they are installed are often not advantageous from the point of thermal performance (very soft clayey/peaty soils or very dry low compaction soils). Foundation heat exchangers represent a “niche” application which needs to be well defined to be successful.

Additionally, free cooling is a method combinable with GSHPs to reduce operating costs. The free cooling system for buildings takes advantage of lower outdoor enthalpy to provide cooling indoors. When the temperature of the air outdoors is appropriately lower than the temperature of the air pulled from indoors, the system lets the outside air in, filters it properly and uses it to cool the room, thus providing “free cooling”. To make this possible, an economiser needs to be installed, thus requiring an investment in equipment. The economiser is comprised of several components, including an outside air intake, an exhaust air exit, a damper assembly to bring in variable amounts of outside air, outdoor air sensors and a controller, which determines whether the outside air is apt for introduction in the building. The suitability of the air depends on its temperature and humidity and extreme values on both variables do not allow the free cooling system to perform. This system

is particularly suitable for large commercial buildings and any building that concentrates a large amount of people, since temperatures in these spaces easily rise and therefore outdoor temperatures tend to be lower even in the warmer months.

Relevant for the shallow geothermal systems are the free cooling on open well applications, which directly use the available temperature of the groundwater, or the (limited) free cooling on a closed loop system using the available temperature from the loop/ground. Free cooling implies that the compressor of the heat pump is not used (mechanical cooling) and it is only the circulation pump that is used (usually COP's of around 1:20). Obviously on the closed loop the temperature will raise with continued load on the loop: at some point the capacity will no longer be adequate and the system needs to change to active cooling.

5. MARKET POTENTIAL FOR GEOTHERMAL HEAT PRODUCTION AND USE IN BUILDING SECTOR IN EUROPE

Geothermal potential in Europe

In Europe the interest in geothermal energy has been growing in the last 10 years and the renovated interest was mainly due to the new de-carbonization EU policies, the advancement in technologies and the use of medium and low enthalpy geothermal reservoirs for heating purposes.

Deployment of geothermal energy is mainly based upon three sectors:

- **Electricity production** (*not relevant to GEOTeCH*): with the use of Organic Rankine Cycle Turbines, it is possible to produce electric energy from medium enthalpy reservoirs with temperatures around 100 °C. This possibility enhances the potential for realization of geothermo-electric power plants around Europe. Some recent applications of this technology can be found in Germany and Turkey; worldwide, an increase of about 1.7 GW in the five years term 2010-2015 has been achieved (about 16%), following the rough standard linear trend of approximately 350 MW/year, with an evident increment of the average value of about 200 MW/year in the precedent 2000-2005 period. The total installed capacity from worldwide geothermal power plant, pointing out countries with active geothermal plants for electricity generation, is illustrated in the Figure 15 below.

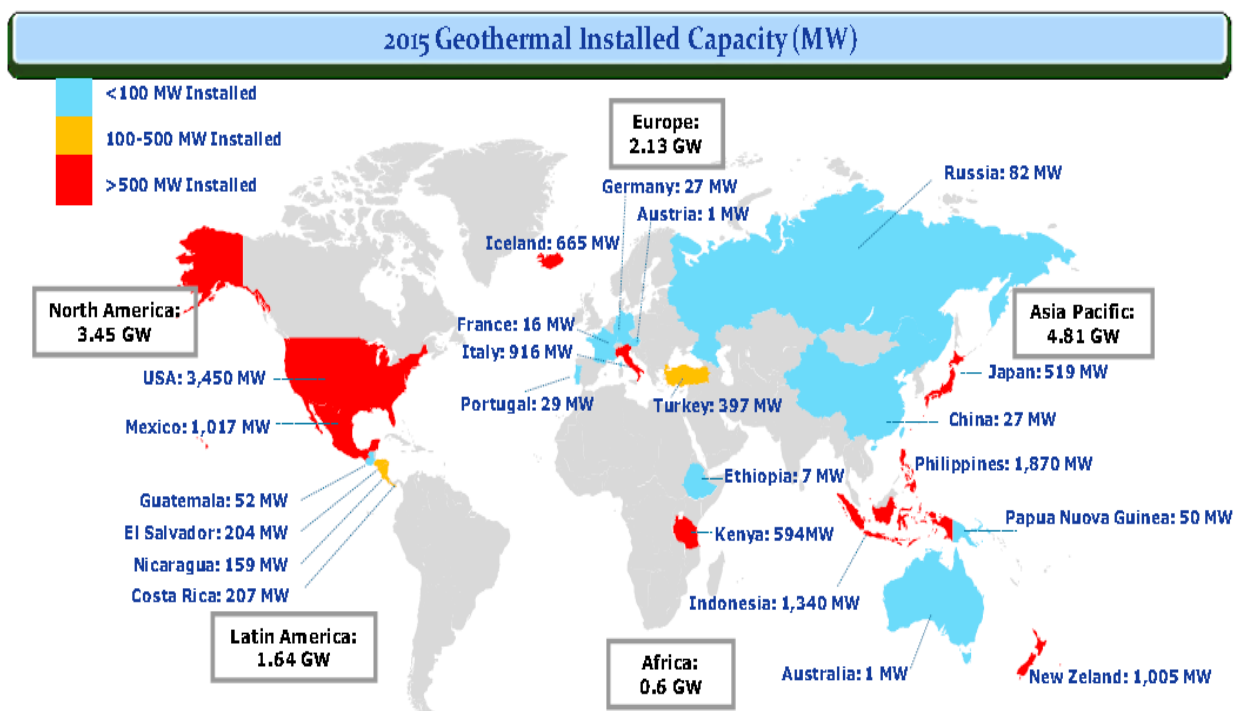


Figure 15. 2015 Geothermal Installed Capacity (MW)

- **District heating and cooling** (*some relevance to GEOTeCH*): the sector of heating and cooling represents about 50% of the entire European energy needs. In this framework, medium and low enthalpy geothermal energy is gaining its role as a competitive renewable system, related both to decarbonisation policies and to low prices for the end users. Geothermal district heating and cooling systems are widespread around Europe and they could be potentially installed in all European countries. Moreover, the district heating traditional technology is moving towards smart thermal grids, where different technologies and renewable energy sources are combined, to

reach higher standards of grid flexibility and a higher degree of security of energy supply. Both deep and shallow geothermal energy can be inserted within smart thermal grids, and several examples already exist. Endogenous geothermal fluids can be directly used for district heating through heat exchangers and for district cooling through absorption chillers. Shallow geothermal energy can also be used in smart thermal grids; some notable examples are the Underground Thermal Energy Storage (UTES) solutions, where shallow underground is used as a seasonal storage of thermal energy to be used in district heating networks and the so-called “cold” district heating systems, where the borehole heat exchanger or well fields are connected to several heat pumps and buildings through a water distribution network. Shallow geothermal systems are very versatile and can be adapted to almost every subsurface condition. The mature markets aim to develop large systems to connect buildings in commercial and industrial areas.

- **Individual geothermal heat pumps** (*relevant to GEOTeCH*): water-to-water heat pumps can harness shallow geothermal energy everywhere. The heat pumps are used for bringing the temperature to the required temperature set-point for the building needs (both heating and cooling). When using ground source heat pumps, the thermal energy design should take into account the annual building energy needs (mWh), the required peak loads (kW) and the relevant soil parameters (geothermal design parameters). The GSHP system, including the soil heat exchanger, should be designed for occupancy comfort (heating and cooling capacities are available) and long term (> 25 years) energy efficient operation. The main limitation consists in a potential seasonal thermal depletion of underground caused by the continuous working of the heat pump, which decreases the system efficiency along time. Ground Source Heat Pump (GSHP) projects should always look for the optimum economical balance between the investment costs of the borehole heat exchangers or well field and the operational costs expected due to the efficiency decrease along time. The integration of geothermal heat pumps within smart local or district heating networks fed by different forms of energy supply has usually revealed to be the most economical solution in many different situations, according to specific energy vector prices and climatic conditions of single countries.

Overview on geothermal heat pumps market in Europe

The **mature markets** of geothermal heat pumps in Europe are **Sweden, Germany, France, Switzerland** and **Norway**, which account for **around 70% of all installed capacity** of the continent³¹. An interesting development can be noted in Central and Eastern Europe, where, while the absolute numbers are low, there is a quite positive trend.

³¹ Antics, M., Bertani, R. & Sanner, B. (2016): Summary of EGC 2016 Country Update Reports on Geothermal Energy in Europe. - Proc. EGC 2016, 16 p., Pisa

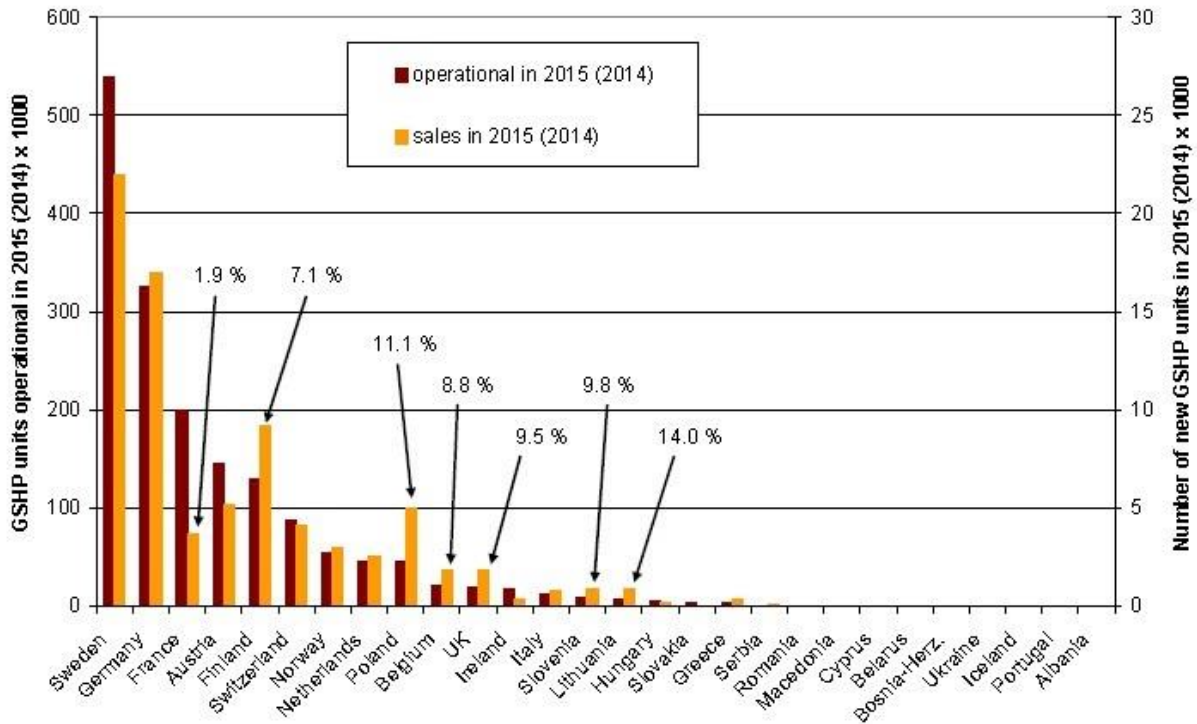


Figure 16. Total number of GSHP and sales in 2015 (some countries 2014) as stated in EGC 2016 country update reports; the ratio of sales in relation to existing installations is highlighted for some countries (part of sale in mature markets are replacement sales)

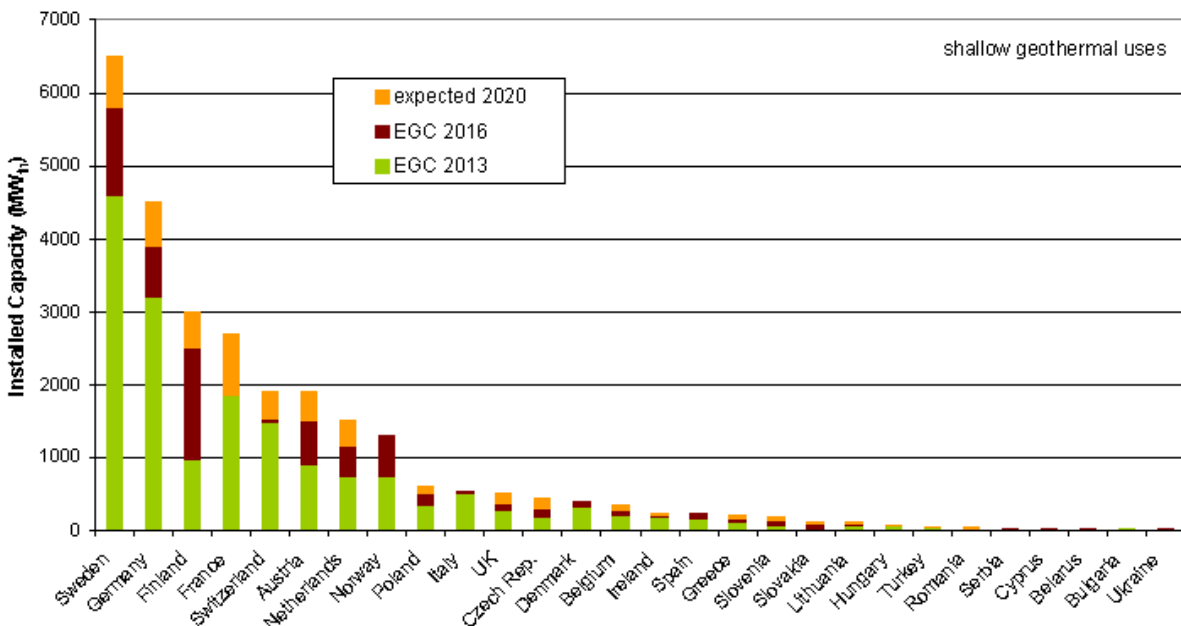


Figure 17. Installed capacity in geothermal heat pumps in Europe 2012-2015, after EGC 2013 and EGC 2016, and reported expectations towards 2020

Geothermal heat pump systems for the heating of residential houses are widespread in European countries. The specific local conditions (climate, geology and hydrogeology, energy vector prices, drilling and work costs) lead the customers choosing a type of geothermal system instead of another heating/cooling installation. The cooling option is increasing in popularity also in northern and central European countries and in the residential sector. For non-residential buildings, heating and

cooling using geothermal heat pumps is already a standard option in many different situations. The transition from simple ground source heat pump systems to UTES applications connected to smart grids has been gradual. The GSHP systems are very favourable for new buildings, while the retrofit is not today a common solution, mainly for technical issues related to available space and with exception of some particular situations. Also there is a lack of energy efficient and commercially successful GSHP concepts for this “niche” of the market.

GSHP market is very sensitive to economic situation and electricity prices. During periods of stagnancy, with electricity prices higher than natural gas prices, the GSHP generally lose their convenience with respect to boilers and burners.

Moreover, in recent years GSHPs are faced by competition from air conditioning machines and air-to-air heat pumps, which have improved their efficiency. Also the first cost (capital cost) are lower as these machines do not need a ground heat exchanger. Advantages of the ground source heat pump compared to the air source heat pump are higher energy efficiency, thermal storage capability in the ground and no noise emissions to the ambient.

In fact, the cost intensity for the initial investment is an issue, which compromises the market of GSHP. GSHP can be considered as a capital-intensive technology in comparison with other small-scale applications. In particular, natural gas boilers and air-to-air heat pumps today are seen as cheaper solutions, even if the efficiencies are lower. The main part of the additional cost with respect to alternatives is taken by drilling of boreholes or emplacement of the ground collectors. Moreover, these works usually have to deal with national and local regulations, mainly related to risk of groundwater pollution, with consequent installation delays.

Potential for GEOTeCH technologies in Europe

All the technologies developed within GEOTeCH project fall within the sector of geothermal heat pumps, but they can also be of interest within more complex smart thermal grids, or at district level application.

The main target is to increase the share of shallow geothermal heat pumps inside the HVAC sector for all types of buildings across Europe. This will be possible through the reduction of cost in the initial investment by:

- reducing the use of energy from each borehole heat exchanger by using a dual source heat pump, hence reducing the borehole length
- decreasing the drilling cost by using optimised and specialized drilling machines able to reach the minimum depth of new borehole heat exchangers
- decreasing the administrative costs and the times for procedures, by decreasing the interaction with shallow aquifers
- reducing the additional drilling costs by integrating the borehole heat exchangers in the building foundations, where possible
- decreasing the needed area of borehole heat exchanger fields, by combining GSHP with air-to-air heat pumps, in a unique solution dual source mode
- decreasing the energy losses of GSHP working mode, by improving the building energy management, which means indirectly a less borehole length needed

All the previous challenges are related each other. A preliminary assessment of the potential for the GEOTeCH technologies in Europe can be done by analysing the surface geology of different countries, which influence the performance of two of the innovations of GEOTeCH technologies.

These two innovations are:

1. Dry auger drilling technology

The current drilling machines used for vertical heat exchanger installations use circulation fluids (air or water), which increase the equipment cost, work on site and furthermore require site coordination for the water/mud infrastructure, disposal of mud and clean up after loop installation. The main aim of the new dry drilling system based on “hollow stem auger” concept is to reduce the installation costs of vertical borehole heat exchangers in suitable geology such as soft to medium compact sediments. Also as work is carried out much drier conditions the working conditions for the operators will improve.

Lowered installation cost and will improve the economic performance of the geothermal investment. Drilling shallower boreholes and the absence of drilling fluids (water or drilling muds) will reduce or even avoid the use of large quantities of drilling water and limit potential hydrogeological contamination risk to aquifers. As a consequence environmental risks are reduced and permitting for drilling works can be simplified.

Obviously the dry auger drilling is suitable for overburden drilling, in general sedimentary cover consisting of unconsolidated materials such as sands, clays and gravels. The drilling methodology is not suited for hard rock type drilling.

2. High performance BHEs and foundation heat exchanger solutions

The aim of the innovative spiral BHE developed in GEOTeCH is to reduce the overall borehole thermal resistance (R) especially at laminar (lower) flow conditions of the circulation medium. As the boreholes drilled with the new dry auger drilling technique, also developed in GEOTeCH, will be shallower than those drilled with conventional techniques, multiple boreholes will be needed per site, reducing the flow rate per borehole. A large gain in the overall GSHP system efficiency is the reduction of pumping energy needed for the system (less pressure loss per borehole), whilst the thermal resistance of each new spiral heat exchanger is similar or better than conventional high (turbulent) flow rate, higher pressure loss loop type heat exchangers.

Furthermore as the new developed dual source will use both air as well as the soil heat exchanger as an energy source, borehole depth can be reduced as the overall load on the borehole is reduced by using air as a source when the conditions are favourable.

The shallower installation depth of the heat exchangers in combination with the new spiral heat exchangers can also be applied to foundation type heat exchangers, especially as dry auger drilling is a common drilling technology already in use in foundation engineering.

For the reason of indicating the most suitable conditions for applying the new technology, the mapping procedure implemented in the task 7.1³² to geo-localise, at macro European Level, the most important parameters and indicators of ground is essential. This task is to assess the potential for the new technologies in Europe.

In particular, the following parameters have been geo-referenced:

- For Drilling → Geotechnical and geo-mechanical properties (average and standard deviation) of the typical shallow lithotypes of GEOTeCH countries, in order to get a preliminary evaluation of shallow underground shear strength.

³² The task will bring to conclude with the Deliverable D7.2 Mapping and Risk Assessment

- For BHEs → Thermal properties (average and standard deviation) of the typical shallow lithotypes of GEOTeCH countries, with particular reference to thermal conductivity and thermal diffusivity.

Regarding the evaluation of shallow underground shear strength, the specifications of GEOTeCH hollow stem auger drilling technology have led to set a threshold limit of shear strength at 15 MPa, which separates the drillable zones from the undrillable ones, although convenient drilling speed can be reached by considering shear strength limits up to 1 MPa. The particular limit of 15 MPa coincides with the border between soft and medium rocks and, in fact, the hollow stem auger technology is inapplicable to most part of medium and hard rock types. In addition, possible groundwater presence increases the final shear strength of unconsolidated layers, with the effect of drilling speed reduction.

A particular issue very well focused on the specific GEOTeCH technology, and not to all low enthalpy geothermal fields, concerns the fact that the innovative BHE is provided to be used for both heating and cooling demands at entire European level. Hence, in order to get useful information about effectiveness of this new integrated very shallow solution in different European regions, climate and geothermal heat flow data were analysed and added to the mapping activity.

Indeed, it was found that:

- Climate data are useful not only to define the amount of heating and cooling needs of buildings in different European regions, but overall to estimate, using thermal properties of subsoil layers in the calculations, the underground temperature behaviour in the very shallow depths, up to reach the “neutral zone”, where temperature does not follow seasonality and it is constant over time
- Geothermal heat flow data are useful to define the depth where geothermal gradient becomes prominent, and so when “neutral zone” ends

The “neutral zone” defines the optimal depth to reach when installing BHEs and this becomes particularly important in combined heating and cooling projects, in order to exploit the maximum ground potential for both uses.

Different factors influence the top and bottom levels of the “neutral zone”. Neglecting thermal influence of urban environment, the following deviations occur, respectively for the top (Table 7) and the bottom (Table 8) level:

Table 7. Deviation of top level of the “neutral zone” due to the percentage variation of different natural parameters influencing heat exchange in the subsoil

	Natural parameter deviation		
	0%	50%	100%
Natural parameters	Variation of the top		
Average temperature	0.00%	0.00%	0.00%
Climatic wave amplitude	0.00%	5.06%	10.13%
Ground layer thermal diffusivity	0.00%	22.78%	41.77%
Ground layer thermal conductivity	0.00%	0.00%	0.00%
Geothermal heat flow	0.00%	0.00%	0.00%

Table 8. Deviation of bottom level of “neutral zone” due to the percentage variation of different natural parameters influencing heat exchange in the subsoil

	Natural parameter deviation		
	0%	50%	100%
Natural parameters	Variation of the bottom		
Average temperature	0.00%	0.00%	0.00%
Climatic wave amplitude	0.00%	1.63%	3.25%
Ground layer thermal diffusivity	0.00%	7.32%	13.41%
Ground layer thermal conductivity	0.00%	33.74%	67.89%
Geothermal heat flow	0.00%	-22.36%	-33.74%

As the amount of exploited energy is strongly influenced by the depth and thickness of neutral zone, this inevitably affects drilling and installation costs. In shallow unconsolidated subsoil, dry auger techniques may be the best solutions in terms of costs containment and drilling speed, while air flush roto-percussion and water flush rotary drilling are the most common solutions for deeper depths. The need to utilise drilling fluids inevitable raises installation costs, and also lowers site cleanliness and workers safety.

The knowledge, with reasonable degree of uncertainty, of the top and bottom level of the “neutral zone” will improve the evaluation of the GEOTeCH technology effectiveness for each specific geothermal project, in many different geographical and geological contexts, with respect to:

- Analysis of drilling costs;
- Evaluation of needed geo-energy on the basis of actual heating and cooling needs;
- Design of the BHE field and connections.

To extract the **maximum amount of energy**, the innovative **BHEs** should reach the “**Neutral Zone**”, which varies according to natural factors (climate and underground thermal properties), from zone to zone. The cost for drilling to reach this depth is to be taken into account in each geothermal project.

Based on surface geology data, from “EuroGeoSurveys' European Geological Data Infrastructure – EGDl”, and subsequent processing, preliminary percentages of country territories where hollow stem auger technology can be used have been calculated as following:

Table 9. Potential application of hollow stem auger technology in GEOTeCH countries

Country	Total territory (km ²)	Territory with potential application of HSA (km ²)	Percentage %
Austria	83,844.99	14,093.89	16.81%
Belgium	30,560.96	18,996.11	62.16%
Czech Republic	78,851.71	17,695.06	22.44%
Denmark	42,469.15	42,385.37	99.80%
Estonia	43,564.02	42,448.61	97.44%
Finland	335,751.19	302,291.87	90.03%
France	548,649.87	114,677.82	20.90%
Germany	357,423.72	188,704.71	52.80%
Greece	88,522.44	25,937.33	29.30%

Hungary	93,446.25	79,230.02	84.79%
Ireland	68,213.68	60,622.24	88.87%
Italy	298,501.61	79,583.44	26.66%
Lithuania	64,771.91	64,771.91	100.00%
Luxembourg	2600.95	62.05	2.39%
Netherlands	34,933.22	34,849.65	99.76%
Norway	393,305.22	11,432.36	2.91%
Poland	308,350.03	274,819.89	89.13%
Portugal	89,191.70	5,364.92	6.02%
Serbia	88,723.58	37,036.33	41.74%
Slovakia	48,954.36	16,449.21	33.60%
Slovenia	20,274.63	587.74	2.90%
Spain	501,786.55	78,327.12	15.61%
Sweden	447,861.96	378,264.35	84.46%
Switzerland	41,440.23	13,887.43	33.51%
United Kingdom	244,500.54	169,156.93	69.18%
TOTAL	4,356,494.48	2,071,676.39	47.55%

Suitability for HSA and heat pump applications will also depend on population density and economic factors.

Most areas of European countries have geographical regions with underground layers difficult to drill with hollow stem auger technology; nevertheless the large number of urbanized areas, cities and city centres (and so the large part of heating and cooling consumptions) are located in the valleys, where underground presents low values of shear strength and thus high drilling speed for hollow stem auger technology up to 50 m.

The use of **hollow stem auger technology** is strongly influenced by geotechnical and geo-mechanical properties of underground. At European level, the system can be easily used where unconsolidated material is predominant. Although the percentage of potential territory varies from country to country, and it is particularly limited in southern European countries, it is to be noted that the highest heating and cooling needs are concentrated in urban areas, usually established in valleys, with predominance of unconsolidated material.

Regarding thermal properties, it was found a certain correlation between high values of shear strength, which influences the difficulty of drilling, and high values of thermal conductivity, which influences the exploitable geothermal energy. Indeed, the energy extractable increases with higher values of thermal conductivity of underground.

Shear strength and **thermal conductivity** represent two **opposite phenomena**. A balance between difficulty of drilling and effective exploitable energy will define the effective potential for the use of new integrated very shallow geothermal technology.

From the activities carried out, we could define some preliminary indications useful for market assessment:

- Auger technology is strongly influenced by underground geotechnical and geo-mechanical properties and can be easily used where unconsolidated material is predominant. Although the percentage of potential territory varies from country to country, and is particularly limited in southern European countries, it should be noticed that the highest heating and cooling needs concentrate in economic developed urban areas, usually established in valleys, with predominance of unconsolidated material
- Exploitable energy increases with higher values of thermal conductivity of underground, although there is a sort of direct proportionality with shear strength so that in terms of actual market potential of the technology, the two properties oppose them each other
- Defining the depth and thickness of the “neutral zone” is of great importance for shallow geothermal solutions. To extract the maximum amount of energy, the BHEs should reach the “neutral zone” and the drilling cost to reach this depth is to be taken into account in each geothermal project
- Adequate thermal design of the buildings and their energy demand is essential for the design of efficient shallow geothermal heat exchangers. Annual and seasonal energy balance between heating and cooling will reduce the size and cost of the borehole heat exchanger as well as improve operating conditions and energy efficiency.

In the following subchapters a detailed focus will be dedicated to the EU markets hosting the demo sites of the GEOTeCH project, highlighting these main points:

- Market research
- Potential market for the implementation of geothermal solutions (residential and commercial sectors)
- Climate conditions
- Regulations in building sector for renewable energies and construction requirements.

5.1 Market in Spain

The following study contains information about the energy situation in Spain, i.e. energy supply, production and consumption, taking into account the country's climate and geography. Spain's potential for geothermal energy will be analysed, as well as the existing installations and applications, which still contribute very little to the energy mix.

Climate conditions

Due to the country's size and diverse geography, the Spanish climate can vary significantly by region. The several distinct Spanish climates are the following:

- **Typical Mediterranean:** along most of the Mediterranean coast, the Andalusia coast, the Balearic Islands and the cities of Ceuta and Melilla. Characterised by hot summers and mild winters, and with scarce and irregular rainfall
- **Continentalised Mediterranean:** in the central plateau and the depression of the Ebro river. Temperatures are extreme in both summer and winter and rainfall is rare but stormy in the summer in some areas
- **Oceanic:** located in the northern part of the country, in the Atlantic coast. Temperatures are mild throughout the year, with cool summers and mild winters. Rainfall is abundant all over the year
- **Semi-arid:** in the southeast of Spain, mainly the region of Murcia and the Ebro valley. Similar to the typical Mediterranean climate (hot summers and mild winters) but even drier
- **Alpine:** located in mountainous areas such as Picos de Europa, Sistema Central, Sistema Iberico, Pyrenees and Sierra Nevada. It has long and very cold winters and short and warm summers. Rainfall and snowfall are profuse
- **Subtropical:** only in the Canary Islands. Temperatures are mild all year long (between 18 °C and 25 °C) and rainfall is scarce

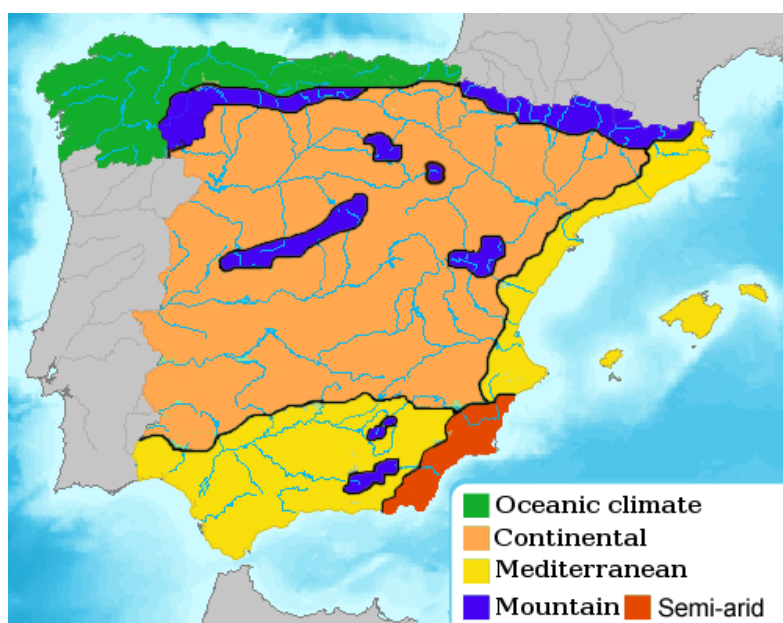


Figure 18. Spain's climate zones

This diversity of climates also has an impact on the energy demand, especially when it comes to heating and cooling. Average air temperatures in a year can range from 2.5 °C in high altitude areas to as high as 17 °C in southern places like Seville and Cadiz. As opposed to most of the EU, highest

electricity consumption in Spain is found in the hotter areas, such as the southern and southeast Mediterranean coast due to the penetration of air conditioning.

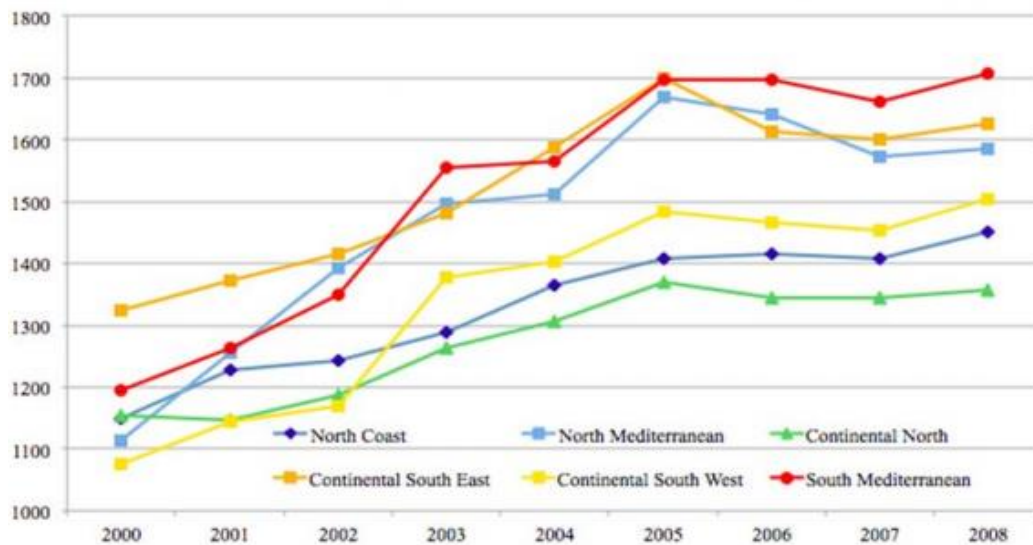


Figure 19. Electricity consumption in households per capita in Spain per climate zones (Source: CEPE 2012)

5.1.1 Market Development

Overview of the energy situation in Spain

Spain relies heavily on fossil fuels for energy supply, including oil, natural gas and coal. As the country is not self-sufficient in these energy sources, they need to be imported. Because of this, domestic production only accounts for around 30% of the total primary energy supply. The following data has been collected from the study carried out by IEA (International Energy Agency) regarding Spain's energy policies.

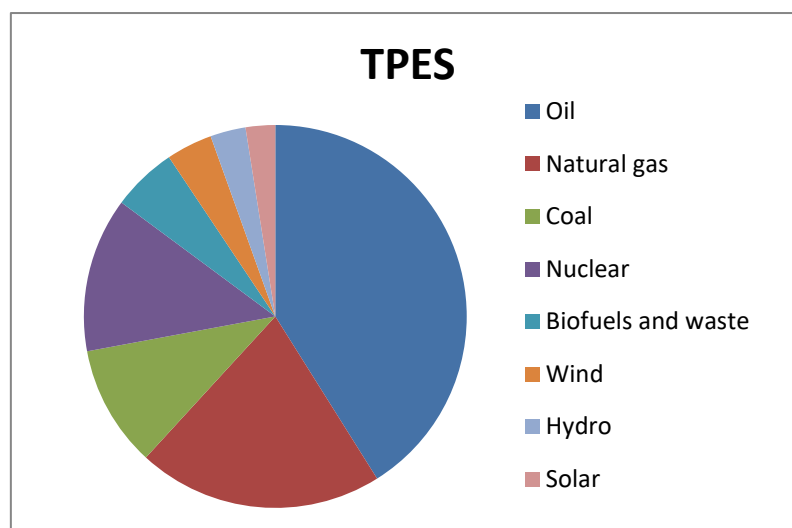


Figure 20. Total primary energy supply of Spain. Source: IEA (2014)

Spain's energy production consists mainly of nuclear power (43.7%) and renewable energy, including biofuels and waste (19.2%), wind (13.1%), hydro (9.8%), solar (8.4%) and geothermal

(0.1%). The share of renewable energy has increased by 93.8% compared with the 2004 data, primarily due to the growth of solar and wind power motivated by great government support. Carbon dioxide emissions have been decreasing since reaching a peak in 2007, the biggest drop being in the power generation sector (41.7%), especially thanks to the boost of renewables.

Regarding energy demand, transport and industry are the largest consuming sectors (34.6% and 30.9% of the total final consumption, respectively), followed by the residential (18.4%) and commercial (16.2%) sectors. Fossil fuels are the main sources in the transport and industry sectors, while in the residential and commercial the most important is electricity. It should also be noted the increased presence of biofuels, especially in the residential/commercial sector (nearly 10% of the total final consumption).

Geothermal energy in Spain

Unlike other renewables like solar and wind, geothermal is still a marginal source of energy in Spain. It accounted for only a 0.02% of the total final energy consumption in 2014 and no more than 1% of the total final consumption of renewable energy.

Data evaluation for Spain is limited due to the non-availability of any official register for geothermal installations, though it has been estimated that the accumulated power of geothermal energy for heat and cold generation reached 167 MW in 2012. Nearly 70% of this energy comes from GSHP and it is used for HVAC systems, process heating and cooling and low temperature thermal storage. Geothermal also has a small market in electricity generation through medium and high-temperature geothermal resources mainly found in the volcanic territory of the Canary Islands.

Spain is a country with a very apt territory for the implementation of GSHP. An estimated 60% of the territory area is comprised of consolidated formations of sedimentary, igneous or metamorphic rocks, with thermal conductivities over $2 \text{ W}/(\text{m}\cdot\text{K})$ in saturated conditions and specific gravity greater than $2 \text{ t}/\text{m}^3$. These characteristics of the ground are optimal for drilling and heat exchange.

The unconsolidated formations present less favourable geological conditions but when paired with the continental climate in the country's central plateau, with a steady and equalised heating and cooling demand, GSHP are also a viable technology.

Areas with an appropriate territory for low-enthalpy geothermal include Madrid, Guadalajara, the eastern basin of the Duero River, Burgos, Valladolid, Palencia, Lerida, Fraga, Huelva, Cadiz, Seville, Valencia and Cuenca.

According to a study carried out by the IGME (Geological and Mining Institute of Spain), the country's estimated gross potential of low-temperature geothermal is 5,710,320 MW, while the **potential in actual consumer areas is 57,563 MW.**

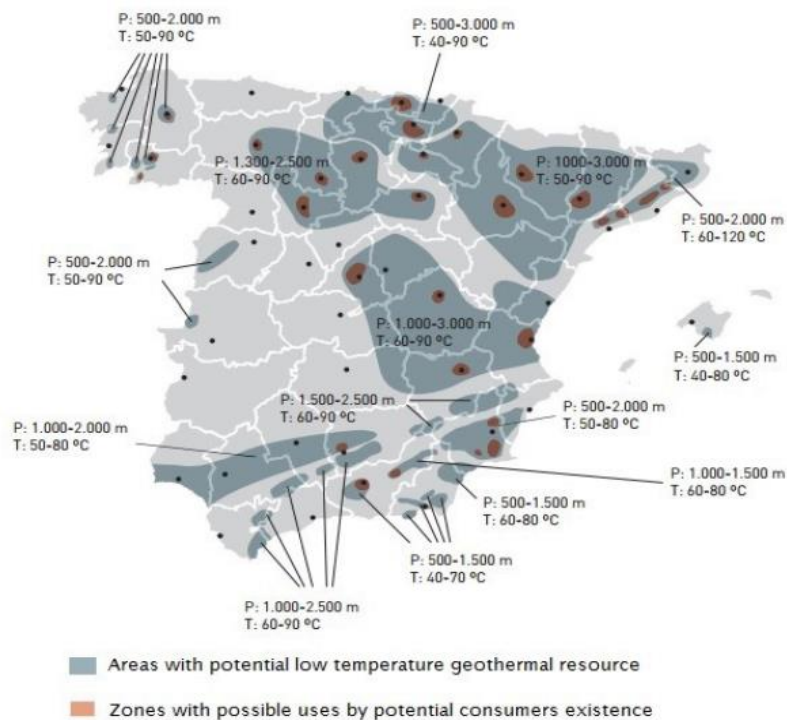


Figure 21. Low-temperature geothermal resources and potential exploitation areas. (Source: IGME)

Spain also has a considerable number of shallow aquifers that cannot be used for supplying because of their chemical properties and are therefore another option for the application of GSHP in an open loop system. These aquifers are spread across most of the country's territory, with the exception of the region of Galicia, the south-western area of the central plateau and parts of Aragon.

According to the **2015 Euroserv'ER Heat Pump barometer**, the **number of geothermal heat pumps in operation was 1,144**, an insignificant amount when compared to air source heat pumps (300,247 units). In the 2011 document *Evaluación del potencial de energía geotérmica (Evaluation of geothermal energy potential)*, which conducted a questionnaire to the companies, it is stated that the number of geothermal installations was 1,079, 97.5% of which were closed-loop systems and 2.0% were open-loop systems (the remaining 0.5% is unknown). The **total installed capacity amounts to 36,273.7 kW**, with an average of 34.3 kW per installation. The following table specifies the number of installations and their installed capacities depending on their function (heating, cooling, domestic hot water, pool heating).

Table 10. Number of installations and their installed capacities depending on their function

Use	Number of installations	Installed capacity (kW)
Heating/Cooling + DHW	514	15,032.4
Heating + DHW	256	5,030.9
Cooling + DHW	124	1,964.0
Heating/Cooling	93	10,753.5
Cooling only	32	1,082.0
Non-specified	20	991.4
Heating/cooling + DHW + pool heating	19	1,089.0

Heating only	6	115.7
Heating + DHW + pool heating	5	78.0
Pool heating only	5	78.0
DHW only	3	52.8
DHW + pool heating	1	6.0
Other uses	1	0.0
TOTAL	1,079	36,273.7

Also according to this document, the Spanish regions with the most installed capacity are Catalonia, the Community of Madrid and Andalusia with 10,885.7 kW, 5,326 kW and 4,435.1 kW respectively.

5.1.1.1 Residential market

According to CEPE (Centre for Energy Policy and Economics), final energy consumption in Spanish households is lower than that of the EU average (16.4% versus 25.4%). When it comes to heating, there is a huge difference between Spain and the EU in its share in the energy consumption (47% versus 70%) in spite of being the most relevant destination of energy. Spanish families consume mostly electricity due to the inferior utilisation of heating and the high proportion of houses that utilise radiators or other auxiliary electrical heating systems instead of gas heating systems, which are more common in the rest of the EU.

GSHP in residential buildings makes particular sense because the lower energy demand compared to that of other sectors can be covered without having to drill too deep or resort to other non-renewable sources.

Shallow geothermal energy and GSHP in the residential market reached a turning point with the setting in motion of the government-induced program GEOTCASA, which promotes the utilisation of geothermal energy in households. With this program, certified companies can provide an integrated service to the final users with installations funded by the administration. Users then have to pay a monthly bill to the company in charge of the installation, a fee that should be at least 20% cheaper than when using conventional sources such as electricity and gas. The benefitting company holds ownership of the geothermal installation for 10 years and after that it has to be paid back to the government. There are currently 24 authorised companies in the GEOTCASA program.

5.1.1.2 Commercial market

Energy demand of commercial and public buildings tends to be higher than that of residential buildings. In Spain, heating and specially cooling represent the most of this demand, so innovation and development in this field is essential to achieve a bigger efficiency. Hybridisation, such as GSHP combined with regular HVAC systems, is a viable solution to become less dependent on non-renewable energy sources. Several projects have been carried out in order to incorporate geothermal for heating and cooling in large buildings, for example, the installation of foundation heat exchangers in public spaces like markets and parking sites.

These buildings are still in testing mode, but further development for FHX is guaranteed since it is a convenient way to implement GSHP in dense areas like cities, where there is not much space for more conventional closed loop systems or BHE.



Figure 22. FHX in a parking site in Playa de la Concha, San Sebastián

5.1.2 Regulations

The most important European standard in the framework of geothermal and the other renewable energies is **Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009** on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

In this directive, global national targets in relation to the share of renewables in the final energy consumption are specified. The Spanish target for 2020 is that 20% of the final energy consumption comes from renewable sources. This directive also establishes that each country must adopt a National Action Plan for Renewable Energy (NREAP), which determines the 2020 national targets for the share of renewables in energy consumption on the sectors of transportation, electricity and heating and cooling.

Current legislation in relation to shallow geothermal energy is generic (related to other energy sources or natural resources), based on regional normative and mainly provided by mining, environmental and industrial departments. Geothermal energy is still considered a mineral resource according to the *Law 54/1980 of 5 November of Mining*; therefore, these geothermal resources (except for the shallow or very low-temperature in determined occasions) are subject to the mining legislation and authorisation system. National legislation from 2000 onwards hardly mentions shallow geothermal scenarios in the Energy plans or building regulations.

A redrafted *Text of the Water Law* determines that drilling must avoid any impact on aquifers. Open loop systems that use groundwater for heating and cooling are also subject to this law. An environmental impact assessment might be requested by the administration to ensure that the project is not going to affect the groundwater systems, especially in the case of open loop systems and Aquifer Thermal Energy Storage (ATES).

The document RITE (*Regulation for H&C Systems in Buildings*) sets directives for any type of thermal installation, with requirements related to welfare and hygiene, energy efficiency and safety of the systems. Even though shallow geothermal is not specified, every new installation of this nature must also meet the requirements set.

To guarantee the further development and large-scale implementation of geothermal energy in Spain, several documents and legal procedures should be revised because they are currently creating barriers for this technology to have a greater influence in the energy sector. Some of the examples are:

- The execution of energy efficiency projects requires a way too complex regulatory framework
- Processing system and concession regimes for shallow geothermal resources should be simpler and more homogeneous for every region, especially in the case of small installed capacities
- Regarding environmental and water regulations, processing times are too long
- The lack of a specific regulation for geothermal energy, which would serve as a reference and support for installers
- Several sectors question and criticise geothermal heat pump installations because of their use of electric power

5.2 Market in the UK

The United Kingdom has a temperate maritime climate (similar to Ireland and the other Low Countries) such that domestic buildings generally do not require cooling. The energy system has a very well developed natural gas grid and more than 70% of domestic buildings use this as their primary heating energy source. Just approximately 10% of domestic buildings are off the gas grid.

Historically, the UK has relied heavily on coal as its primary energy source for electricity production with approximately 20% nuclear. In the last 30 years, there has been a move away from coal towards natural gas fired power stations. In the last fifteen years, wind energy capacity has grown significantly. This has meant that in 2013 the carbon intensity of electricity was close to the EU median at 512 gCO₂/kWh. This has meant that heat pump technology has had to demonstrate SPF values of higher than 2.3 to show any carbon saving potential relative to gas heating with radiators. The break-even point for running cost savings has required similar levels of efficiency.

In the **period 2013-2016** there has been **significant progress in reducing the carbon intensity of the grid electricity system**. This has been mainly achieved by:

- Efficiency improvements in the building sector
- Promotion of PV systems
- The rapid increase in wind energy production (as significant RES resource for the UK)
- Development of large-scale biomass fuelled electricity production

This, and the further development of gas fuelled power stations, has reduced the amount of coal fired power generation to a very low level. Consequently, the carbon intensity has dropped towards approximately 300 gCO₂/kWh. This represents the long-term benefit of all UK heat pump markets.

5.2.1 Market Development

The development of GSHP technology in the UK has started in the 1990s with a few domestic building conversions. Real uptake of the technology did not take place until 2005 as the first incentive schemes and public information programmes (The Clear Skies and Low Carbon Building schemes) came into effect (Rees and Curtis 2014). The first quality standards for GSHP also came into effect about this time. Market development saw a period of rapid growth in the period 2005-2010 and this corresponds to further incentive schemes coming into effect. The UK is unusual in having a large ‘Supplier Obligation’ incentive scheme which is imposed on the privatised electricity distributors. This requires a small percentage of utility bills to be redirected into large-scale (more than € 2bn to date), centrally managed, building efficiency improvement programmes. These schemes have been the EEC, CERT and ECO schemes. Their relationship to the growth in domestic installations is shown in Figure 23.

The **total number of GSHP installations** reported in **2015** has been **approximately 22,000**. Growth can be seen being currently steady at 2,000-3,000 installations per year. Comparison with

other Member states with similar climates, such as the Netherlands and Denmark, shows a lower level of penetration of GSHP into the heating market. This may be due to the predominance (and so the effect of factors like training and competition) of gas domestic heating technology. It also indicates that there is greater potential for growth in the market.

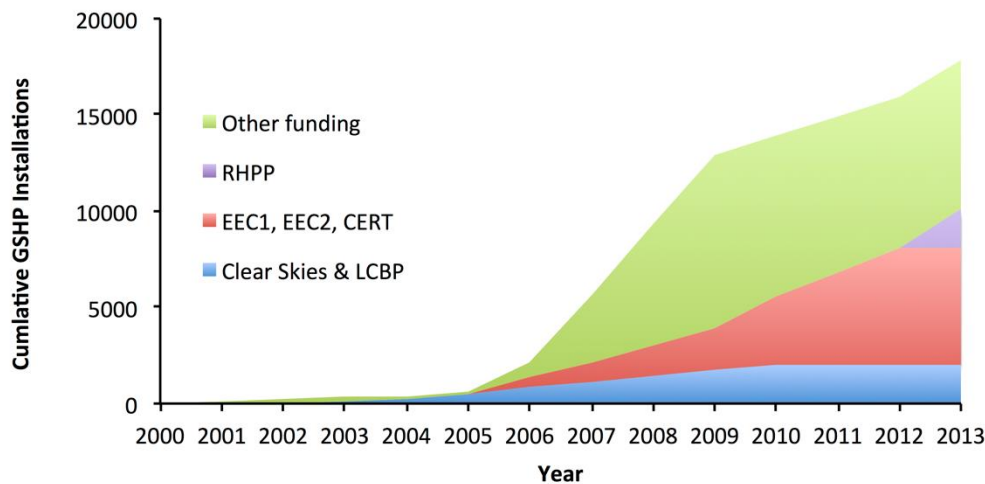


Figure 23. Growth in the UK domestic market and the relationship to the main incentive schemes

The non-domestic market in the UK is relatively modest, with relatively few designers and installers active in the marketplace (particularly since the financial crisis in 2008-2010). Having said this, there is a number of large GSHP installations that serve as examples of good non-domestic practice. Notable examples include Churchill Hospital in Oxford (280 borehole heat exchangers) and Welsh Assembly building in Cardiff.

The UK has been one of the leaders in the development of foundation heat exchanger technologies – mostly energy piles. It is said that there are **more than 10,000 energy piles installed in the UK**. The development of this market has been led by only a few major contractors and with the close involvement of larger firms of consulting engineers (e.g. Arup). A notable example of the large projects using energy piles is One New Change in London.

National Strategy

Reduction in buildings related to carbon emissions is an important element of the UK national carbon reduction strategy planned for the 2050 timeframe (CCC, 2010). This will require the long-term movement away from the reliance on natural gas for heating buildings and electrification of the heating market. This implies a large market for heat pump technology and the importance of retrofit applications.

The overall strategy for decarbonisation of the heating sector has three important elements:

- Deployment of heat pumps in off-gas-grid properties initially
- Deployment of district heating in urban areas with historic buildings
- Long-term deployment of heat pump technology in sub-urban areas

Recent incentive schemes have consequently been focussed on off-gas-grid properties.

Although GSHP growth is part of the national carbon reduction strategy, the levels of growth demonstrated in current market data noted above, are much less than expected. Consequently, the UK is very unlikely to reach the level of installations stated in the NREAP at 300,000 by 2020. Overall, the national strategy can be seen being very supportive to heat pump technology.

5.2.1.1 Residential sector - The Domestic Building Market Outlook

Relatively small number of individual householders is currently taking up heat pump technology. The current ECO incentive scheme is mostly being taken up by Registered Social Landlords. This suggestion will be important for industry to work closely with such developers in order to maximise growth in the next few years. These developers face choices between passive improvement measures and different heating technologies.

Recent reports about the uptake of the scheme funding suggest that there has been much greater interest in ASHP rather than GSHP. This could be partly due to the fact that ASHP are seen as simpler to install and, in particular, less disruptive to existing properties. This suggests that, if successful demonstrations can be made, new drilling technology such as the one being developed within the GEOTeCH project may be influential.

It is widely acknowledged that the UK has not been developing enough houses to keep up with demand for a number of years. This has become a political issue so that it is likely that a number of measures will be put in place to improve rates of development in order to reach target levels of 250,000 new houses per year. Even a small percentage of such a market would be a significant boost for the heat pump industry. This would require **better economic performance and simplification of installation procedures in order for GSHP to compete with ASHP technology**. Again, this should be addressed by the technology being developed in this project. A 10% share of this market for GSHP or hybrid A/GSHP is conceivable.

However, this level of installation (i.e. 250,000 per year) would require a tenfold increase in industrial capacity and this may be limited by other factors, including available training of the workforce.

This issue is currently being addressed by the national industry body - the UK GSHPA.

5.2.1.2 Commercial sector - The Non-Domestic Building Market Outlook

Although the UK has a mild climate, non-domestic buildings often require combinations of heating and cooling, hence a widespread interest in GSHP technology for commercial buildings continues to exist in the UK.

However, the rate of conversion from interest at the concept stage to real uptake is low. Industrial capacity is also low so that new contractors would need to be drawn into the market if the rate of installations was to grow significantly. The current rate of installation of larger (over 50 kW) systems is less than 100 per year.

The **rate of uptake of GSHP technology** will be **strongly influenced by the regulatory environment**. One of the factors that has brought benefits to the GSHP industry and incentivised large developments has been the local planning requirements for a minimum percentage of on-site renewable energy. This has been allowed with 2008 planning laws and has been an option taken up by a number of city planning authorities – the so called ‘Merton Rule’ approach. However, this legal power has been threatened with repeal and so it is uncertain this will remain a benefit. The question of the acknowledgement of decarbonisation of the grid in regulation calculations has been noted earlier.

Although the current building regulations do not impose a requirement for renewable technologies, there is now a requirement (as a consequence of the recast EPBD) making all non-domestic projects give formal consideration to low-carbon alternatives, including heat pumps. However, economic factors of practical issues may be given as good reasons to avoid such technologies. At this point, it is unclear that this will lead to real increases in the non-domestic market for GSHP.

One area of the market that is under-exploited in the UK is small/medium scale non-domestic buildings (with the exception of the school building market). This may be due to lack of confidence/capacity in the industry to tackle this market but also economic factors, besides the complexity of the technology. It is very difficult to estimate the potential size of this market but there are a significant number of buildings with heating/cooling capacity requirements in the 20-50 kW range. Addressing this market on a large scale will require new installers to enter the market. The possibility of a technically robust plug-and-play solution that is licensed could attract such new SME participants into the market.

There continues to be steady interest in foundation heat exchanger technology – both screen walls and energy piles – in the UK. Such developments tend to be focused on larger commercial developments (offices, university buildings and retail developments). The market continues to be dominated by a few contractors. At present, there is considerable research interest in this technology and growing interest from consulting engineers. There has also been growth of this technology in infrastructure applications such as underground railway stations. Overall, growth in this market is likely to be modest and strongly linked to the economic cycle.

5.2.2 UK Regulation and Incentives

The growth in the GSHP market in the UK can be seen to be correlated with some large incentive schemes (Figure 23) even though only a small percentage of their value has gone into investment in heat pumps. In fact, the focus of the latest supplier obligations scheme (the Energy Conservation Obligation, ECO) has changed so that heat pumps are not explicitly supported and most investment is focused on external wall insulation development. Some funding is focused on economically deprived geographical areas and households vulnerable to fuel poverty. This element of the funding is mostly taken up by Registered Social Landlords (Local authorities and charitable Housing Associations). This has resulted in many retrofit developments of small housing projects. Some of these have resulted in the deployment of heat pump technology. Figure 24 shows an example of social housing installation.



Figure 24. An example of a UK social housing ASHP retrofit installation

UK regulations relating to building energy efficiency have been guided by the EPBD since 2006. Energy efficiency is judged primarily on the basis of carbon emission rates. This gives the designers some flexibility to make choices between system type and fuels for the building systems. Whether

this works in favour of promoting heat pump technology depends on the relative efficiencies of systems and the carbon emission intensities of electricity as compared to natural gas.

In the current (2010-2016) building regulations the emission rate that has to be used for calculations is fixed at 512 gCO₂/kWh. As noted above, this is a very conservative figure that does not reflect recent significant reductions in electricity grid carbon intensity. Hence, this does not encourage the uptake of heat pump technology in new buildings as much as it should. This particularly occurs in the non-domestic market where it is necessary to make comparisons with both conventional heating and cooling systems. There should be some advantages to GSHP technology when competing with gas heating and air-cooled chiller alternatives. This carbon intensity data will probably not be revised until new regulations coming into force in 2018.

The levels of energy efficiency required in the 2013 building regulations (i.e. currently in force) are driven by the recast EPBD. In absolute terms, the carbon emissions rate targets are not low enough to require developers to include renewable energy technologies: in general compliance can be demonstrated by improved fabric performance. There has also been, following political pressures, some relaxing of the requirements for near-zero energy homes which was expected to be a requirement in some applications in 2016. This might not change until 2018. There is also some uncertainty whether the UK will follow the recommendations of the EPBD after the expected withdrawal of the UK from the EU. However, assuming the UK follows its current trajectory for carbon emissions reduction, from a technical point of view there is good evidence that heat pump technology will play an important role.

Besides the building regulations, another driver of the uptake of GSHP and other renewable technologies has been the incentive scheme known as the Renewable Heat Incentive, RHI. This has been designed to incentivise renewable technologies (both domestic and non-domestic) through payments based on kWh of renewable heat used. The incentives are designed to offset the higher capital costs so that payback can be seen in approximately seven years in a range of technologies (each with different incentive tariffs). This has had some benefits to encourage the uptake of GSHP but not sufficiently to increase installation rates in a significant way. It is uncertain whether this incentive programme will remain in operation, depending on future political changes.

5.3 Market in Italy

Data for Italy show an increase of GSHPs installed in the period 2007 - 2009 (+ 60% in 2 years). Italy in that period was a relatively new market and the building sector was still active. Then, starting from 2010, together with the building sector crisis, the GSHP market suffered a setback. In 2010, 27% of the entire geothermal power of Italy derived from GSHP.

The reasons of the setback should be found in the difficult adaptation of traditional borehole heat exchangers and low temperature heat pumps to the energy retrofitting projects. Incentives are indeed not adequate to support traditional GSHP for retrofitting projects and the competition with air-to-air heat pumps in most parts of Italy is high, because of the mild Mediterranean climate.

The use of geothermal energy for prominent cooling seems not to be still a convenient solution, although many examples of installations exist in southern regions, such as Puglia and Sicily, where many public buildings have been energy renovated through the use of GSHP systems.

New improvements about integration of shallow geothermal systems within district heating networks and smart grids, as well as technical solutions aimed to reduce the initial costs of investments, can push forward the Italian GSHP market both for new constructions and for energy retrofitting projects.

5.3.1 Market Development

In order to understand the potential of the market for GSHP in Italy, a focus on energy needs and consumptions and on the market of building sector and its regulations should be provided.

Focus on energy consumptions for heating and cooling

The energy trends for heating and cooling and the energy vectors used in Italy are exposed here. The main energy vector in Italy for heating is the natural gas. In 2015, 61.2 billion of cubic meters were imported from foreign countries, while 6.8 billion were extracted from wells located on the national territory. Of these about 68 billion consumed, around a half - 34 billion – were used for heating purposes³³.

In the heating sector, the renewable energy covered around 9.4 Mtoe in 2015, with respect to 112.8 Mtoe of fossil fuels; therefore renewable energy covered the 7.7% of the heating request (see Figure 25 and Figure 26)³⁴.

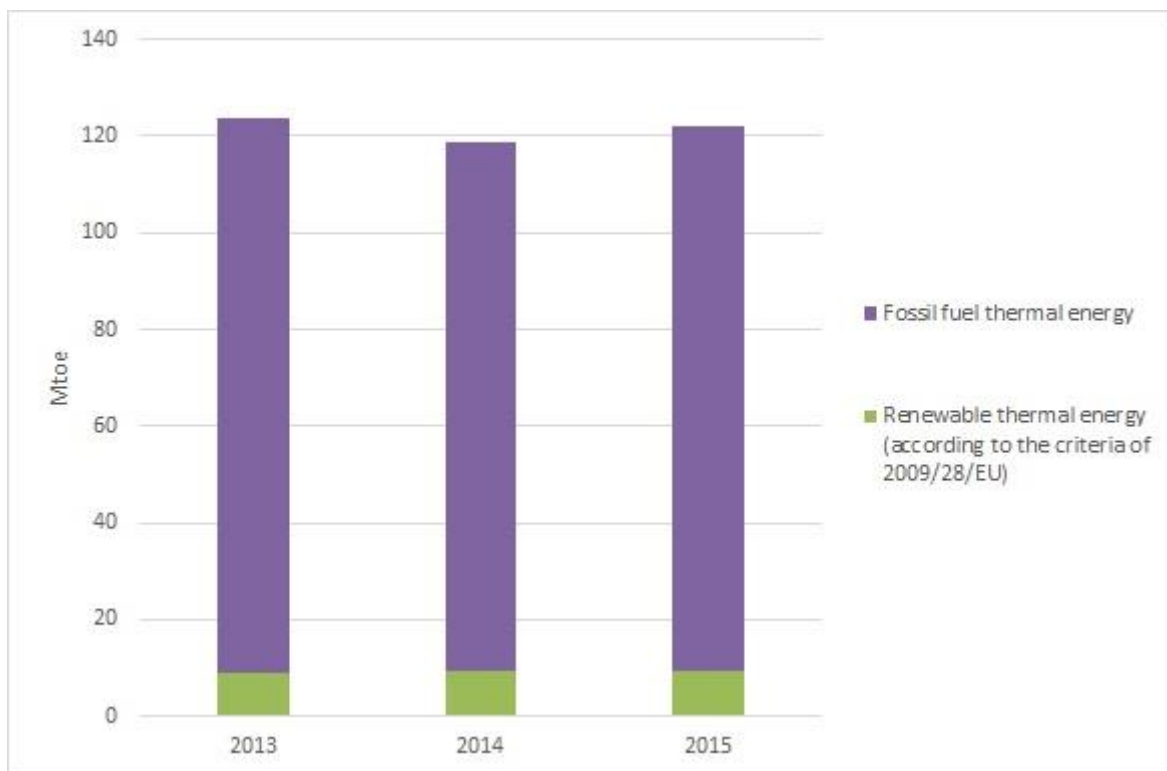


Figure 25. Thermal energy in Italy

³³ Ministero dello Sviluppo Economico – La situazione energetica nazionale nel 2015

³⁴ Elaborations on GSE and CO.Aer data

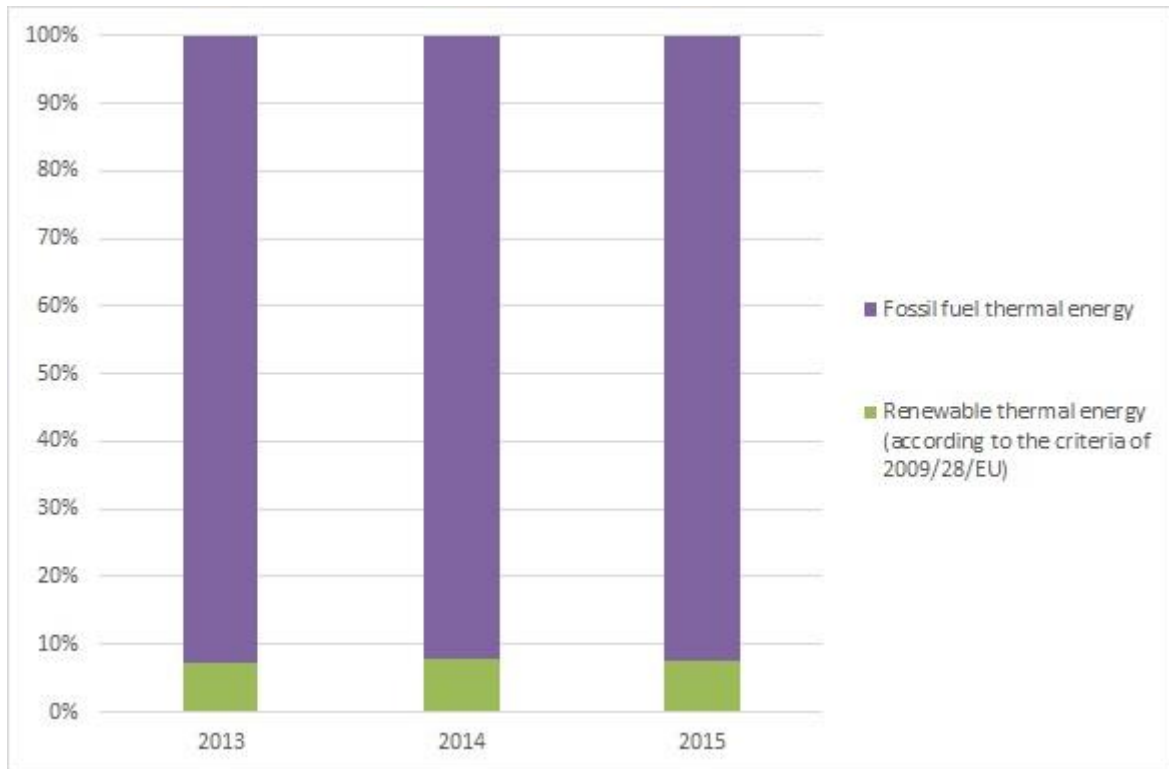


Figure 26. Thermal energy in Italy percentages

Ground Source Heat Pumps (GSHPs) covered a very small part of the total renewable thermal energy - 0.08 Mtoe in 2015, corresponding to 0.7% - as shown in Figure 27 and Figure 28³⁵.

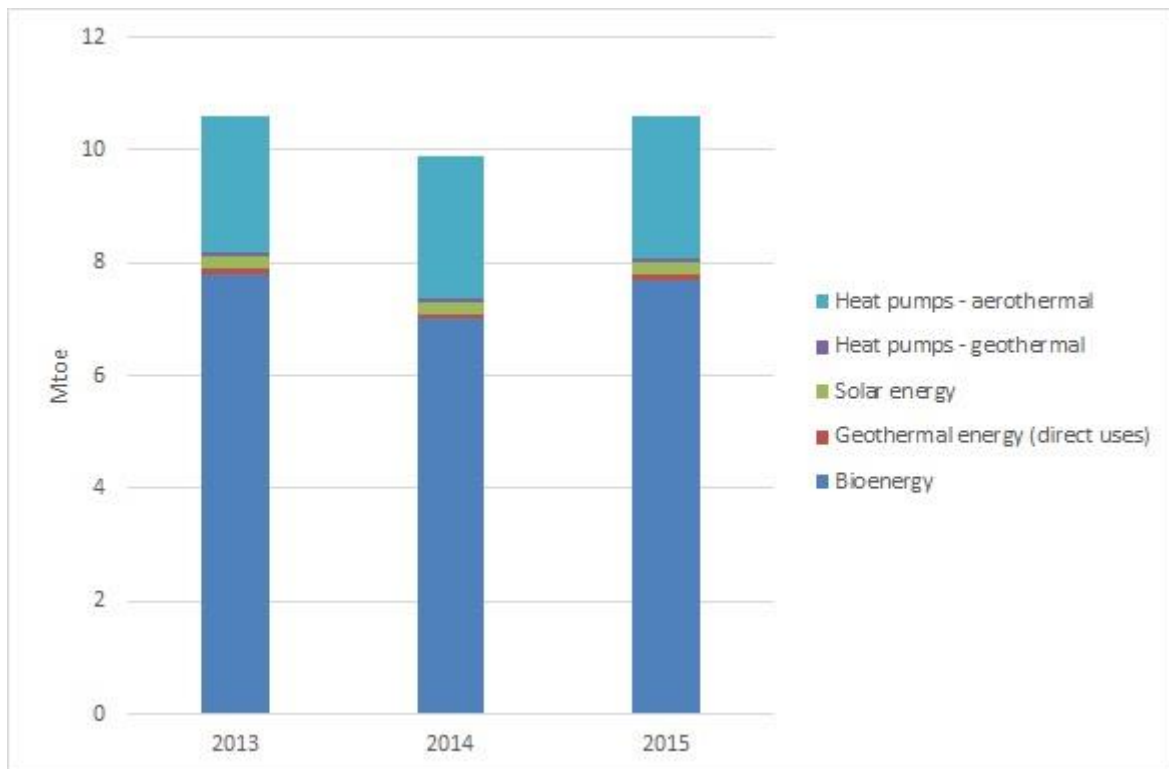


Figure 27. Renewable thermal energy in Italy

³⁵ Elaborations on GSE and CO.Aer data

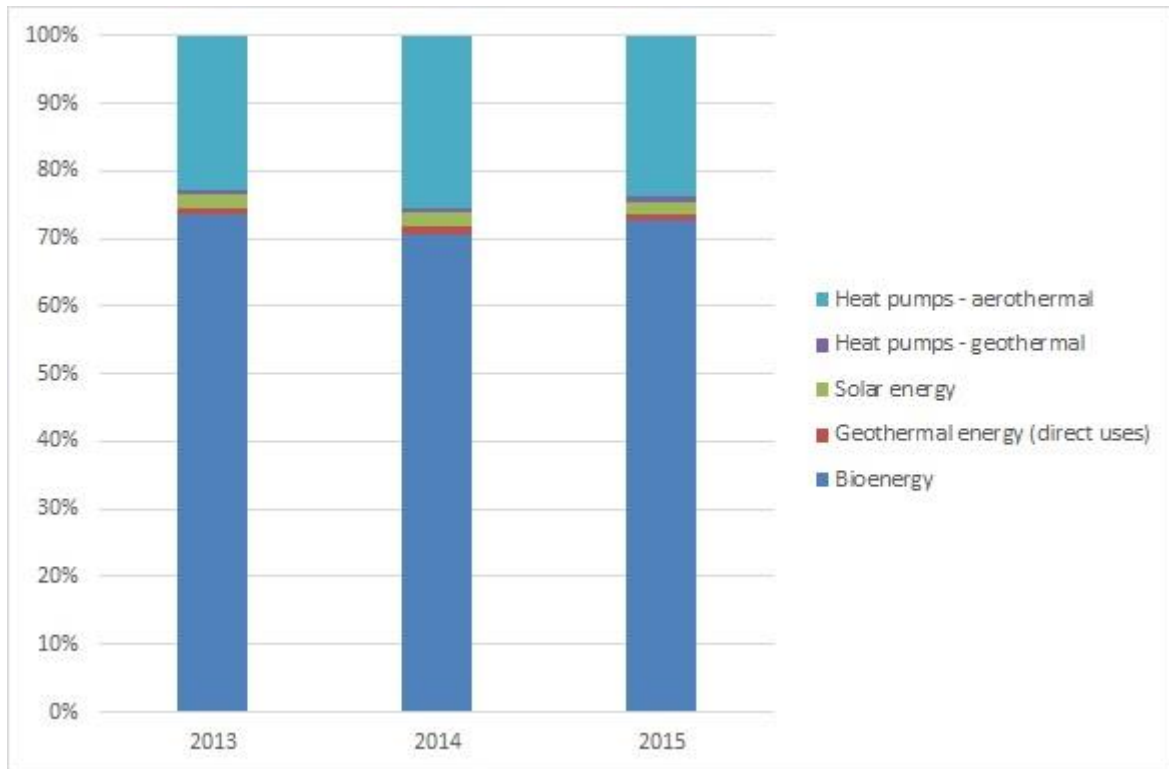


Figure 28. Renewable thermal energy in Italy percentages

In the **residential sector**, the energy vectors (for all the purposes: heating, cooling, hot water, lighting, etc...) are the ones illustrated in Figure 29 and Figure 30. Natural gas is the prominent energy vector, followed by electricity (which is the main energy vector for GSHP) and biomass.

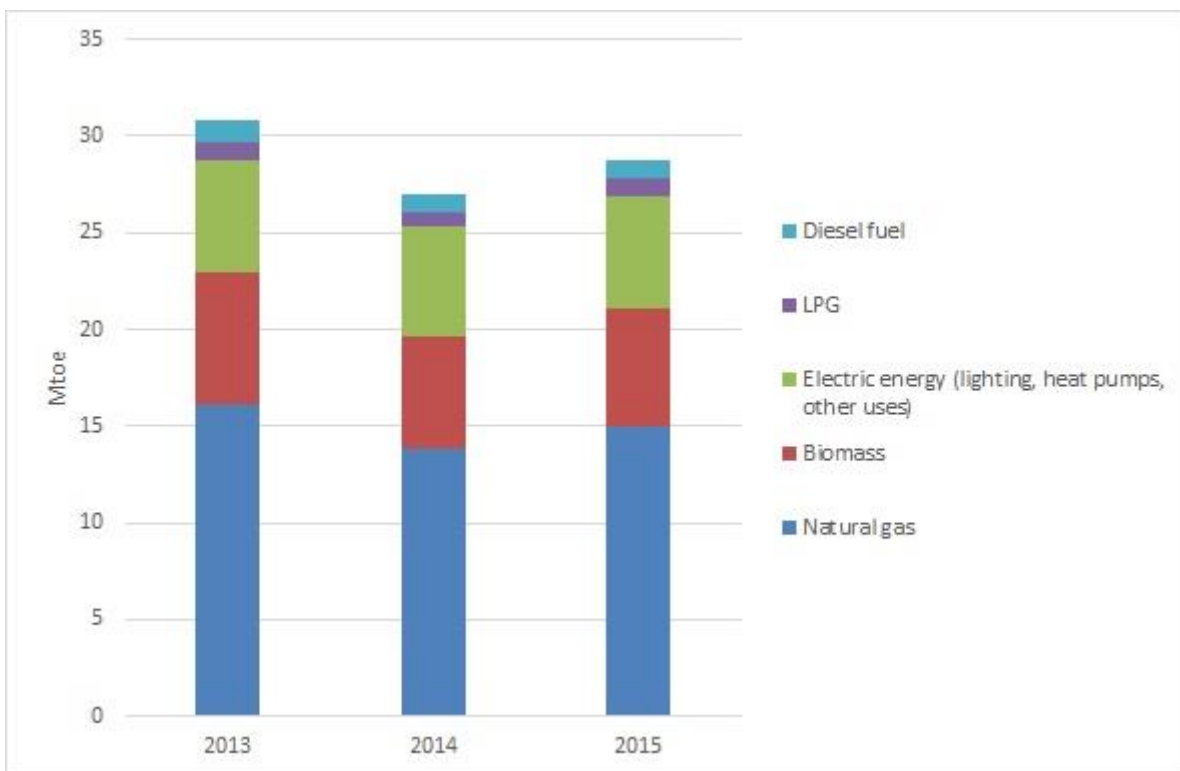


Figure 29. Energy vector contributions in residential sector

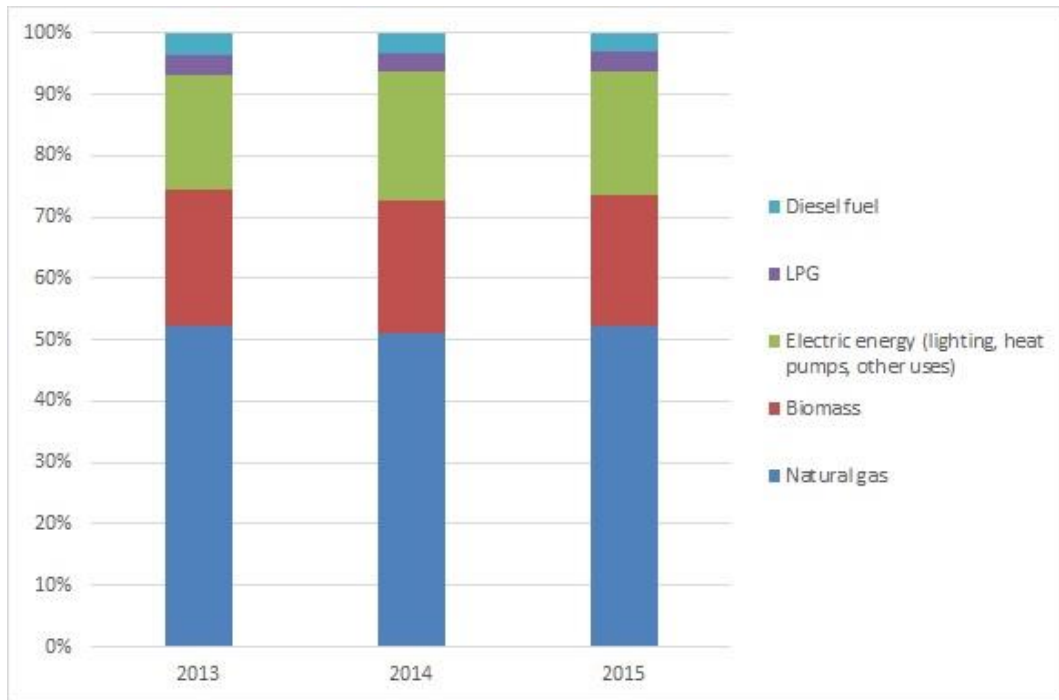


Figure 30. Energy vector contributions in residential sector percentages

With regard to the use of electricity for only heating (basically heat pumps and electrical boilers), strong differences exist between North and South of Italy.

In the South, because of the warmer climate, air-to-air heat pumps are more used for heating. The relatively short heating season allows also the use of electric boilers to cover low heating needs³⁶ (Figure 31).

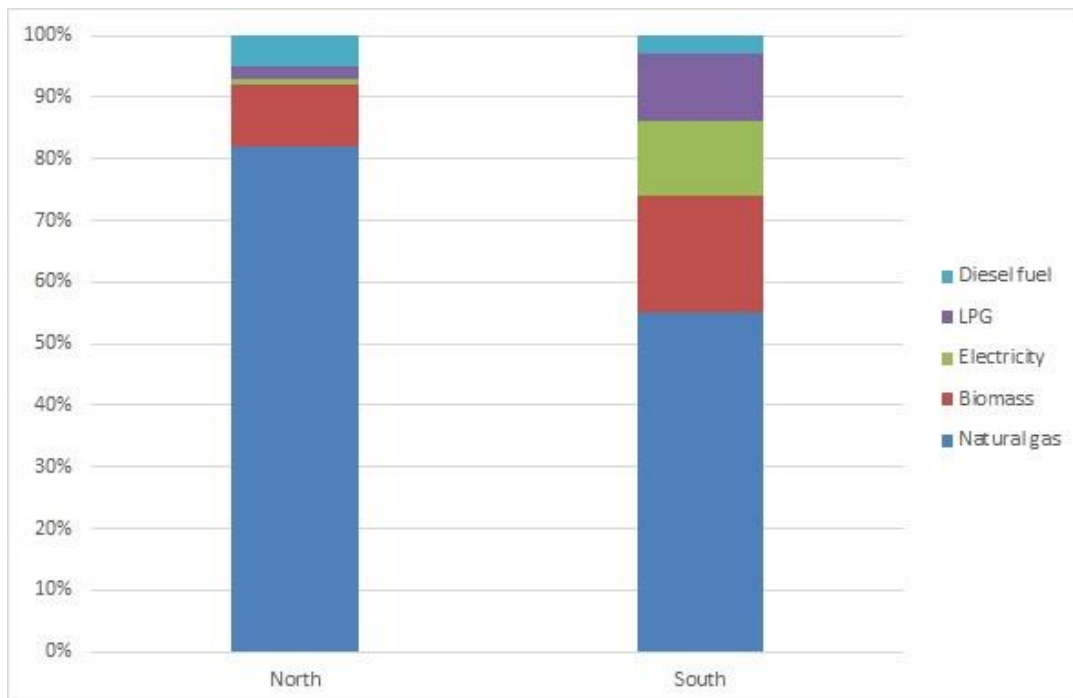


Figure 31. Energy vector contributions in residential sector for heating percentages and differences North – South

³⁶ Faiella I., Lavecchia L., La povertà energetica in Italia, Questioni di economia e finanza, La Banca d'Italia Numero 240 Ottobre 2014

For residential sector, energy costs are not proportional with energy consumptions. The following Figure 32 and Figure 33 illustrate the energy cost contributions in the residential sector.

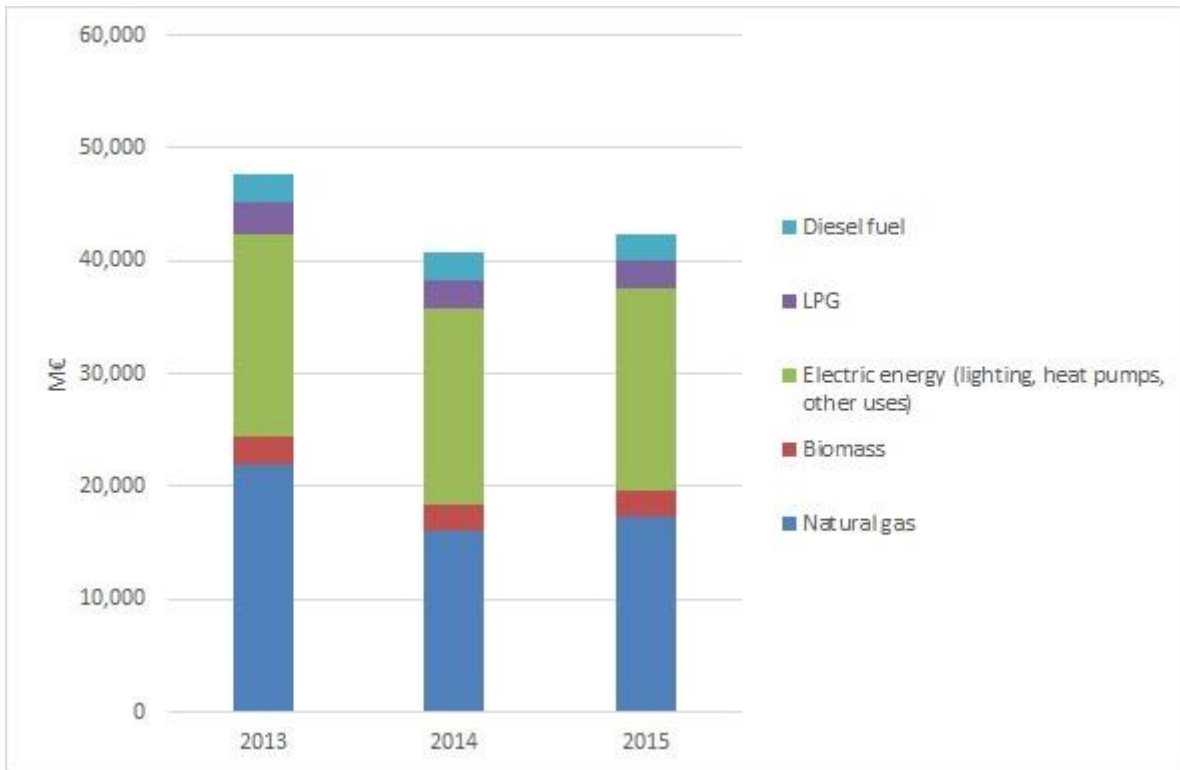


Figure 32. Energy cost contributions in residential sector

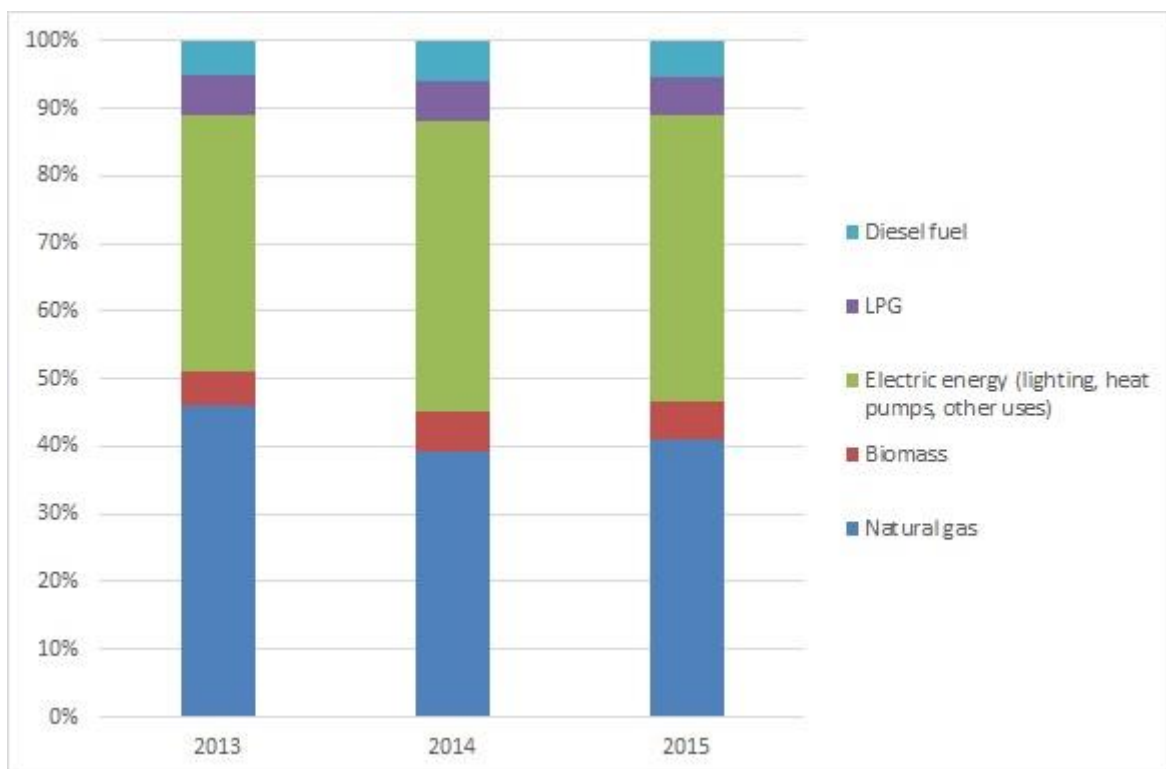


Figure 33. Energy cost contributions in residential sector percentages

For residential sector, electricity covers 20.2% of consumptions but its cost is 42.3% of the total energy cost of a family. This situation disadvantages GSHP, whose economic convenience strongly depends on the electricity price.

In recent years, the energy vectors have seen an increase in all their prices on the market, but electricity registered the highest increase³⁷. Figure 34 illustrates the trends of natural gas and electricity prices in last years in the residential sector, together with their cost for Italian families.

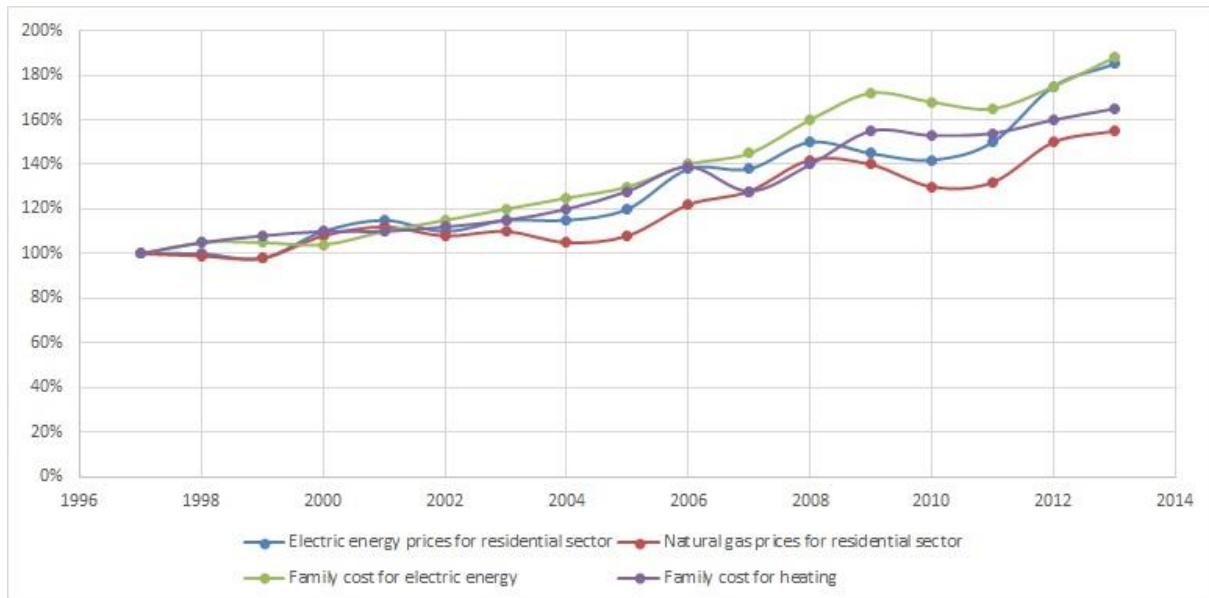


Figure 34. Increase of energy vector prices with respect to base year 1997

Finally, the quota of heating cost on the total cost of a family in one year is strongly different from North to South, because of climatic differences. The heating costs are increasing in recent times everywhere in the country, but the differences between regions are relevant and evident (see Figure 35).

³⁷ Faiella I., Lavecchia L., La povertà energetica in Italia, Questioni di economia e finanza, La Banca d'Italia Numero 240 Ottobre 2014

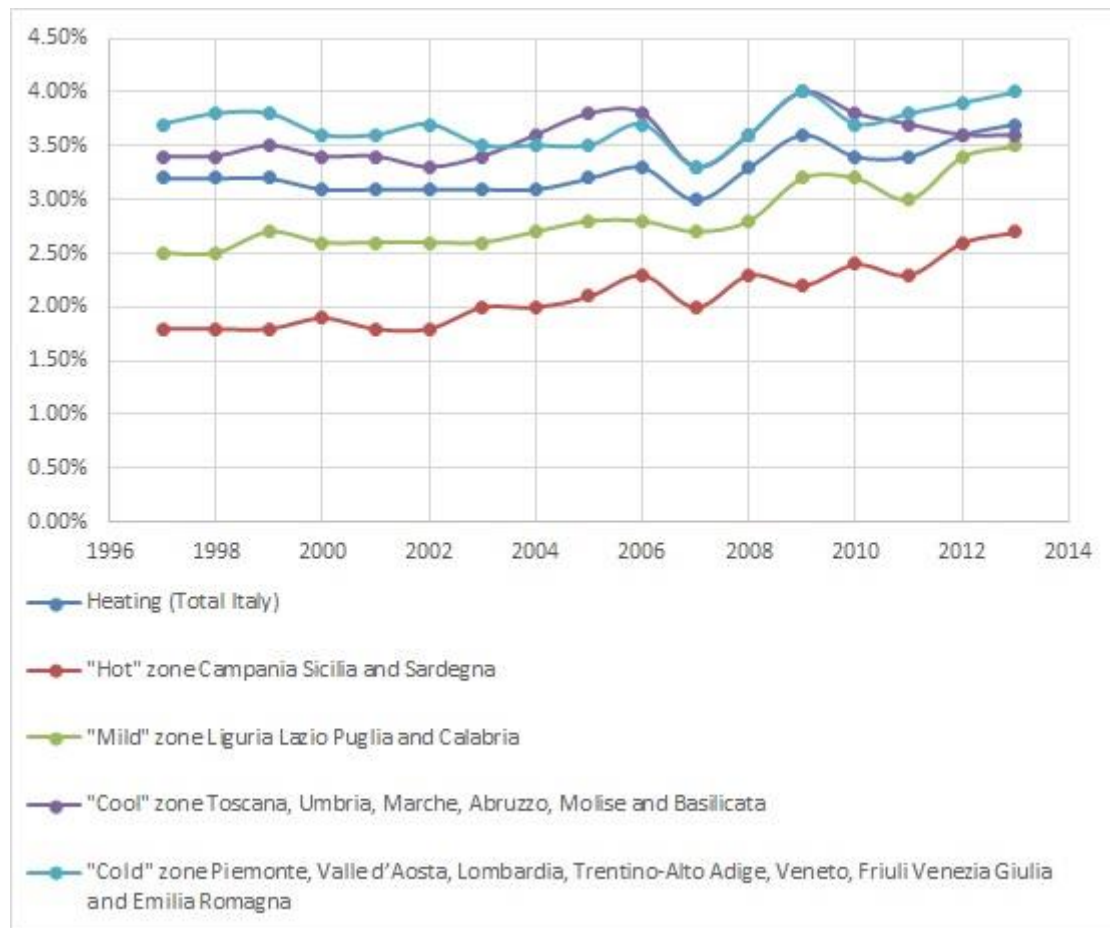


Figure 35. Percentage of heating cost with respect to the annual cost of a family, divided for four climate zones of Italy

The cost for cooling should be kept into account to complete the analysis about the convenience of GSHP in Northern and Southern Regions of Italy. Because of electricity prices increase, we can suppose that also the cost for cooling, mainly based on electric air conditioners, increased as well.

Focus on building sector

Along with the trend of energy consumption, the trend of the construction market should be kept in consideration in all countries and so in Italy, too. In fact, the market trend of building sector predominantly affects all the sub-sectors related to construction works and plants.

GSHPs are characterised by works and components related both to construction (mainly geotechnical works, such as drilling and excavations, and foundation components, such as piles and slabs) and plants (thermo-technical and electronic works and related components, such as heat pumps, thermo-hydraulic system and electronic controls), so they are directly and indirectly influenced by the building sector market.

Directly, a positive market of building sector, accompanied by energy efficiency standard laws, makes attractive the installation of GSHP for new buildings and it encourages a correct energy rehabilitation of existing buildings. In such situation, GSHP can give a strong contribution. On the contrary, a stagnant market drags down the investments for GSHP as well.

Indirectly, a lively market guarantees the presence of local companies specialised in geotechnical and thermo-technical works on the territory and it creates a competition, with consequent reduction of prices. The absence of local companies, because of building crisis, could make the investments for GSHP less attractive because of price hike, difficulty to find specialised installers and

incertitude of a correct maintenance on long term operation of the heat pump. The situation of building sector for Italy is highlighted in Figure 36³⁸.

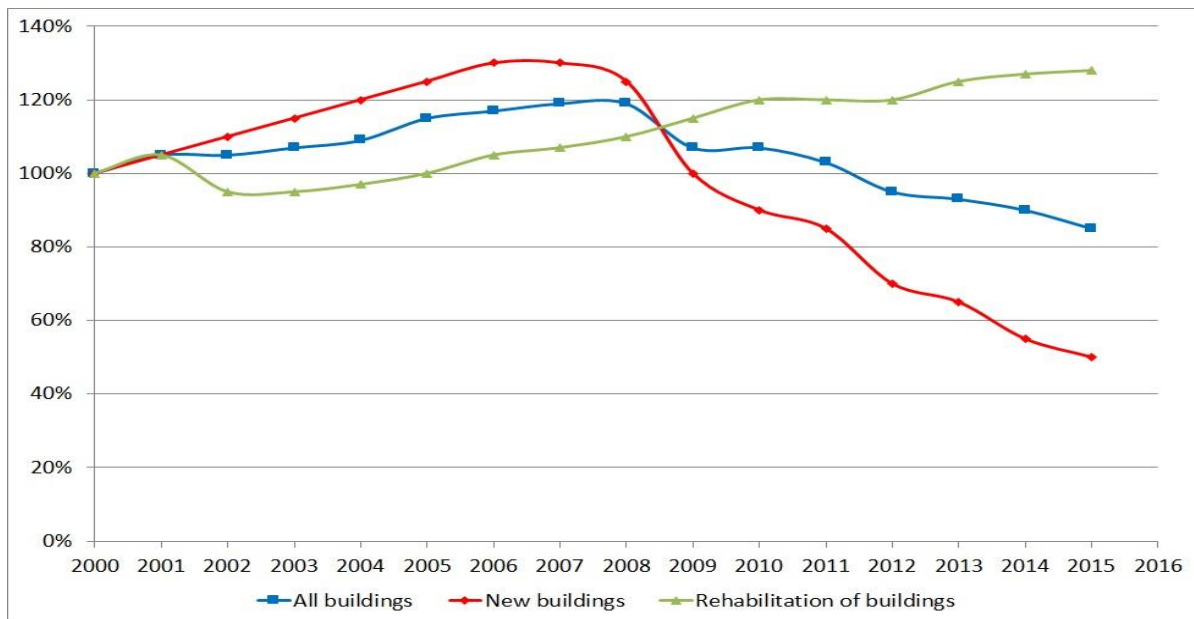


Figure 36. Percentage variation of the investment in buildings, with respect to the baseline – year 2000

The building sector in Italy is experiencing a trend of crisis. Since year 2007, the new buildings are facing a negative trend. On the contrary, the rehabilitation of old buildings has a positive trend, but it is unable to sustain the sector, being the total balance negative.

The negative trend is even clearer if referring to the construction permits for residential buildings, as shown in Figure 37.

Referring to the year 2015, the total investment in buildings has been about 125,348 M€. Figure 38 shows how the investments are divided among the sectors.

³⁸ ANCE, Osservatorio congiunturale sull'industria delle costruzioni, a cura della Direzione Affari Economici e Centro Studi dell'Associazione Nazionale dei Costruttori Edili, Dicembre 2015.

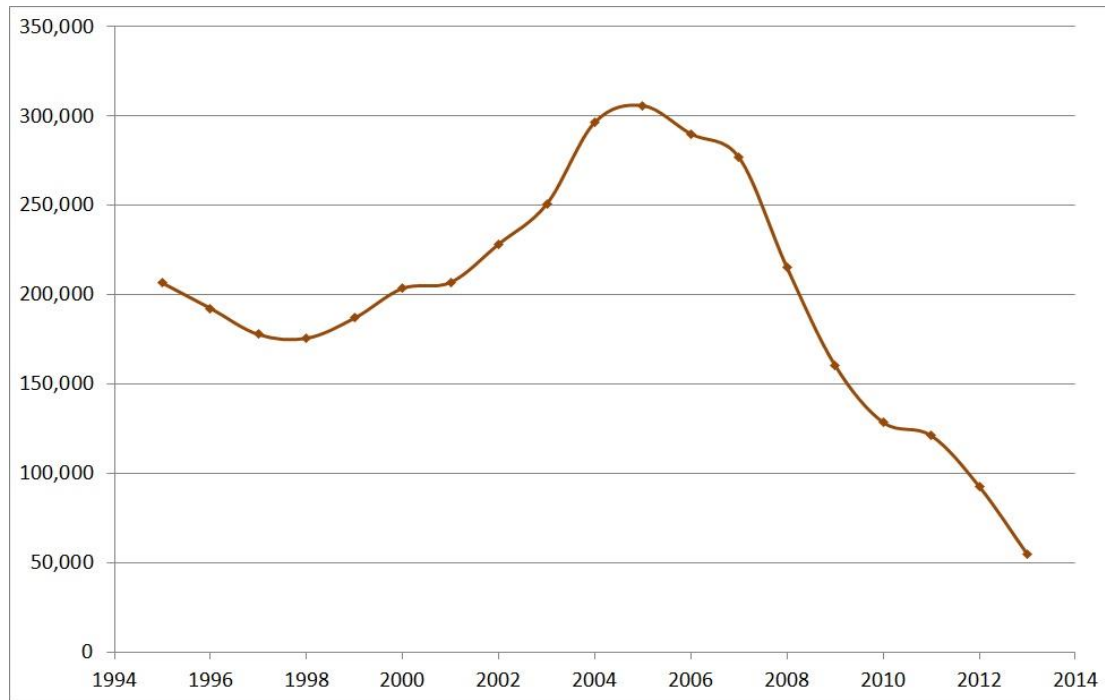


Figure 37. Number of construction permits for residential buildings

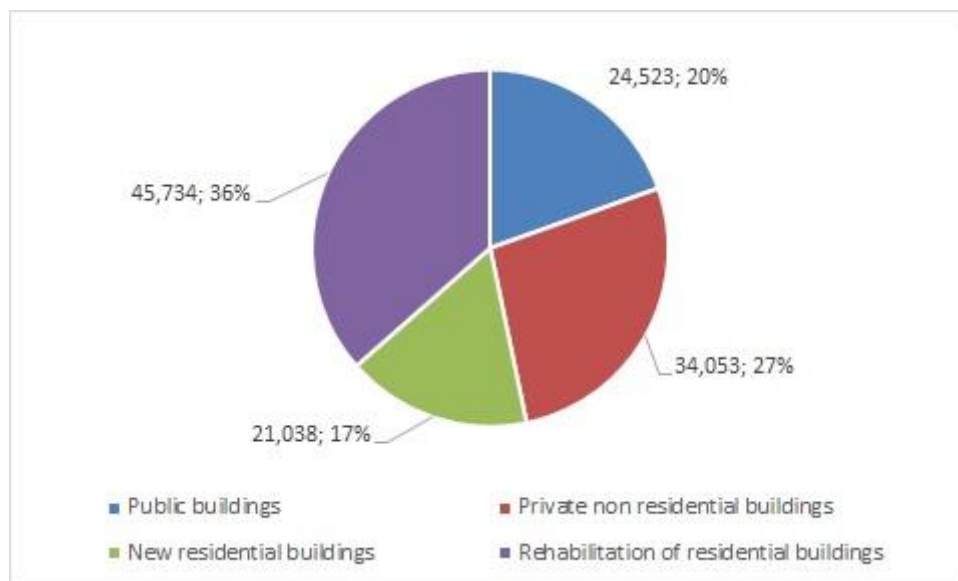


Figure 38. Division by sector of the investments in buildings – year 2015

Focusing on the built landscape, the total number of buildings in Italy is: 12,187,698³⁹.

The following Figure 39 divides the building stock by the construction year.

³⁹ ENEA-STREPIN – Strategia per la Riquilificazione Energetica del Parco Immobiliare Italiano, November 2015

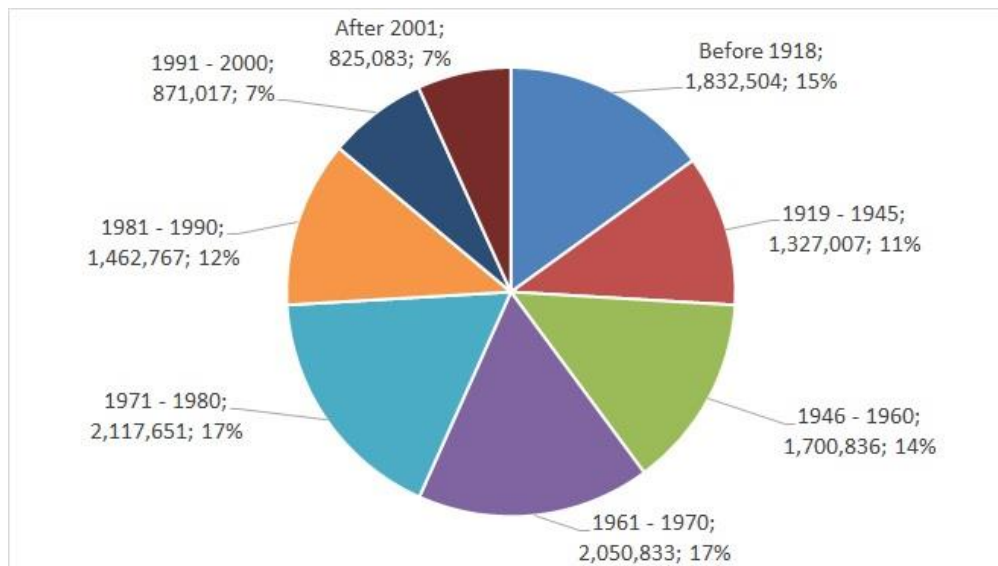


Figure 39. Age of the buildings in Italy

The built landscape of Italy is strongly largely inefficient. According to the elaborations provided by ENEA, the average values of primary energy consumptions are reported in Table 11:

Table 11. Average primary energy consumptions for the most common types of Italian buildings - 2015

Building type	Primary energy consumption for heating [kWh/m ² /y]
Single family house	142
Condominium	125
School	130
Offices	170
Hotel	150

The rehabilitation potential of Italian residential buildings, together with a rough estimation of costs, is therefore reported in Table 12.

Table 12. Rehabilitation potential of residential buildings

	Number of interested buildings	Percentage on the total buildings	Total energy savings [GWh/y]	Total cost (B€/y)
Residential buildings	365,631.0	3.0%	4,644.0	13.6

Concerning instead the existing public buildings, the law (D.lgs 4 Luglio 2014, n.102) imposes the rehabilitation of at least 3% per year of the state building surface from 2014 to 2020. Projections of energy saving potentials (and related rough estimation of costs) are therefore illustrated in Table 13 below.

Table 13. Projections of energy saving potential for state buildings, by respecting D.lgs 4 Luglio 2014, n.102

	2014	2015	2016	2017	2018	2019	2020
Interested area (m²)	412,919	400,532	388,516	376,860	365,554	354,588	343,950
Consumptions (GWh/y)	62.8	60.9	59.1	57.3	55.6	53.9	52.3
Rehabilitation cost (M€)	84.5	82.0	79.5	77.2	74.8	72.6	70.4
Annual energy savings (GWh/y)	17.0	16.5	16.0	15.5	15.1	14.6	14.2

According to these numbers and trends, the **future for GSHP market in Italy can be promising and self-sustaining only if strongly related to energy rehabilitation of existing buildings**, basically for the following reasons:

- Market of new buildings is in a continuous decline. Even if the number of GSHP sold are few and the specific market for GSHP is small, the sector cannot self-sustain on the long term if only related to the new buildings
- Regulations and laws in Italy strongly encourage the private buildings and impose to public buildings the energy rehabilitation of existing built landscape

At the present moment, GSHP is a technology that faces more difficulties than others in correctly integrating in the existing buildings. Anyway, GSHP sector cannot lose the opportunity to be a viable selection of building owners and designers for energy rehabilitation projects, both for stand-alone and network-connected buildings.

The values and numbers presented are valid for all energy saving potentialities present in the market, from substitution of windows to the installation of GSHP.

The choice of GSHP to increase the energy performance of a building, up to fulfil the law requirements, in synergy or in opposition to other energy saving technologies is strongly related to the economic convenience of the investment.

A factor justifying the initial investment is the number of hours GSHP will work along the year, which is basically related to the climate conditions for the majority of final user needs. Indeed, climate influences heating and cooling needs.

Italy has a high variety of climate conditions and it can be divided in 7 zones, as shown in Table 14.

By elaborating the data, Figure 40 shows the percentage distribution of different types of indicators in the 7 climate zones⁴⁰.

⁴⁰ Elaboration from ENEA-STREPIN – Strategia per la Riqualificazione Energetica del Parco Immobiliare Italiano

Table 14. Data on populations and buildings, divided per climatic zone

Climatic zone	Degree days Gradi Giorno (GG)	Limitations of heating period	N. of municip.	N. of resident. buildings	N. of offices	N. of schools	Population
A	GG<600	1/12 - 15/03	2	4,875	18,525	14,014	22,989
B	600<GG<900	1/12 - 31/03	157	699,573			3,176,382
C	900<GG<1400	15/11 - 31/03	989	2,710,544			12,657,407
D	1400<GG<2100	1/11 - 15/04	1,611	2,858,016	18,265	12,976	14,970,952
E	2100<GG<3000	15/10 - 15/04	4,271	5,191,960	28,210	24,914	27,123,848
F	GG>3000	No limitation	1,071	722,730			1,619,003

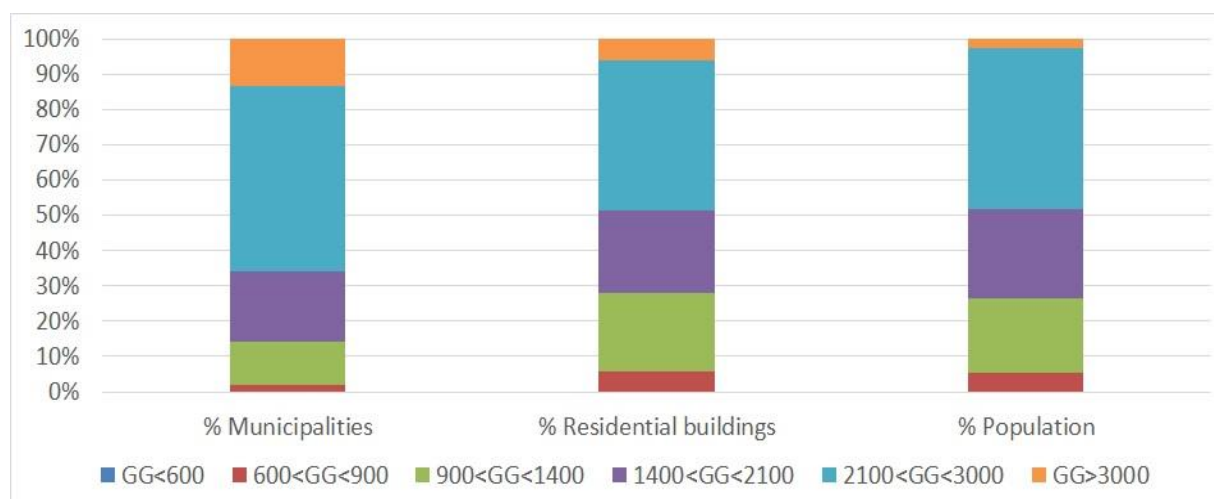


Figure 40. Percentage distribution of municipalities, buildings and population divided by the climatic zones

Also taking in account the available incentives, GSHP in Italy has a good economic balance (<10 years pay-back period) for all zones where heating needs are preponderant, basically E and F zones, hence 66% of the Municipalities, 49% of the building stock and 48% of the population. (Figure 40).

In other zones (from A to D), in addition to fossil fuels and biomass systems, the competition with air-to-air heat pumps for heating is high and the economic balance of GSHP is difficult to achieve, overall when competitive renewable thermal energy systems get access to incentives, too. In these zones, the cooling component is fundamental for the GSHP to achieve the best economic results among alternatives.

5.3.2 Italian regulations and incentives

Low enthalpy geothermal energy was defined as renewable thermal energy from the European **Directive 2009/28/EU** (in Italy D.Lgs. 28/2011⁴¹). This D.Lgs. imposed for new private buildings

⁴¹ Decreto Legislativo 3 marzo 2011, n. 28 Attuazione della direttiva 2009/28/CE sulla promozione dell'uso dell'energia da fonti rinnovabili, recante modifica e successiva abrogazione delle direttive 2001/77/CE e 2003/30/CE.

(or private buildings) subjected to relevant renovation (> 25% of the entire building surface) the following values of renewable energy:

- 50% of hot water
- 35% of heating (up to 31 December 2016)
- 50% of heating (from 1st January 2017)

For public buildings instead the values are:

- 60% of hot water
- 45% of heating (up to 31 December 2016)
- 60% of heating (from 1st January 2017)

The **Directive 2010/31/EU** (in Italy L. 90/2013⁴²) imposes also that:

- From 2018 all the new public buildings should be Nearly-Zero Energy Buildings
- From 2021 all the new buildings should be Nearly-Zero Energy Buildings

The **Directive 2012/27/EU** (in Italy D.lgs 102/2015⁴³) imposes also that 3% of the state public building stock has to be renovated per year.

For energy rehabilitation interventions on the building stock, in Italy there are:

- 65% Tax deduction on audit, design and installation⁴⁴
- “Conto Termico” subsidies, alternative to tax deduction for private users, and accessible also to municipalities⁴⁵
- White certificates bonus on Mtoe savings⁴⁶

The regulatory environment seems to be favourable for GSHP, because a geothermal heat pump, alone, can cover from 50% to 70% of the total thermal power of a building, and so to be a desirable solution to respect emission limits thresholds and to have access to incentives. Nonetheless, the energy obligations are almost only for new buildings, which is a drawback in a period of relevant decrease of requests for building permits.

GSHP technology has become a construction standard in Italy for new buildings, in order to fulfil the energy requirements, but the GSHP sector needs now to be quickly converted in an easily adaptable technology for the energy rehabilitation projects. In that way, it could access to the incentives for energy savings, which are quite limited nowadays for GSHP, being prominent the selection of other solutions by end-users (replacement of windows, façade and roof insulation, substitution of boiler, solar thermal panels, air-to-air heat pumps), more easily installable than GSHP in urban context.

⁴² Legge 3 agosto 2013, n. 90 Conversione, con modificazioni, del decreto-legge 4 giugno 2013, n. 63 Disposizioni urgenti per il recepimento della Direttiva 2010/31/UE del Parlamento europeo e del Consiglio del 19 maggio 2010, sulla prestazione energetica nell'edilizia per la definizione delle procedure d'infrazione avviate dalla Commissione europea, nonché altre disposizioni in materia di coesione sociale

⁴³ Decreto Legislativo 4 luglio 2014, n.102 Attuazione della direttiva 2012/27/UE sull'efficienza energetica, che modifica le direttive 2009/125/CE e 2010/30/UE e abroga le direttive 2004/8/CE e 2006/32/CE. (14G00113) (GU Serie Generale n.165 del 18 – 7 - 2014)

⁴⁴ Legge 28 dicembre 2015, n. 208 Disposizioni per la formazione del bilancio annuale e pluriennale dello Stato (legge di stabilità 2016)

⁴⁵ Decreto Interministeriale 16 febbraio 2016 Aggiornamento Conto Termico

⁴⁶ Decreto Ministeriale 28 dicembre 2012 Determinazione degli obiettivi quantitativi nazionali di risparmio energetico che devono essere perseguiti dalle imprese di distribuzione dell'energia elettrica e il gas per gli anni dal 2013 al 2016 e per il potenziamento del meccanismo dei certificati bianchi

5.3.3 Market distribution of GSHP in Italy

At the present moment, there are no official national statistics about market distribution of GSHP in Italy, divided by climatic zones or by GSHP types.

Since 2010, Italian Geothermal Association (UGI) has started a survey aimed at creating a database of GSHP and other uses of geothermal energy in Italy: some data have been collected so far, and the estimated number of GSHP units sold is around 13,200⁴⁷. However, a lot of work has still to be done because of undefined national strategy for plant registration and management.

Because of the lack of national strategy, some Regions acted independently, to manage the GSHP sector.

As an example of Regional database of GSHP, the public data of GSHP (closed loop) available from Lombardia Region are reported in a database (named “Registro Sonde Geotermiche”) active since 2010⁴⁸

The total number of registered closed loop GSHP plants in Lombardia up to 15 October 2016, according to the Regional database, is 4029. Considering the total estimated amount of GSHP estimated around 13,200 units⁴⁹, the registered GSHP in Lombardia represent around 30.5 % of the total Italian market.

Figure 41, Figure 42 and Figure 43 illustrate an elaboration starting from the data present in the database of Lombardia Region. Figure 41 divides the GSHP sector in two groups: private and public building; as expected the rate of GSHP use in private building is definitely higher than for public owners; Figure 42 divides the GSHP sector between new projects and rehabilitation projects; in this case, the GSHP use in new buildings covers 60% of the total; finally, Figure 43 divides GSHP sector on the basis of building type: residential, commercial or industrial. The residential sector strongly represents the majority of GSHP projects.

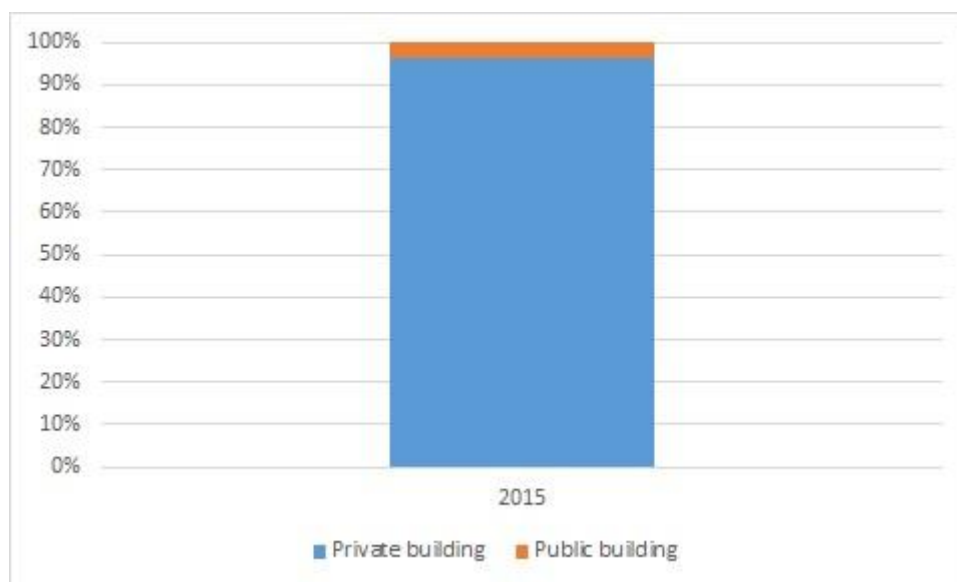


Figure 41. Percentage distribution of private and public buildings with GSHP in Lombardia Region

⁴⁷ Conti P., Cei M., Razzano F., Geothermal Energy Use, Country Update for Italy (2010-2015) - Proc. EGC 2016, 16 p., Strasbourg

⁴⁸ D.d.g. 27 settembre 2010 - n. 9072 Approvazione delle modalità operative e della modulistica per la richiesta di autorizzazione all'installazione di sonde ai sensi del regolamento regionale n. 7/201

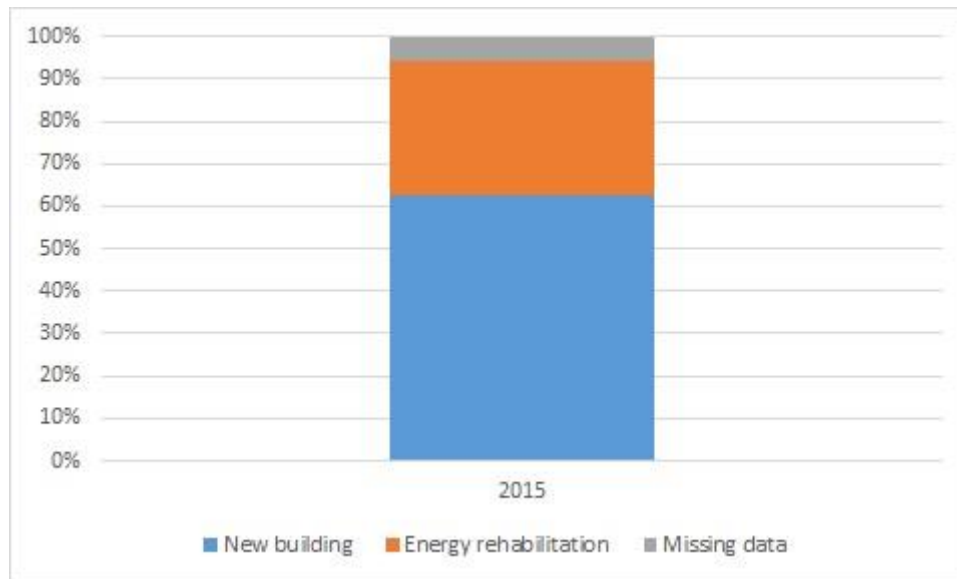


Figure 42. Percentage distribution of new buildings and rehabilitation projects with GSHP in Lombardia Region

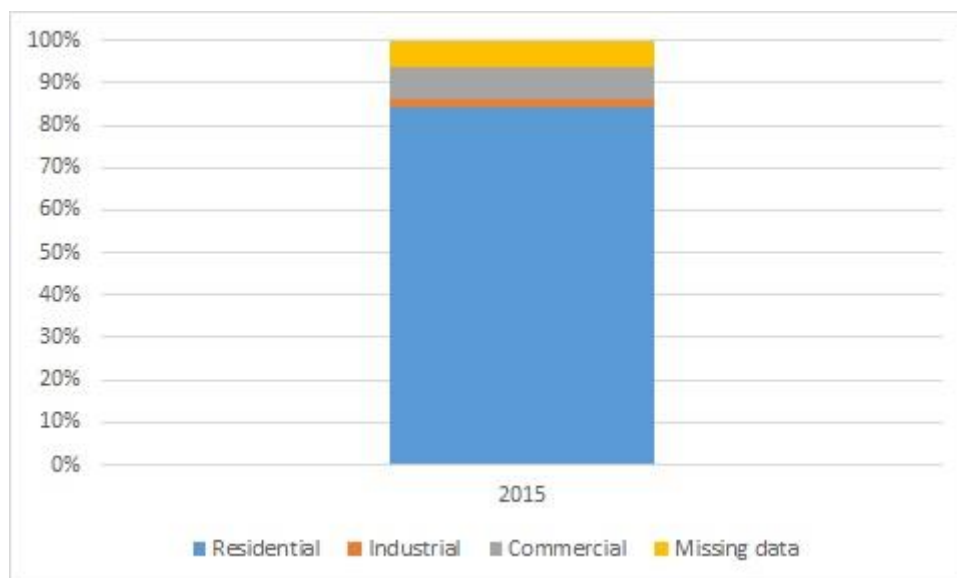


Figure 43. Percentage distribution of residential, industrial and commercial projects with GSHP in Lombardia Region

Along the years, the numbers of registered GSHP faced a negative trend, in particular regarding the new buildings. (Figure 44).

It is worth interesting to notice that the rate of rehabilitation projects has followed the crisis of the new buildings along the years and in particular in the period 2012 – 2015. In the very last period, an inversion of tendency can be noted, with rehabilitation projects rising up again to the levels of 2012. Today, around 30% of all GSHP in Lombardia has been built together with an energy rehabilitation project of existing buildings.

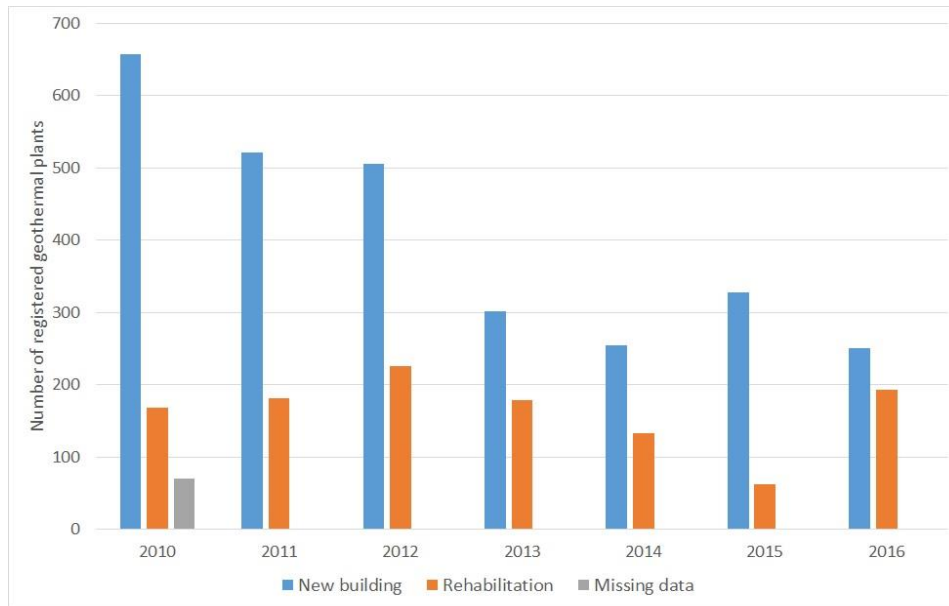


Figure 44. Yearly trend of registered GSHP divided according to the project type

As regarding the data of building types fed by GSHP, they can be representative of the most typical uses of GSHP for all the E and F climate zones of Italy. In terms of numbers, commercial and industrial buildings are few with respect to residential buildings (around 10% each in contrast with 80% of residential), but the capacity per project (and so the numbers of BHE per project) is generally definitely higher than for single or even multifamily houses.

Figure 45 and Figure 46 show the annual trend of GSHP, divided among residential and other categories of buildings. This is another proof showing that the market of GSHP (and consequent decrease in last years) has been largely influenced by the residential houses trends.

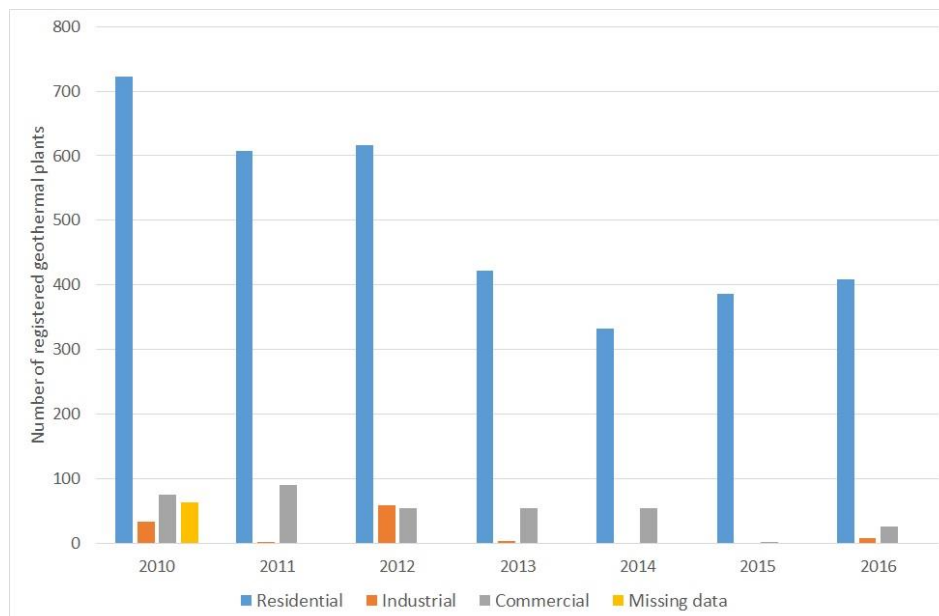


Figure 45. Yearly trend of registered GSHP divided according to the building type

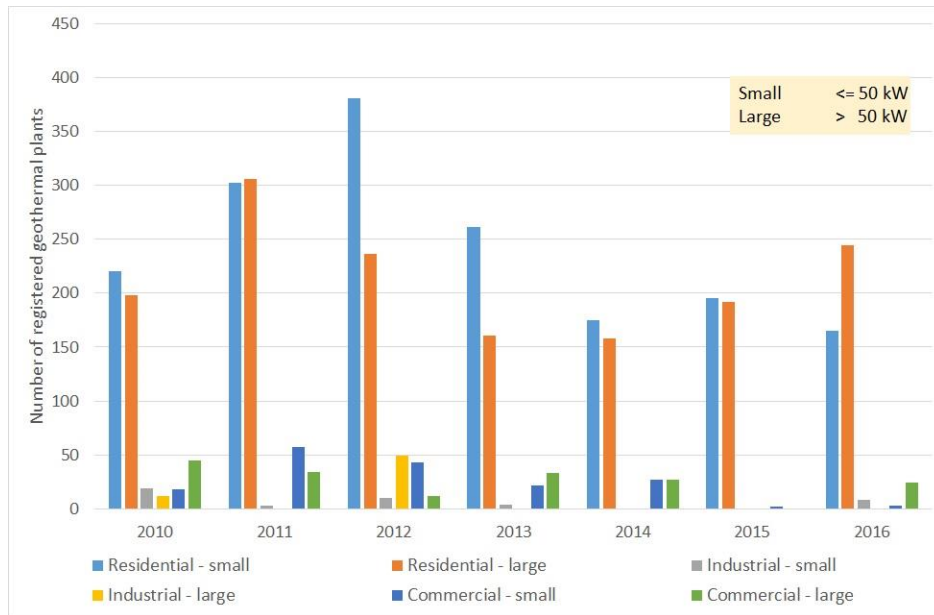


Figure 46. Comparison between large and small GSHP projects (threshold: 50 kW), divided per building type

5.4 Market in Netherlands

Climate conditions

The Netherlands have a temperate maritime climate influenced by the North Sea and Atlantic Ocean, with cool summers and moderate winters. Daytime temperatures vary from 2 °C – 6 °C in the winter and 17 °C – 20 °C in the summer.

Since the country is small, there is little variation in climate from region to region, although the marine influences are less inland. Rainfall is distributed throughout the year with a dryer period from April to September.

Especially in fall and winter strong Atlantic low-pressure systems can bring gales and uncomfortable weather. Sometimes easterly winds can cause a more continental type of weather, warm and dry in the summer, but cold and clear in the winter with temperatures sometimes far below zero. The Netherlands is a flat country and has often breezy conditions, although more in the winter than in the summer, and more among the coastal areas than inland.

According to the **Koepfen-Geiger classification**, the climate of The Netherlands can be classified as *Cfb Climate*: a warm tempered humid climate with the warmest month lower than 22 °C over average and four or more months above 10 °C over average⁵⁰.

Average annual temperatures in the Netherlands are around 9 °C in the North of the country, 11 °C in the South and South-West. These temperatures are reflected in the soil background temperatures. In areas with higher building density or more urban settings, heat island effects will raise the soil background temperature by a few degrees.

⁵⁰ <http://www.weatheronline.co.uk/>

5.4.1 Market Development

The annual heating demand for the Netherlands⁵¹ is currently about 1,200 PJ which is 40% of the total National energy demand. Of the heating demand 44% is industrial (temperatures > 100 °C), domestic use is 29%, commercial buildings 20% and agriculture 7%. It is estimated that 25% of the heating demand can be provided by renewables⁵².

As all EU Member States, the Netherlands, under the EU Energy Efficiency Directive, have implemented a National Renewable Energy Action Plan (NREAP⁵³) to achieve the required energy savings targets and stimulate the use of renewable energy. In the Dutch National Action plan a clear role is indicated for shallow ground source heat pumps as well as ATES and BTES thermal storage.

In the Netherlands, the most well-known shallow geothermal applications, since the early 1990's, are the ATES systems (Aquifer Thermal Energy Systems) which are used for both heating and cooling. In general the ATES systems are of larger capacity (> 50 kW, up to 1 MW) and mainly used for (free) cooling of large buildings (offices, hospitals, airports and larger public buildings). Although their main function is direct cooling using groundwater directly (free cooling), the ATES systems will also provide heating through the use of heat pumps, often in combination with conventional gas boilers. Currently (2016) there are several thousands of ATES systems in use.

Table 15. Commercial and domestic heat pumps (annually installed numbers and total to date in brackets) and heating contribution (Source: statline.cbs.nl)

	2013	2014	2015
Commercial GSHP	630 (9,182)	500 (9,555)	438 (9,782)
Commercial ASHP	23,169 (87,683)	26,715 (114,353)	27,898 (142,251)
Domestic GSHP	2,422 (34,700)	2,010 (36,431)	1,648 (37,625)
Domestic ASHP	14,317 (67,956)	17,313 (84,95)	21,278 (105,800)
Total thermal (heating) GSHP	4,253 TJ	4,595 TJ	4,902 TJ

Since 2000, closed loop heat pump systems (BTES) have been introduced in the Netherlands, mainly for domestic use. Most of the systems, with the exception of applications for small to medium sized apartment blocks, consist of a single water to water heat pump (5-10 kW) with closed loops on the owners' property. Generally the houses will have low temperature underfloor heating systems. The heat pump systems are used for space heating and DHW. In some cases free cooling on the ground loop is used for cooling purposes in summer. Based on the numbers in Table 15, the number of **GSHP systems** (almost all domestic installations) **installed to date must be close to 40,000**.

Since the year 2000, when the closed loop heat pump systems were introduced in the Netherlands, an increase in the market for drilling rigs has been noticed. Several companies have expanded their business to include the geothermal drilling. Also new companies have emerged to take profit of this new opportunity. This includes the residential market for both single homes and large scale housing projects, as well as the commercial market. The commercial market includes office buildings, schools, airports, etc.

⁵¹ Schoots, K., Hammingh, P. (2015), *N45ationale Energieverkenning 2015*

⁵² Schepers, B. en Aarnink, S., *Kansen voor Warmte*: CE Delft (2014)

⁵³ Agentschap NL, *Nationaal Actieplan voor Energie uit Hernieuwbare bronnen*, 2010

In the Netherlands **currently there are roughly 150 drilling companies**, most of which are water-well drilling and or dewatering drilling companies. About 60 of these companies also drill boreholes for closed loop systems⁵⁴. The drilling method used by these companies is straight flush or reverse circulation drilling. Market leader in design & construction of drilling rigs in the Netherlands is Conrad Stanen BV.

Drillers active on the Dutch market are required to have certification⁵⁵. Drilling rigs and ancillary equipment have to comply with ABOMA safety check guidelines and need annual inspection.

The current SER Energieaccord voor duurzame energie⁵⁶ (SER is Social Economic Council, advisory body to the government) gives to shallow geothermal energy (ATES + BTES) an indicative growth budget of the current 5.0 PJ (2015) heating contribution to a potential of 16.0 PJ in 2020 to 21.0 PJ in 2023. In the case of shallow geothermal, the main focus is on heating although cooling has become a standard feature in commercial buildings as well as in households as houses, due to more stringent building regulations.

Currently the market for shallow geothermal energy systems in the Netherlands is in a period of declining growth. This is partly due to reduced building activities caused by the economic crisis and drop in house prices. On the other hand, ground source heat pumps are finding competition in air source heat pumps as these have a lower initial cost.

In the Netherlands the government provides a subsidy (ISDE by RVO/Economic affairs) for renewable equipment (wood pellet burners, heat pumps etc.): in 2016, up to the month of August, 8,200 applications were made and 85% of them were domestic. Of these non-business applications 25% were made by heat pumps (ASHP and GSHP). Instead, in the business applications, 70% involved heat pump equipment. The applications indicate a clear interest in sustainable equipment in general and heat pumps in particular.

Although there is potential for further development of the shallow geothermal market in the coming years, it remains to consider whether the ATES and BTES systems on the market can grow their number considerably. Absolute requirements for further growth will be well defined legislations with regard to environmental issues and spatial planning as well as improvement of the competitive position of shallow geothermal.

A more competitive position can be achieved by:

- Lower initial cost of installation
- Higher energy efficiency
- Valuation of GSHP cooling capacity (extremely important equipment/concept feature)
- Integration of large scale GSHP into smart grid networks (off-shore/on-shore)
- Favourable policies with regard to energy conservation and energy storage
- Stringent building codes
- Reduction of noise emission (compared to ASHP)
- Architectural appreciation (out of sight)

5.4.1.1 Residential market

In the Netherlands, in the residential market shallow geothermal systems in combination with heat pumps have taken off since the year 2000. Very specific for the Dutch market is the development of

⁵⁴ Market research by Conrad Stanen (December 2015)

⁵⁵ Protocol mechanisch boren (BRL SIKB 2100)

⁵⁶ SER Energieaccord voor duurzame groei (September 2013)

large areas of terraced family housing consisting of single family dwellings with a back garden. Building density is quite high, with up to 100 dwellings per hectare.

Over the last ten years some of the projects realised are:

- Schoenmakershoek, Etten-Leur (1,200 homes; installed GSHP capacity 7.2 MW)⁵⁷
- Mannee, Goes (370 homes and apartment blocks, installed GSHP capacity 2.1 MW)
- Valburg, Zetten (200 homes and apartments, installed GSHP capacity 1.4 MW)
- Vathorst, Amersfoort (100-200 homes and apartments, installed GSHP capacity 1 MW)
- Vegelinbuurt, Leeuwarden (100 homes, installed capacity 0.4 MW)
- Coendersbuurt, Delft (70-100 homes, installed capacity 0.6 MW)

Several locations for large scale domestic developments are under consideration and planning should take place the coming few years. Although it is not certain that the projects will have GSHP, it is clear that under the new building code requirements (BENG) ground source technology will be considered for the reduction of primary energy use.

5.4.1.2 Commercial market

In the commercial market the ATES (WKO systems) are a standard solution for all large buildings such as hospitals, sport facilities, offices, public buildings. The challenge will be to improve the quality of the systems, specifically the control integration into the building heating and cooling system. Furthermore, as the WKO systems are very much used for cooling, it is difficult to achieve a long term thermal balance (monitoring is required) in the well system. Excessive heat rejection is prohibited and should be balanced by introducing cold into the aquifer. Another issue is the low energy performance per pumped volume of water, leading to lower overall energy efficiency of the systems.

Closed loop GSHP systems have been installed on a number of smaller (< 25-100 kW) office buildings. Slowly architects and mechanical installers are starting to realise that closed loop systems have a distinctive benefit, which is the low maintenance cost. Although “free cooling” is a mantra, mechanical cooling (main cooling function) on closed loop systems is getting to become accepted practice.

One more benefit of closed loop GSHP systems is that they can be developed in a phased manner, introducing the GSHP system as building develops on site (commercial development projects). With open well ATES systems, investment into the extraction and injection wells and all transport pipework and controls has to take place at the start of the building development. Most project developers and energy companies are reluctant to make this pre-investment.

Potential market for the implementation of geothermal solutions

The main drivers for the application of shallow geothermal systems are the building regulations, which require reaching certain energy savings levels (EPC). Shallow geothermal systems have a high score in the rating, making them an attractive proposition to achieve the set goals.

In commercial buildings, quality certification schemes such as BREEAM, reward the use of shallow geothermal heating and cooling. Certification of building quality is directly related to the commercial value, finance-ability and let-ability of the properties. Often the building quality

⁵⁷ Witte, H.J.L., Gelder, A.J, van & Klep, P. 2006. A very large distributed ground source heat pump project for domestic heating: Schoenmakershoek, Etten-Leur (the Netherlands). In: Stiles (ed). The Tenth International Conference on Thermal Energy Storage, Ecostock 2006 Proceedings. May 31 - June 2, 2006, Stockton College New Jersey (USA)

certification is a requirement by the financiers or foreign real estate property investors, who play an important role in the Dutch market.

In the Dutch building code, energy savings are expressed as the EPC (Energy Performance Coefficient). The relevant norm is the NEN 7120 (energy performance of buildings). The latest revision of the EPC took place in January 2015. Furthermore an energy label, indicating the energy quality of the building is required when the building is handed over to the tenants or buyers.

At the end of the year 2020 all new buildings in the Netherlands should be close to energy neutral (BENG) and all new government buildings should achieve this by the end of 2018. There will be three criteria to evaluate the almost energy neutral (BENG) buildings:

- The maximum energy demand (kWh) per m² floor area
- The maximum primary energy usage in kWh per m²
- The minimum share of renewable energy for the building

In the above 2020 scenario, ground source heat pumps have a direct contribution to make in the reduction of primary energy usage and an indirect contribution in the share of renewable energy contribution, as the use of GSHP will reduce the amount of renewable energy required.

5.4.2 Regulations

In 2013 new legislation (AmvB Bodemenergie) with regard to shallow geothermal energy was implemented, regulating the use of shallow geothermal with regard to environmental regulations, quality certifications, underground thermal interference and permitting. Under the new law, provincial authorities remain the regulatory body for open well applications using groundwater and municipalities are responsible for closed loop geothermal systems.

By law a few technical aspects of closed loop GSHP systems are regulated such as the absolute minimum (-2 °C) and maximum injection temperature (30 °C). The use of frost protection using easily degradable additives such as MPG is allowed. All geothermal systems are allowed to have an annual thermal imbalance cooling down the ground (heat extraction). They are not allowed to have excess heating on the ground (cooling).

Drillers installing wells or GSHP systems are required to have certification⁵⁸ and designers of geothermal energy systems need a proven and certified quality registration (BRL-6000-21).

Due to the sedimentary geology of the Netherlands and the very extensive sandy aquifers deposited by the Rhine, Meuse and other rivers, open wells with high yields are feasible in large parts of the country. Open well based ATEs systems are therefore very popular and with the exclusion of specific groundwater protection zones, can be implemented in many locations. Open well drilling/installation and usage always requires permitting, which includes long term monitoring of a system energy balance (heat and cold extracted/injected) as well as total pumped water amounts.

Closed loop systems up to capacity 70 kW (source side) are regarded as small systems and require reporting of system parameters and whether the system to be implemented will have detrimental thermal effects (thermal interference) on neighbouring systems. Larger systems (> 70 kW) require permitting. If larger areas of housing or commercial use are under development and the municipal authorities require planning and coordination of underground thermal interference, they have the option to initiate a so-called “interference area”, which, within the framework of the law, will have specific rules and regulations to avoid negative interference and will allow optimum long term thermal usage of the area.

⁵⁸ SIKB, Beoordelingsrichtlijn Mechanisch Boren.BRL-SIKB 2100

To assist local authorities with the implementation of shallow geothermal systems, the Dutch Ministry of Infrastructure and Environment (Ministerie van I&M) has developed guidelines (BUM/HUM)⁵⁹ in order to harmonise the implementation of geo-energy systems nationwide.

⁵⁹ Groenholland, *Methode voor het bepalen van interferentie tussen kleine gesloten bodemenegiesystemen*, 2011

6. MARKET REQUIREMENTS FOR THE VERY SHALLOW GEOTHERMAL SYSTEMS IN EUROPE

In this chapter, the actual market requirements for the systems developed within GEOTeCH project will be investigated, focusing on standards and state of deployment of each technology in the European context.

6.1 Drilling equipment, methods and technology

In general the drill rig market for shallow geothermal applications in Europe is serviced from countries like Germany (Nordmeyer, Klemm etc.) and Italy (Fraste, Commachio, Soilmec etc.). Although other countries will have local suppliers, they are all relatively small.

A quick market scan gives the following numbers for manufacturers of water well and shallow geothermal drilling rigs per country.

This list does not cover the smaller manufacturers.

Table 16. Number of manufacturers in different European countries

Country	Number of manufacturers
DE	16
IT	15
FR	5
NL	3
UK	3
SE	2
BE	1
DK	1
FI	1

The trend over the last ten years has been to reduce manual labour on drill rig by mechanisation of rod handling etc. Safety has also become a more relevant issue as can be seen by the introduction of remote control etc.

Most of the rigs used in shallow geothermal have never been specifically designed for the task, usually they are general purpose rigs that are also used for geotechnical work, dewatering and drilling of small wells for sprinkler installations, gardens or agricultural purposes.

In general, common purpose rigs currently on the market have the following features:

- Track mounted
- Diesel engines with little emission or noise restriction
- Weight between 4-8 tonnes
- Rod handling usually by hand
- Simple pumps (centrifugal agricultural type)
- Average age probably around 10 years, expected life span 15-20 years

Most drilling companies are SME's employing less than 10 persons. Work carried out will in most cases be local or regional.

Throughout Europe the market for shallow geothermal installation has emerged over the last ten years. Production rates (m/day) are relatively low, due to the fact that the equipment is not optimised for the task.

Table 17. Guidelines/regulations for drilling in some of the countries

Country	Guideline	Description
NL	BRL SIKB 2100	Beoordelingsrichtlijn 2100 - Mechanisch boren
NL	BRL SIKB 11000	Beoordelingsrichtlijn 11000 - Ondergrondse bodemenergie systemen
DE	DVGW W 120	Qualifikationsanforderungen für die Bereiche Bohrtechnik, Brunnenbau und Brunnenregenerierung 2005-12 (DE)
DE / CH	DACH-Gütesiegel EWS	Gütesiegel für Erdwärmesonden-Bohrfirmen 2001/2006 (CH/DE)
GB	BS 5930:2015	Code of Practice for Ground Investigations
BE	VLAREM 55.1	Guidelines for vertical drilling
SE	C-Borrare	Certification of well drilling companies

Many countries are still developing guidelines and regulations concerning drilling, grouting, borehole backfilling. In addition to these standard guidelines for drilling several countries are developing guidelines in particular for shallow geothermal drilling and installation of open loop and closed loop systems.

Potential market for drilling equipment

The European market shows a growing interest in shallow geothermal drilling. Most European countries are developing programs to improve the market for geothermal solutions. This goes hand in hand with developments for low energy housing solutions.

Many drilling companies in Europe are investing in new drilling equipment and improving current drilling equipment for shallow geothermal drilling. These improvements concern the implementation of more advanced equipment but also improvements in working conditions. It is important for drilling companies to keep up with this quickly changing market and reap the benefits in the coming years.

Drilling rig manufacturers are expanding their range to meet this increased demand. Mostly this concerns modifications of existing models to make them suitable for shallow geothermal drilling. Some manufacturers are developing drilling rigs for the sole purpose of shallow geothermal drilling.

Changing regulations for borehole grouting and back filling and preventing contamination of different water bearing ground layers provides a good chance for manufacturers. There is a clear demand for additional equipment for this purpose. Also improvements of the technology available are necessary.

6.1.1 Drilling methods for GSHP

Several drilling methods are currently used for GSHP installation, each with its own advantages and drawbacks.

Straight flush rotary and air rotary are both methods that are current industry standards and will allow relatively high production rates. Both methods however have very distinct drawbacks with respect to working conditions on site, especially in the context of multiple borehole settings as in geothermal applications.

Shell and auger has low cost for the equipment. However, the rate of drilling (meters per day) is so slow, that it will not be acceptable from an economic point of view, with the exception of very specific locations.

Very specific drawbacks are noise, dust and working with high pressure air on the rotary air application and the water and mud containment and general working conditions on the straight flush rotary. The required air and water handling infrastructure often requires additional manpower and space on site, also it reduces site mobility.

Sonic drilling is fast, but is in its current state not a reliable technology for installing ground source heat exchangers.

Auger drilling is a very usable drilling method. The machinery and equipment are very straightforward, not overly costly and the operating principle is simple and reliable. Spoils containment is relatively manageable as are working conditions. Lack of extensive water/mud management infrastructure on site will allow quick mobilisation.

6.1.2 Developments in technology

Recent years have seen developments in the technology used on drilling rigs. These developments focus on improvement of the production capacity and reduction of the ecological footprint. Also operator safety and the rig operating conditions have been improved.

The market demands these improvements in technology as the users of the drilling equipment are faced with ever changing demands in operator safety, production speed, etc. This can be motivated by changes in rules, regulations and law or by the need to have the most competitive complete package to outpace the competition.

The BTES closed loop system only requires a drilling rig with simple but effective technology which is accessible for many large and medium drilling companies. The closed loops are installed to a depth of 80 to 160 meters and this requires a drilling rig with a pull-back of 5,000 to 10,000 daN and 400 to 800 kgm of torque on the drill-head. Combined with a high horsepower engine and high capacity straight flush pump it is possible to drill up to four holes of 120 meters depth in one day.



Figure 47. Typical drilling rig for shallow geothermal drilling (Conrad Boxer 200)

By manufacturing drilling rigs which are very focused on the installation of closed loops the individual parts of the rig can be matched much better than in case of a multipurpose rig. This improves the efficiency of the drilling rig and makes it possible to increase the drill rate.

Developments in recent years have made the above mentioned possible.

- EURO 6 diesel engines are installed in the rig to reduce emissions
- Remote controls enable the drill rig operator to safely move around the drill area
- The automated drill-pipe manipulator makes it unnecessary that the operator handles the drill-pipe with the winch

- Developments in measuring and control systems give better insight in the drilling process and allow for more balanced performance during drilling
- Improvements in rig automation makes it possible to manage the rig power output better, it uses exactly that what it needs, thus reduces fuel consumption

6.1.3 Maintenance and durability

As a result of the increased competition in the market the drilling companies have to work as efficiently as possible and have to prevent any downtime as much as possible. This is especially the case in large drilling projects where the margin is low. Drilling rig design, maintenance and durability plays a major role in obtaining these goals.

Due to better engineering solutions the construction of drilling rigs has improved and this benefits the durability of the drilling rigs. Also improvements are made by using better materials.

Maintenance of drilling rigs is improved by using service contracts for the drilling rigs. This gives the drilling companies insight in the cost of maintenance and because a planning can be made for the maintenance the service moment does not interfere with drilling projects. Thus the drilling rig has a downtime which is as low as possible.

In case of unexpected breakdowns the manufacturer has a service fleet which can travel to the rig on very short notice to remedy the fault or repair and replace parts.

6.1.4 Regulations for rig manufacturers

With regard to regulations on drilling rig production there are very clear EU guidelines. These European directives on all aspects of machine production are described in the ISO norms as recorded by the European Committee for Standardisation (CEN). Directive 2006/42/EC.

Production of the machinery has to be in conformity with the following standards or other normative documents

- NEN-EN-ISO 16228-1:2014
- NEN-EN-ISO 16228-2:2014
- NEN-EN-ISO 4413

Drilling rig manufacturers have to follow these norms. This results in the machine having a CE-marking. This means that the machine complies with the applicable European directives on safety and health.

Health and Safety and working conditions in general are also an indispensable part of drilling rig production. Therefore new technological developments will have to incorporate features that integrate Health and Safety aspects in a very efficient manner. Working conditions are another point of importance as this will have a direct effect on the quality of the work and on the achieved production.

6.1.5 Compliance with changing regulations for drilling companies

If we take the Netherlands as an example we see that new regulations have come into place since the growth of the market for open loop and closed loop systems. These regulations prevent contamination of ground layers as result of improper drilling activities and borehole filling methods. Drilling activities in general are describes in the guideline SIKB BRL 2100 Mechanical drilling⁶⁰. The SIKB BRL 1100061 in particular describes the guidelines for underground installations for geothermal energy.

⁶⁰ BRL SIKB (Stichting Infrastructuur Kwaliteitsborging Bodembeheer) Beoordelingsrichtlijn 2100

Companies in the business of drilling rig engineering and production have to closely follow these guidelines to be able to provide the market with equipment which enables the drilling companies to be approved for drilling activities by the governing bodies. Developments in the engineering of drilling rigs include:

- Borehole logging systems
- Borehole back-filling machinery
- Switch to other drilling methods

6.2 Foundation heat exchangers

One of the most striking features of this type of geothermal system is the reduction of one of the main entering barriers to geothermal energy, its high cost associated to the necessary excavations to set up the pipe system. This reduction comes up as a result of gathering foundation building with borehole heat exchangers. As foundations are a necessary element for any modern building, it reflects a fix cost, and introducing on them pipes, for extracting geothermal energy, does not involve a big amount of work. Thus, it means a “small” cost compared with total costs.

However, it also presents some disadvantages with regard to borehole typology, further than the lack of experience associated to every new invention. As an example sizing should be carried out before the beginning of the construction. In order to avoid future problems it will be needed a fluent communication with the client and the contractors to know exactly how HVAC system will be.

6.2.1 Research and state of deployment

Several researches have been carried out on geothermal energy and its extraction. One of the main facts about geothermal energy is that climate is a key element. It changes totally the system behaviour and also the demand, as it proved a paper⁶² presented at Clima 2010. This paper shows the experience of tests for up to eight different types of weather in Europe and ten locations. Results found out that foundation heat exchangers (FHX) can work on a wide range of climate, working better where the heating load is not very high (cold climates such as marine with cool summer, humid continental and subarctic). The higher the heating demand, the more length the hydraulic system needs to exchange heat. Even though an increased initial investment, those climates are the ones with higher energy saving thanks to FHX.

Other studies can be found about how temperature and pipe insertion modify the mechanical behaviour of foundations. Both studies have been carried out for energy piles and not for screen walls, which are more recent and can deliver more thermal exchange capacity.

One of these studies comes from a PhD Thesis⁶³ which studies the mechanical behaviour of reinforced concrete when used as thermo-active elements. The following conclusions were found out:

- mechanical properties are reduced as temperature increases. When temperature reaches 70 °C resistance can diminish up to 20%. This should not be alarming because heat exchangers are supposed to work between 16-20 °C when heating and 25-30 °C when cooling. The fluid will be warmer than this, but it is never supposed to reach 55 °C, so it not probable to need to oversee any foundation because of that

⁶¹ BRL SIKB (Stichting Infrastructuur Kwaliteitsborging Bodembeheer) Beoordelingsrichtlijn 11000

⁶² Spitler, J. et al. 2010. *Residential Ground Source Heat Pump Systems Utilizing Foundation Heat Exchangers*. Proceedings of Clima 2010, Antalya Turkey, May 9-12

⁶³ Martínez, I. 2014. *Evaluación del comportamiento mecánico de estructuras de hormigón armado utilizadas como elementos termoactivos*. PhD thesis. Universidad Politécnica de Madrid

- pipe insertion in concrete reduces its resistance. It has to be outlined that this reduction is more significant when pipe is positioned orthogonal to loading direction, reaching a 16-28% of resistance reduction, while when positioned parallel, loses are about 6-13%. Results vary in function of the concrete used and the samples shape (cubic or cylindrical)

Despite this PhD Thesis shows real and relevant information, further analysis (which is being done at D3.5) is required to quantify the amount of strength lost in real cases. That is because sample shape is considered small with regard to the pipe used in the study (Pipe volume was 4.5% for cubic sample and 5.7% for cylindrical sample).

It has also been studied how expansion or compression due to thermal reasons affect the mechanical behaviour of the foundation. The following figures have been extracted from a recent study⁶⁴, they show how stresses and strains are distributed all over the foundation for friction piles and end-bearing piles.

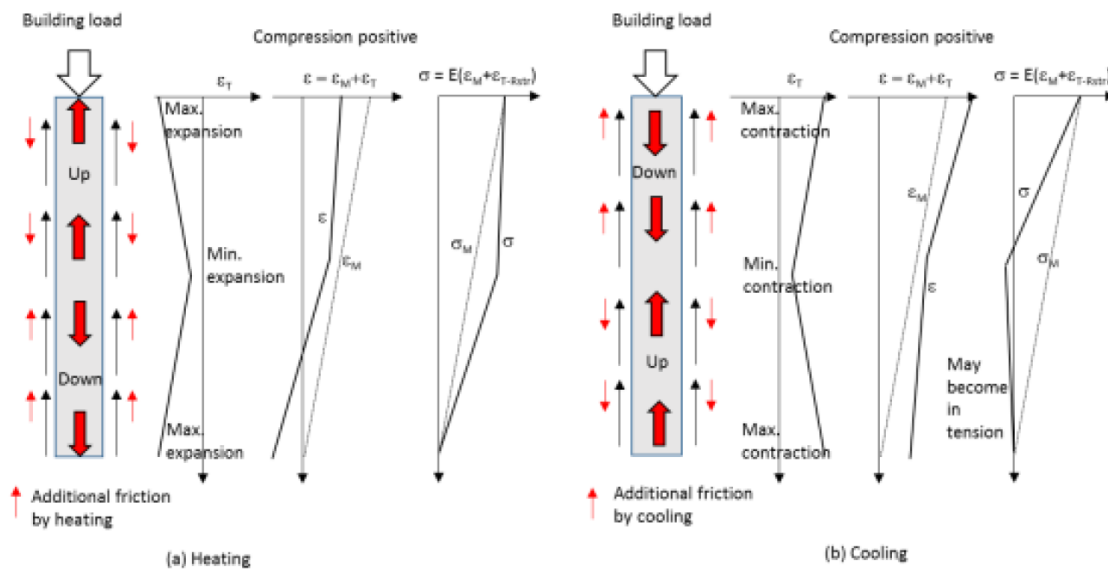


Figure 48. Thermo-mechanical performance of a friction pile

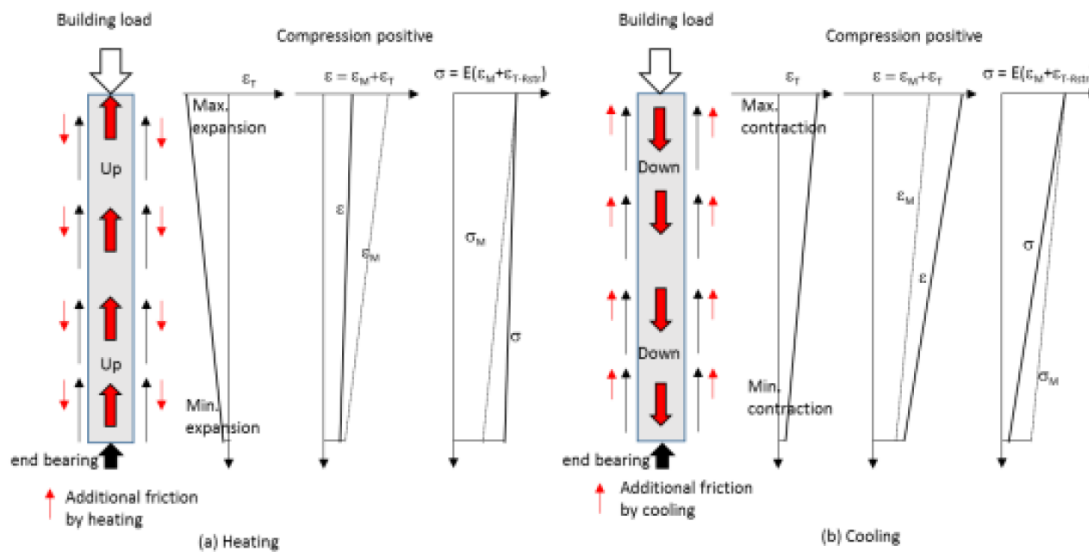


Figure 49. Thermo-mechanical performance of an end bearing pile

⁶⁴ Rui, Y. 2015. *Finite Element Modelling of Thermal Piles and Walls*. PhD dissertation. University of Cambridge

It is important to highlight that when heating, the pile will suffer an increased stress due to its expansion. In the case of the end bearing pile, it will behave somewhere between the cases of free expansion and fully restrained⁶⁵. That is because the pile will try to expand freely but the end bearing strata and the overlying structure will tend to resist its movement. When cooling the stresses suffered by the pile will be reduced.

Field experience in FHX is limited in comparison with other geothermal systems. Diaphragm walls have been tested during this project at few real buildings and also for some other research purposes; however it has never been implemented on a regular basis. By contrast, energy piles started to be used at the end of 1980s and got consolidated about year 2000⁶⁶.

Examples of European projects including energy piles are numerous in the tertiary sector (for office, public or retail spaces). The One New Change building, built in 2010 in London (UK), is founded on piles among which 219 are geothermal piles. They contribute to the heating and cooling of 52,000 m² of office and retail space.

Dock Midfield (Zürich) airport, built in 2003, is also a good example of how powerful FHX can be. This airport terminal was founded on 350 30-m long bored piles with large diameters (between 0.9 and 1.5 m) among which 300 were turned into geothermal piles. Each pile was equipped with 5 U-loops. Geothermal piles are utilised for heating and cooling the terminal. 85% of the heating is provided by the energy piles while almost the whole cooling demand is satisfied by direct cooling on the piles.

Another great European example is the Main Tower of Frankfurt (Germany) with more than 100 energy piles plus a diaphragm wall made of a hundred of heat piles. To illustrate the multitude of buildings in the tertiary sector that can include energy piles, Brandl (2006) quoted the Keble College in Oxford (UK) or the Arts Centre in Bregenz (Austria).

At the international level, no real comparison is available but a great interest from Chinese researchers through many numerical investigations implies that the developing China is about to widely utilise this technology. At the US vertical or horizontal geothermal loops are more accepted for domestic use, this can be seen as a logic consequence originated by a different urban model.

To sum up the previous ideas it can be said that **Europe is a pioneer in energy piles but their utilisation is still confined to the heating and cooling of buildings of the tertiary sector** (offices, retail spaces, public halls...) while conventional vertical or horizontal loops are preferred for heating and cooling the households. **FHX use has been increasing with time** (see Figure 50) despite geothermal energy is losing market share with regard to air heat pumps (see Figure 51). A quick conclusion can be the following: FHX are the most promising future for shallow geothermal energy in Europe.

⁶⁵ Loveridge L, Powrie W and Smith P. *A review of the design and construction aspects for bored thermal piles*. Ground Engineering March 2013

⁶⁶ Brandl, H. 2006. *Géotechnique* 56, No. 2, 81–122

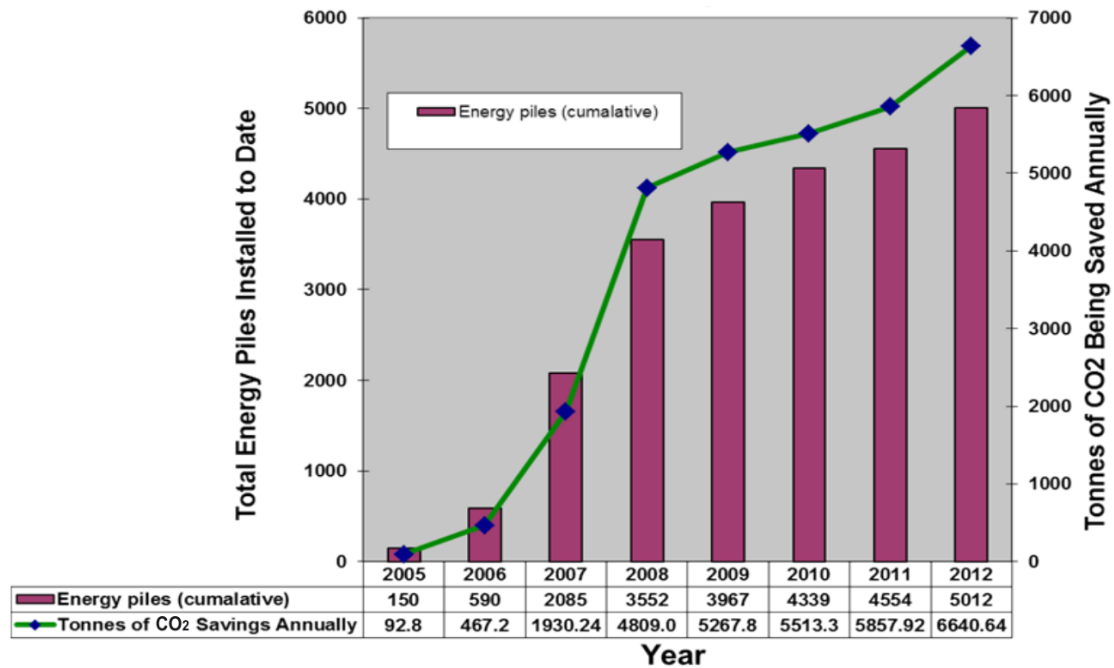


Figure 50. Energy piles installed in the UK and resultant annual report CO₂ savings to date at Sept 2012⁶⁷

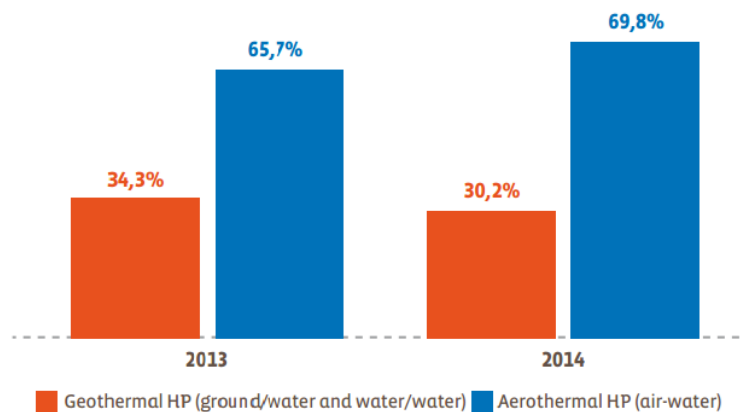


Figure 51. Market share between geothermal and aerothermal heap pumps with hydraulic distribution system in 2013 and 2014 (Source: EurObserv'ER 2015)

Even though diaphragm walls have not been implemented on a regular basis, there have been few buildings where this kind of FXH has been used.

Three of the most relevant cases found in the literature will be presented:

Shanghai Museum of Natural History

This building is located above the city metro (line 13). The museum was opened in 2015. Its building area is 12,029 m² and has 5 floors, resulting into a 45,085 m² floor area. Energy piles and diaphragm walls have been used as FXH. Diaphragm wall performance was studied in 2011, and the following information comes from this study⁶⁸ results.

⁶⁷ Amis T and Loveridge F. 2014. *Energy piles and other thermal foundations for GSHP*. REHVA Journal

⁶⁸ C. Xia et al. 2012. *Energy and buildings* 52, 50–55

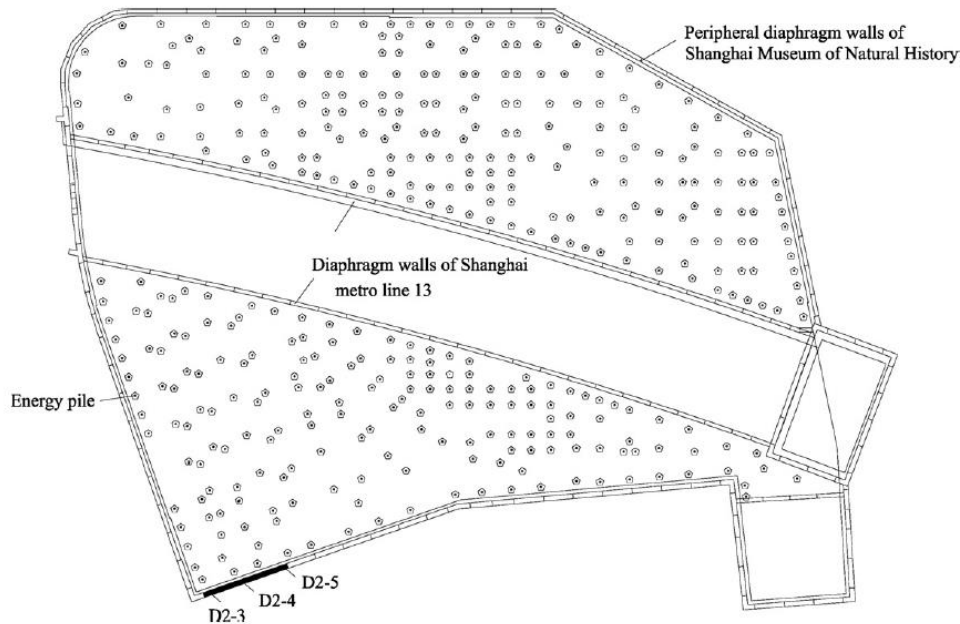


Figure 52. Floor plan of heat exchangers embedded in diaphragm walls and piles at Shanghai Museum

The heat exchangers (HX) used at the screen walls were 452 W-shaped HX buried in 38–40 m depth with an absorber tube made of PE100 with 25 mm of diameters and 2.3 mm of thickness.

Up to four different influences on the performance (exchange rate) were analysed:

Heat exchanger type

The heat exchange rate of W-shaped heat exchanger reached to **66.3 and 73.7 W/m** for tube type (a) and (b) at the inlet temperature of 35 °C, which are approximately 1.2–1.4 times higher than that of single U-shaped type (c).

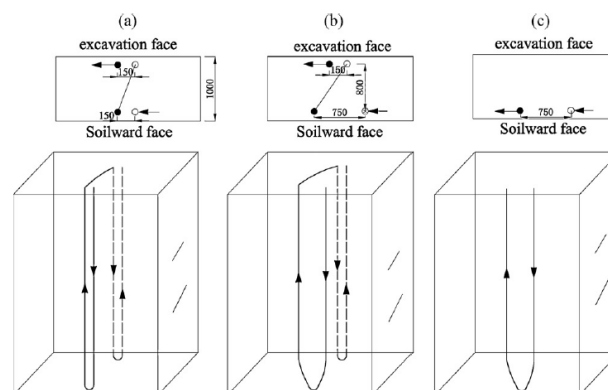


Figure 53. Three types of underground heat exchangers investigated: (a) W-shaped, (b) improved W-shaped and (c) single U

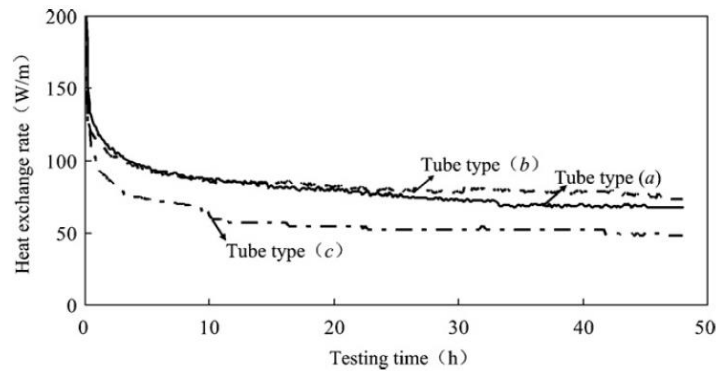


Figure 54. Relationship curves of heat exchange and time under different types of heat exchangers

Water velocity

The heat exchange rate rises significantly with the increasing of water velocity when the water velocity is below 0.9 m/s (from 73.8 W/m to 150.0 W/m), but changes slightly when it is larger than 0.9 m/s. Therefore, the effective water velocity for this project was 0.6–0.9 m/s.

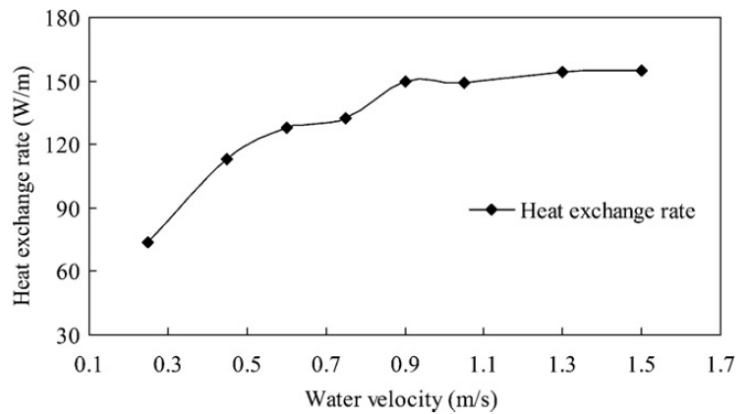


Figure 55. Relationship curve of heat exchange and water velocity

Inlet water temperature

The heat exchange rate increases with the temperature of inlet water, with an approximate linear relation. On average, it is improved by 15% every 1 °C increases of inlet water temperature.

Table 18. Experimental results of heat transfer test under different types of buried pipes (W/m)

Heat exchanger types	Inlet temperature (°C)		
	32.0	35.0	38.0
Tube type (a)	40.3	66.3	85.0
Tube type (b)	43.2	73.7	98.7
Tube type (c)	33.6	50.0	68.4

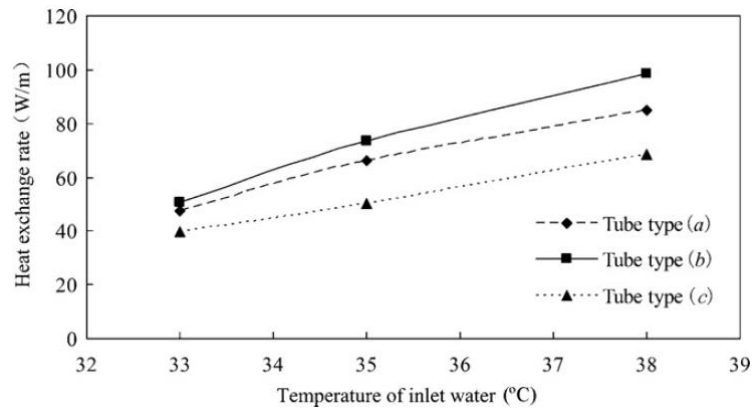


Figure 56. Relationship curves of heat exchange and temperature of inlet water

Operation mode

Two different operation modes were studied: continuous and intermittent (intermittent ratio 1:1). The exchange rate in the intermittent mode is 14.7% higher than in continuous mode.

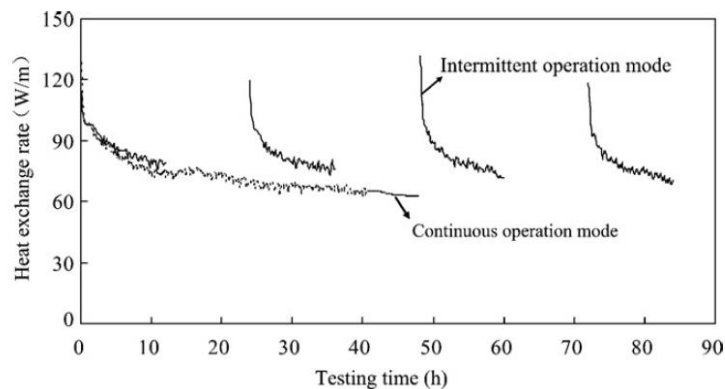


Figure 57. Relationship curves of heat exchange and time under continuous and intermittent operation

Surface ratio

Finally, a surface ratio can be calculated from the existing data in an approximate way because the paper doesn't specify the length of the diaphragm walls. Therefore, it was supposed a distance between exchange tubes. It is stated that there are 452 heat exchangers and the approximate perimeter of the diaphragm walls is 815 m. Then, the distance between tubes is 1.81 m. However, this value might be inaccurate because the perimeter was calculated scaling the plan view. The distance between two branches of the same heat exchanger is 0.75 m and the distance between different heat exchangers seen in Figure 53 seems to be close to the calculated value. Taking into account all the parameters it was considered a distance of 2 m. Even though, it will be more precise to compare the lineal ratio (W/m) of one heat exchanger.

Table 19. Calculated results of heat transfer test under different types of buried pipes (W/m)

Heat exchanger types	Inlet temperature (°C)		
	32.0	35.0	38.0
Tube type (a)	20.15	33.15	42.50
Tube type (b)	21.60	36.85	49.35
Tube type (c)	16.80	25.00	34.20

Knightsbridge Palace Hotel

This building is located in Knightsbridge neighbourhood, London. Its construction commenced in September 2009 and the hotel was opened in 2012. Its building area is only 1,100 m², but it has 10 superstructure levels and a 6 basement levels, which will reach 24 m below pavement (see Figure 58). Due to this deep excavation and water tightness situation, the structural basement walls were constructed adopting diaphragm walls: 800 mm wide and up to 36 m depth. The total length was 155 m and it was reached used 39 panels. Geothermal loops were only installed on a 100 m of length and in the shallower zone (until 24 m). Energy piles (49), with a diameter of 1.5 m, were also used as FXH.



Figure 58. Diaphragm Wall panel layout (left) and 3D section of superstructure and basement (Source: Amis, T et al. Integrating geothermal loops into the diaphragm walls of the Knightsbridge palace hotel project)

As the screen walls would be surrounded by ground only in the external face, the designers developed a solution in order to maximise the heating and cooling potential of these foundations whilst minimising the impact on reinforcement quantities and potentially deleterious effects on construction quality. The solution was installing the loops only in the closest reinforcement to the ground as shown in the next Figure 59.

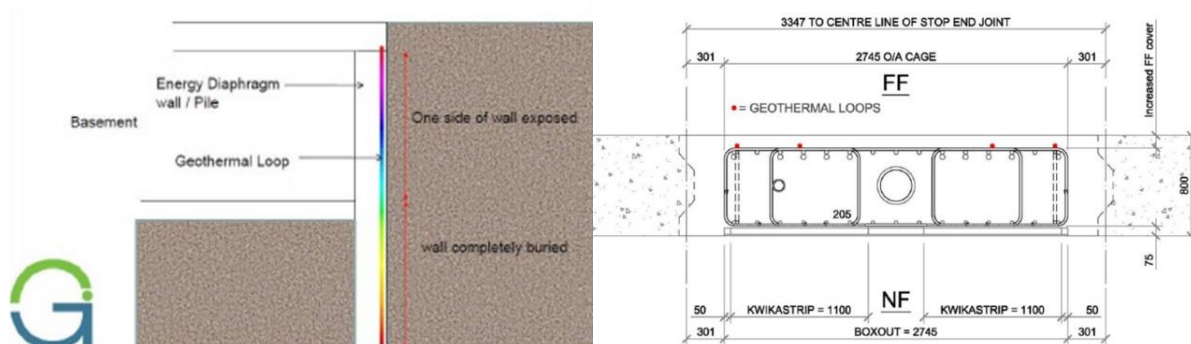


Figure 59. Scheme (left) and plan view detail (right) of the diaphragm walls (Source: Amis, T et al. Integrating geothermal loops into the diaphragm walls of the Knightsbridge palace hotel project)

The installation of the loops to the reinforcement cage did not require additional time to the process, what mean a pretty similar speed between cage insertion and loop installation. It must be said that the reinforcement used for this walls was complex (3 cage sections for each panel) and a considerable time was required to splice cages together. Anyway, attaching the loops was not a critical activity and did not require additional time for the works, what was a success.

This geothermal system was designed to achieve the 10% renewable energy required by London city. This system delivers 150 kW of heating and cooling. Despite it would be interesting to calculate a surface ratio for the diaphragm wall, it is impossible, with reasonable degree of certainty, as no information about energy piles performance.

Sant Antoni's Market

It is a modernist building from 1882. It is a metallic structure on a Greek cross plant. It is one of the most important and bigger market in Barcelona, with a 5,214 m² surface. However, for more than ten years it has been inactive. It was decided that is high time to reactivate market activity through a rehabilitation whose aim is to integrate this building in the city as an historic, sustainable and efficient building. Hence, FXH have been thought as the best solution.

Through previous studies it has been possible to approximate the heat exchanging surface ratio around 35 W/m². For this, loop density in the wall has been calculated to be 2.66 m/m² with a 25 mm PE-Xa tube. The total number of installed loops is 580, with an average length of 78 m (thus, 45,270 m of tube). These tubes were installed with strict methods and proper coordination and collaboration of all parties, achieving a 100% success in tube installation, no defect was found in the whole network.



Figure 60. Loop and horizontal tubes connection at the crown beam in Sant Antoni's market

Once the loops were installed, it was time to connect them with horizontal pipes (PE-Xa tubes with 50x4.6 mm size). The scope of the design was to optimise the connections and a proper sectorisation of the hydraulic circuit. The design chosen was to divide the system into 16 groups of 36 double-loop circuits. Four heat pumps (4x150 kW) will be installed, thus a heat pump will be available for each 4 independent groups.

This simple design allowed a fast implementation. In two months all connections from the loops to the collectors were made. These connections are embedded at the crown beam of the wall, so they are safe for the remaining rehabilitation works. Thanks to the FHX a 25% of the market's energetic needs will be covered. The system has 600 kW of heating power and 450 kW for cooling.

6.2.2 Stakeholders and construction requirements

With regard to the stakeholders concern, maintenance and performance may be the most important topics as it has been explained that cost should not be. On the other hand, contractors concern will focus on design, sizing and the construction process.

6.2.2.1 Design and sizing

One of the key aspects of these heat exchangers is the right sizing. Even though it looks obvious, it is one of the most difficult issues and minimum performance levels are required by stakeholders to guarantee the investment recovery. Several factors are involved in the system performance, such as phreatic level and its behaviour, water flows, geology, local climate, annual and type of demand, depth, pipe length and kind of foundation.

A technical sizing guide would be helpful for designers and also for clients to understand easier what they need and what are the most suitable alternatives they have to achieve it. Currently it does not exist any at European level. However there are few national regulations which include some guidance for design. These will be mentioned at the regulation section. Following there is a recommendation for typical design parameters.

Table 20. Recommended design parameters for screen walls (Source: Adaptation from D3.1)

Design Parameter	Expected Range	Units
Wall		
Depth	Min 8	m
Width	Min 2	m
Thickness (nominal)	Min 45	cm
Pipe		
Lateral spacing (multiples of)	15-30	cm
Diameter	20 / 25 / 32	mm
Turn radius	Min 8D	mm
Number of layers	1 to 3	-

An important consideration in any thermal foundation scheme is redundancy. The geothermal design needs to include redundancy – which covers some potential non-performance of the system due to construction problems, blockages or design parameter selection. The thermal foundations are buried beneath the structure and any further work/ maintenance is impossible. In practice, the redundancy is set by the geothermal contractor and included in his tender, but this should be examined during the tender process to ensure adequacy for all parties.

The scheme redundancy should adequately include the risks of installation from the foundation contractor. This risk depends on the concreting technique, and the percentage of geothermal foundations on the overall layout. The construction work needs to deliver the designed criteria, and where this element of work has been through so many subcontract parties (that may not be in contract with each other) these risks must be adequately assessed to ensure the scheme is buildable and deliverable.

6.2.2.2 Construction

Another relevant issue is how it affects the building process. Implementing the system into a foundation has to be easy and fast. Otherwise it may increase the delivery time and risk the deadlines accomplishment. From the existing experience it is an easy process even though not as fast as expected due to the big amount of care that is needed to integrate properly pipe loops. It is supposed to become faster as experience and techniques get developed.

There are two main areas of the construction sequence that need to be addressed to deliver satisfactorily solution:

- The physical integration of the loops into various construction activities, avoiding damaging the loops. Loss of function may be caused by one of the following loop defects:
 - Abrasion or scratching
 - Creasing by excessive bending
 - Puncture, which may also allow ingress of ground materials that cause blockage to flow
- The integration of a FHX into the construction programme so as to minimise additional workforce, risks and cost

Thermal piling is a relatively new concept and of which there is as yet relatively little experience within in the industry. Any thermal pile or geothermal scheme should be considered early in the conceptualisation of the project, and in conjunction with the mechanical and electrical engineer.

Installing loops in diaphragm walls is only the start of the construction of a geothermal scheme which runs throughout the length of the build programme. The scheme bridges across the usual civil/mechanical divide. It affects the foundation contractor, progresses on to the ground worker, substructure contractor, main contractor, M&E contractor and finally finishes with the Building Management System (BSM) installer. The link throughout this chain is the geothermal contractor, and the important issue is to ensure dissemination of requirements across all interested parties.

HVAC system design should be finished before FHX works begin. FHXs will provide about 20% of the building energy demand, which can be approximated (for tertiary buildings) around 100 W/m², although with time efficiency is rising so demand is lowering. The BSM will be the responsible for energy selection between the geothermal and others kind of energy, it should always select the renewable energies produced by the building before other external sources.

Geothermal system can work coupled with the HVAC system or independently through inertial slabs, which are the most efficient system, but it more expensive than other alternatives. HVAC system needs to be designed to work with the geothermal system because not all the systems work properly with it, such as VRV. Another relevant issue for efficiency is how the heat transfer will be done; water/water is the most efficient choice.

It is vital that the roles and responsibilities are understood by each party and there is an understanding (which should be priced) as to how geothermal activity impacts on their work. It is recommended that a coordinator is appointed (preferably from the main contractor) to oversee interfaces, and ensure a smooth integration, which will ultimately lead to minimising of the programme and costs.

6.2.2.3 Maintenance and durability

Stakeholders will become the owner and manager of the infrastructure once built. It is logical they require minimum standards on security and durability.

Stakeholders concern about the security of the system in case something fails. It could compromise the building efficiency and it could even mean not meeting the demand. As there are no design guidelines for this work, additional care should be taken. In case of failure detection it is needed to isolate that part from the rest of the hydraulic circuit to avoid further failures or a general malfunctioning. So for safety reason there is a need to execute control on the network. Hence, the installation of following devices is highly recommendable:

- **Stopcocks:** It will permit local isolation when problems are detected or for maintenance. Installing stopcocks at each loop would allow very good local isolation
- **Safety valves:** It allows flow to exit the system if overpressure is detected

Another issue that has a relevant effect on failure isolation is how the system is designed. Heat pump and screens are connected by main pipes. From previous researches carried on at this project,

it has been found out that circuit length cannot be too long, otherwise it will not arrive enough pressure to the farther point. Consequently, parallel connections from the heat pump will be needed. Hence, the hydraulic circuit will have different branches (sectors) working at the same time which will be possible to close for maintenance or security reasons without any impact on the remaining sectors.

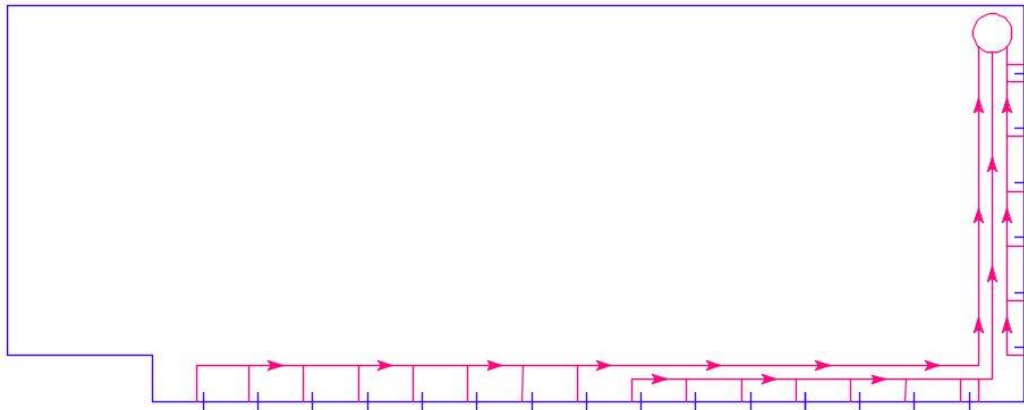


Figure 61. Sectors (3) example with two diaphragm walls and one heat pump

However, there is something even better than solving or isolating a failure: Prevent it through anticipation. This is carried out through system monitoring. Fundamental magnitudes and parameters involved in the system should be checked continuously, letting optimise the performance.

For foundation heat exchangers these variables are:

- Flow
- Pressure
- Temperature

Additionally, monitoring will become the best way to decide when a system cleaning is needed. For proper monitoring and cleaning the following devices are proposed to be installed:

- **Flow measurers:** flow information will be monitored through these elements
- **Manometers:** they will be located at key points to prevent failures and detect malfunctioning
- **Thermometers:** located at the input and output of each sector pipes of the heat pump if this one does not have its own. Additional thermometers can be included at each loop so as to check its performance
- **Filling and emptying system:** this system is fundamental for good maintenance of the heat exchangers. It will allow carrying on pre-launching tests, launching the system for first time and emptying and refilling it when cleaning is needed
- **Purge system:** each time the system is being launched or re-launched a purge will be needed to ensure there is no air inside that could interfere the right functioning. It may also be used whenever it is thought to be needed

So that it is possible to have proper control and good monitoring of the system it has to be accessible somehow even though it is buried on concrete. It is not necessary to have access to the whole pipe network but, at least, to the key points of it.

At the top of the screen wall (usually there will be a crown beam) a little hollow insertion must be included in order to save some free space for the connection between loops and horizontal pipes. This should be accessible by the side at all point or punctually at key points (depending on the client requirement), such as manometers or stopcocks. Following pictures about the design are shown:

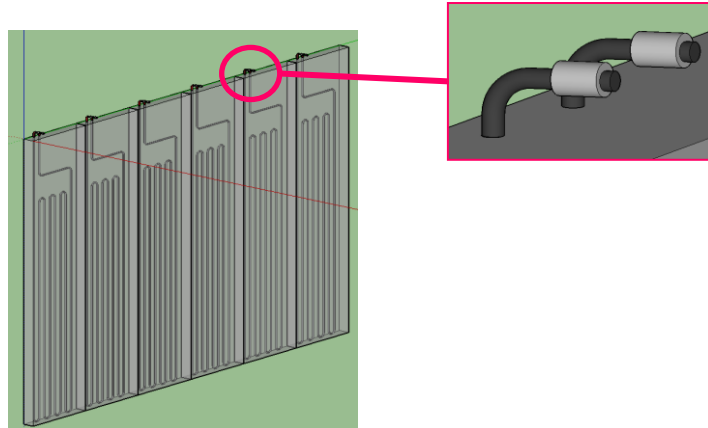


Figure 62. Diaphragm wall with six loops (left) and detail of loop connection (right)

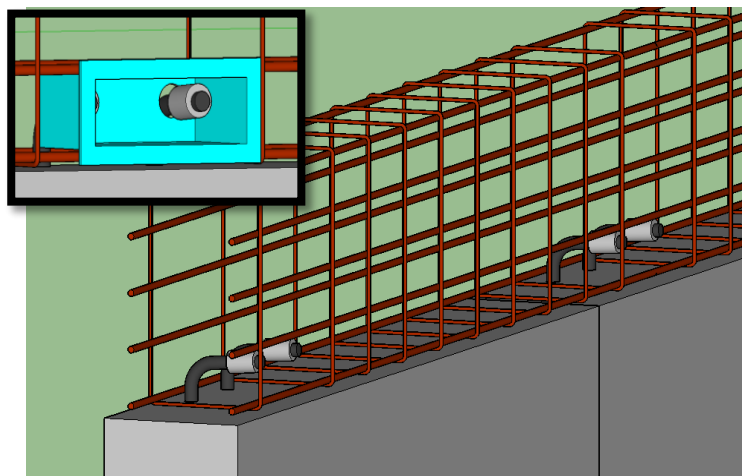


Figure 63. Crown beam reinforcement on top of the wall and detail of hollow insertion

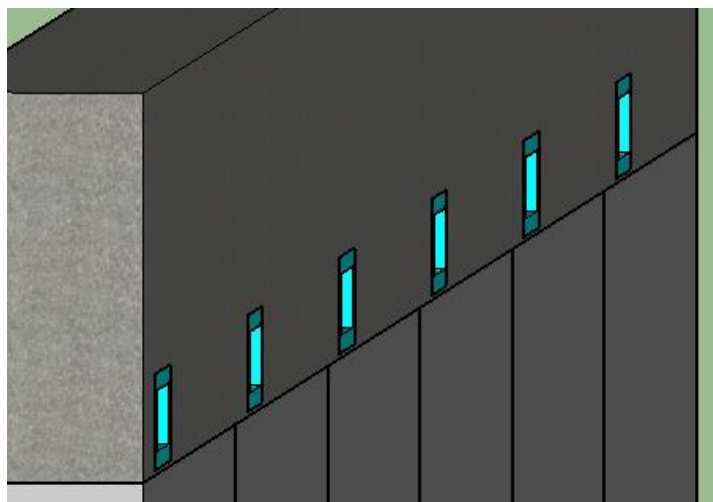


Figure 64. Finished Crown beam aspect for a thermo-active diaphragm wall

All mentioned before are the **standard requirements** that stakeholders should concern. Nevertheless, each client can decide to include more or less control devices and/or systems on the network corresponding to the risk they want to assume for the system managing.

Due to the nature of a thermo-active foundation e.g. lack of access and long design life, a very high level of quality and durability of all ground heat exchanger components is required. The most important areas of study are the following:

- Increase of stresses due to increased temperature (thermal expansion, differential bending moments, etc.)
- Reduced concrete cover (risk of increase cracking)
- Difficulties for concrete pouring that could affect structural capacity
- Risk of leakage

All this is currently being studied at the Task 3.6.

6.2.3 Regulation

With regard to regulations little has been found about the constructive part. Construction codes, such as Eurocode, do not include anything related to pipes, or objects, allocation inside foundations neither concrete (except reinforcement). Until it is taken into account, detailed structural calculus will be needed to ensure built elements safety as it has been proved that pipe insertion in concrete reduce its resistance in a range between 6-28%.

On the other hand, there are the energetic and geothermic regulations. Energetic regulations are usually local, but EU has been working with several directives and strategies to foster sustainable energies and nearly zero-energy buildings.

Due to the lack of European regulations, national regulations have been appearing for the last years, some of them give good advice for design or construction of FHX.

- VDI 4640 – It is one of the most well-known regulations for geothermal energy. However it does not contain detailed information for energy geo-structures
- SIA D0190 – Guidance for thermal piles, especially thermal capacity and construction. No details for other structures
- GSHPA Thermal Pile Standard – A best practice guide, also considering construction processes. Design guidance limited
- UNE 100715-1 – Design and monitoring guide for shallow vertical closed circuit systems. Limited information about construction

Additionally, buildings with FHX will be closer to achieve energetic certifications, which are highly valued by purchasers and suppliers because:

- suppliers can demonstrate to clients that their products and services meet the appropriate standards. This can enable companies to access and sell into new markets
- purchasers can trust third-party certified products and services to meet set standards, and therefore avoid costly mistakes and reduce risk

Two of the most worldwide best known certifications are:

- **BREAM**: It measures sustainable value in a series of categories (9), ranging from energy to ecology. Each of these categories addresses the most influential factors, including low impact design and carbon emissions reduction; design durability and resilience; adaption to climate change; and ecological value and biodiversity protection. Within every category, developments score points – called credits – for achieving targets, and their final total determines their rating;
- **LEED**: it includes a set of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighbourhoods that aims to help building owners and operators be environmentally responsible and use resources efficiently. There are 100 possible base points distributed across six credit categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation in Design.

Buildings can qualify for four levels of certification:

- Certified: 40–49 points

- Silver: 50–59 points
- Gold: 60–79 points
- Platinum: 80 points and above

6.3 Integration of geothermal systems with building installations

Energy efficiency in buildings

Lower energy usage in buildings is a vital step towards the reduction in the total use of primary energy, as in Europe buildings use approximately 40% of the energy. To improve energy efficiency in the built environment, the EU effectuated the Energy Performance of Buildings Directive (EPBD)⁶⁹. The EPBD furthermore present the way forward for the requirements for nearly zero energy buildings (nZEB) in 2020.

Other steps have been taken in the directives 2009/125/EC and 2010/30/EU providing guidance on eco design (ED) and on energy labelling (ELD). For example for chillers and hydronic heat pumps the Eurovent certification and labelling applies. The 2012 EED Directive (Energy Efficiency Directive) requires member states to establish long-term strategies for the renovation of the building stock.

Not only the EU, but also institutions like the IEA promote low/zero energy buildings and the use of renewable energy such as solar thermal and heat pumps.

Low/zero carbon and energy efficient heating and cooling technologies for buildings have the potential to reduce CO₂ emissions by up to 2 Gt g and save 710 million tonnes oil equivalent (Mtoe) of energy by 2050. Most of these technologies, including, solar thermal, CHP and heat pumps are currently available⁷⁰.

Low to zero energy buildings

Different low impact building concepts exist such as “Active House”, “Niedrigerenergiehaus”, “Passivhaus”, “zero energy house”. The common approach is very low energy requirements, and healthy living environment (lighting and ventilation) augmented with environmental aspects as sustainable construction (recyclable materials, low energy materials etc.).

The exact definitions of near zero energy buildings target levels may vary between the various EU member states, but the basic principles on the approach to the concept is similar. The shared strategy is the 20-20-20 approach. This is first of all setting maximum levels on the energy requirements of buildings and secondly to reduce the amount of primary energy to achieve this. The third step is to produce (a set %) the primary energy required from renewable sources.

The three measures, leading to a reduction in the produced amount of CO₂ emissions, require an integrated approach from the design perspective as they will interact.

Obviously, the limitation of kWh/m² in new and renovated buildings will be achieved by improving insulation, passive cooling and heating design, the use of higher quality materials and build quality⁷¹. The second step, limiting the amount of primary energy, very much benefits the use of heat pumps which have very large leverage (COP) on the primary energy consumed.

⁶⁹ Directive 2010/31/EU of the EU parliament and of the council of 19 May 2010 on the energy performance of buildings

⁷⁰ IEA Technology Roadmap, Energy efficient buildings: heating and cooling equipment, 2011

⁷¹ IEA Technology Roadmap, Energy efficient building envelopes, 2014

The third step, requiring a percentage of the primary energy to be from a sustainable and renewable source, cannot be provided by a heat pump, but the amount (from the renewable source) required will be very much reduced, making the most of the available sources and invested capital.

6.3.1 Geothermal heat pumps in low energy buildings

It is clear that heat pumps in general can play an important role in energy conservation in both new and renovated buildings, if the design approach and application of the heating, cooling and ventilation systems are able to utilise the capabilities of heat pumps. As shallow geothermal heat pumps are regarded as a sustainable and renewable technology, heat pumps can contribute in achieving member states targets in the reduction of primary energy usage and greenhouse gasses.

As the requirements for heating are much reduced in the new or renovated low/zero energy housing, low temperature heating from a (geothermal) heat pump can provide space heating. The demand for hot water (DHW) can also be serviced by the (geothermal) heat pump, much as has been the case in domestic housing that has been installed with heat pumps over the last 10 years.

With the increased insulation of the buildings a growing demand for ventilation and cooling will be called for. Especially the cooling can be done very efficiently through free cooling, using the geothermal loop of the geothermal heat pump system and directly using the available (low) source temperature. With the low energy usage in the building it seems likely that this source of cold will be sufficient. If not, the geothermal heat pump can be used for mechanical cooling.

From an article in the REHVA journal⁷² energy usage in zero energy buildings can be summarised into:

- High temperature space heating (55 °C – 80 °C)
- Low temperature space heating (35 °C – 55 °C), radiant heating
- DHW temperature (40 °C - 65 °C)
- Cooling energy for space cooling (7 °C – 19 °C)
- Cooling for dehumidification (< 12 °C)

Furthermore, it is anticipated that energy demand for space heating will drop to values of around 15 kWh/m². DHW production will be significantly greater than space heating requirements (at least 2x). Ventilation with heat recovery will be a requirement.

In the approach to zero energy buildings, heat pumps seem to be the preferred equipment option (all electric), however the DHW production is still regarded as a problem. Possibly integration with solar heating can resolve this, at least in certain geographical areas in Europe.

In the zero energy approach heat pumps are mentioned, often without indicating they are capable of using multiple energy sources such as air, waste heat or the ground and groundwater.

Of these, air source and ground source have the advantage of being available everywhere, waste heat is very specific and can be considered when this source is available and deemed attractive. For ground source applications of smaller installed capacities (< 50 kW) such as single homes, smaller apartment blocks or small communal systems, closed loop systems are the most likely candidate as they can be applied in all geologies and climates and they do not depend on the availability and quality of groundwater.

Air source and ground source heat pumps have specific advantages and disadvantages that will need to be considered when opting for this equipment:

Air source heat pumps:

- Lower investment cost (+)

⁷² Enrico Fabrizi, System for Zero Energy Housing; REHVA journal, November 2014

- Maintenance subject to air quality and exposition of air coil (-)
- Easy installation, well known technology, large choice in available equipment (+)
- Good efficiency performance heating at ambient $> 10\text{ }^{\circ}\text{C}$ (+)
- Loss of efficiency and capacity at lower temperatures $< 2\text{ }^{\circ}\text{C}$ (-)
- Loss of efficiency through defrosting cycles at temperatures $< 7\text{ }^{\circ}\text{C}$ (-)
- Strong electrical draw (on grid) at low temperatures through the use of electrical resistance heating (-)
- Mechanical cooling possible (+)
- Noise emissions from fans (-)
- Space requirements for outside condenser/evaporator coil/fan (-)

Ground source heat pumps:

- Higher first investment cost due to ground coupling (-)
- Lower maintenance cost (+)
- More complex design and installation more limited choice in equipment (-)
- High heating efficiency, using the ground's thermal buffering qualities (+)
- Free cooling potential with very high efficiency, using only the circulation pump (+)
- Thermal storage capability in the borehole (inject heat from cooling in daytime, extract heat for space heating or DHW production at night) (+)
- Introduce the thermal storage capability of the borehole in "smart grid" approach (+)
- No outside features (architectural benefit) (+)
- No noise emissions outside (+)

Some initial results monitoring low energy buildings using air source and ground (ground loop) as a source are mentioned in an article on the IEA annexes 32/40⁷³. From the results it can be seen that ground source heat pumps provide the highest energy efficiency (SPF), which is in the range of 3.3 to 3.8. Another finding is that the technically least complex concepts seemed to have the best performance.

6.3.2 GEOTeCH dual source heat pump

The dual source heat pump under development in the H2020 GEOTeCH project intends to combine the positive features of both air source and ground source heat pumps. A direct result will be the reduction in length of the ground loop, reducing first cost and making installation easier and quicker.

For the purpose of shallower and quicker installation, a special auger type drill rig and a new spiral soil heat exchanger is being developed within the Consortium. However, the GEOTeCH dual source heat pump can be used with conventional soil heat exchangers or with foundation heat exchangers.

Lower first cost is an important aspect, however other relevant qualities are:

- High energy efficiency through source selection
- Free cooling potential via ground loop
- Thermal storage potential via ground loop
- Noise emissions from air coil can be regulated (daytime – night-time)

⁷³ Carsten Wemhoener, Heat pumps for nZEB in IEA HPP annexes 32 and 40, REHVA journal, September 2014

- Advanced controls with remote access – network – smart grid
- To have the best performance

6.3.3 Conclusions

Current legislation is aiming to reduce greenhouse gas emissions by requiring new and renovated housing to be low/zero energy buildings. In all EU member states as well as worldwide, this process is under way and energy concepts are being developed for the specific requirements.

Currently it is envisaged that heat pumps will play an important role in space heating and DHW production as they have the capability to significantly reduce the requirement for primary energy.

Apart from projects with very specific conditions, the majority of the heat pumps to be used will either have air or the ground (closed loop) as their renewable source. Very distinctly ground source heat pumps have the disadvantage of higher investment cost, but the benefits of higher efficiency, free cooling potential, thermal storage and no noise emissions.

In the GEOTeCH project through the development of a dual source (air/ground) heat pump, the positive features and capabilities of both types of heat pumps are combined. This in principle makes the dual source heat pump very well suited for its role in the low/zero energy building of the near future.

7. COMPETITOR ANALYSIS: COMPETING SHALLOW GEOTHERMAL SOLUTIONS IN THE GEOTHERMAL EUROPEAN MARKET

In this chapter, an analysis of some commercial solutions competing with GEOTeCH purposes (specifically with the GEOTeCH spiral heat exchanger) is presented, focusing on manufacturers of borehole heat exchangers and heat pumps, given that these are the most developed products spread in the European geothermal market.

Regarding the drilling equipment, an overview of the competitive European market has been already provided within paragraph 6.1.

Identified competitors for vertical borehole heat exchangers are the following:

- Muovi Tech
- Jansen
- HakaGerodur

These competitors have been characterized, pointing out for each of them, some general info of the Company, description and main features of the solution(s) most interesting, applications and costs where available. Then, a comparative table will sum up main elements of all competitors.

Table 21. Characterization table for MuoviTech


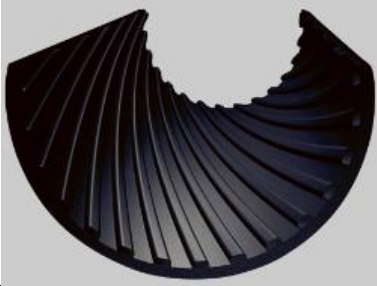


Company name: MuoviTech	
	<p>Company profile:</p> <p>MuoviTech is the European leader in products for geothermal energy, with own factories in Sweden, Finland, Poland, Netherlands, US and UK. Complete supplier of collectors, manifold chambers, distribution pipes, casing pipes, valves, fittings, and everything needed for installation until a heat pump / cooler.</p>
Solution type/name: TurboCollector®	
Description + picture	
<p>TurboCollector® is a patented pipe with fins inside. The fins provide a more turbulent flow and extract more efficient energy than a pipe with a smooth inside.</p>	
Applications:	
Used for both small residential and large tertiary buildings	
Performance and features:	
<ul style="list-style-type: none"> • Lower operating time for the circulation pump: • Lower borehole resistance with lower flow rate • Borehole length more than 200m • Reynolds Number less than 2000 • Big projects with many boreholes • High viscos fluid • High concentration of antifreeze • Cooling mode with oscillation loads 	
Cost	
<ul style="list-style-type: none"> • 5-10% faster payback time of the entire system • Longer life time for pump 	
References:	
<ul style="list-style-type: none"> • http://www.muovitech.co.uk • http://www.muovitech.com/?page=turbo2&show=1 	

Table 22. Characterization table for Jansen

Company name: Jansen	
	Company profile: Jansen, a tradition-rich company with its headquarters in Oberriet, Switzerland, develops designs, manufactures and markets precision steel tube and steel systems as well as plastic products for the building and other industries.
Solution type/name: JANSEN vertex premium corrugated pipe vertical ground loop	
Description + picture	
<p>Compared to ordinary ground loops, JANSEN corrugated pipe ground loops are much more efficient.</p> <p>The outer corrugations increase the surface area, while the inner corrugations produce turbulence in the brine flow, which greatly increases the energy transferred.</p> <p>In addition, the optimized corrugation design increases the resilience and bendability of the loop for safer and quicker installation.</p> <p>The textured surface guarantees an efficient seal of the vertical borehole. The ground loop is delivered to site ready for installation, only the site welding remains to be done.</p>	
Applications:	
Used for both small residential and large tertiary buildings	
Performance and features:	
<ul style="list-style-type: none"> • PE 100 RC • Different versions • Highest performance • Heating Cooling (free cooling), Air conditioning, Hot water production, Snow- and frost-free paved surfaces 	
Cost	
Not available	
References:	
<ul style="list-style-type: none"> • http://www.jansen.com/en/ • http://www.jansen.com/en/plastic-solutions/products/products/geothermal-systems/geothermal-systems-in-detail/p/jansen-powerwave-erdwaermesonden-69/ 	

Table 23. Characterization table for Haka Gerodur

Company name: Haka Gerodur	
	<p>Company profile:</p> <p>Leading manufacturer in the field of plastic extrusion. Haka AG was established in 1932 in St. Gallen and later merged with Gerodur AG, Benken SG. Haka Gerodur manufacture plastic products at three sites in Switzerland and Germany for the areas of heating & sanitary, piping systems, profiles and geothermal systems.</p>
Solution type/name: GEROtherm® Coaxial probes	
Description + picture	
<p>The GEROtherm® Coaxial probe with a welded or threaded head and an outer diameter of just 63 millimetres is a solution for small drilling depths of up to 50 metres. It is easy to install and efficient. It is quick and easy to connect the flow and return pipes of the coaxial probe with the certified SAVE distributors.</p>	
Applications:	
Small residential buildings	
Performance and features:	
<ul style="list-style-type: none"> • The individual solution up to 50 metres • Use near-surface geothermal energy (soil heat or soil cold) • The heat is transported by a liquid heat carrier such as a water/glycol mix (brine). 	
Cost	
Not available	
References:	
<ul style="list-style-type: none"> • http://www.hakagerodur.ch • http://www.hakagerodur.ch/upload/downloads/en/erdwaerme/DAV_15-xxxx_EWS-2113_Flyer_EWS_Bohrmeister_en.pdf 	

COMPETITOR ANALYSIS - Vertical borehole heat exchanger

Company	PRODUCT	APPLICATIONS		PERFORMANCE	FEATURES	BORHOLE LENGTH
		Small residential build.	Large tertiary build.			
Rehau	RAUGEO HELIX XXL Foundation heat exchanger	x	x	Material: PE-Xa Built-in safety; No welded joint; Temperature resistance up to 95°C; Telescopic design	New type of material PE-Xa ; Over 10 % improvement in the extraction output	10 – 20 m
Muovi Tech	TurboCollector®	x	x	Turbulent flow for the energy extraction	Patented pipe with fins inside	200 m
Jansen	JANSEN vertex premium corrugated pipe vertical ground loop	x	x	Material: PE 100 RC Resistance to crack Turbulent flow for energy extraction; Heating; Cooling (free cooling); Air conditioning; Hot water production; Snow- and frost-free paved surfaces	Corrugated pipe with increased surface area;	Ground loop lengths 10 m to 150 m
Haka Gerodur	GEROthem® Coaxial probes	x		Material: PE 100 RC Resistance to crack	With integrated <i>GEROthem®</i> System - modular system components	50 m

Regarding instead the **ThermoActivated Foundation** (TAF) solutions, the value chain for this product could be split in three different parts as follows:

Table 24. Value chain for Foundation Heat Exchanger

Foundation heat exchanger (FHX) product	Hybridization with conventional HVAC systems	Energy management systems
Material Suppliers	Engineering companies	Conventional BMS
REHAU	SACYR INDUSTRIAL	SAUTER
UPONOR	COMSA	CONTROLLI
STUWA	GEO THERMAL INTERNATIONAL	SIEMENS
Drilling companies (commodity)		
RADIOKROMSA		
TERRATEST		

For the heat pump solution developed within GEOTeCH project, some identified competitors are the following:

- Ciat
- ClimaVeneta
- Daikin
- Nibe
- Vaillant

Below tables of characterization for these last competitors are provided.

Table 25. Characterization table for CIAT



Company name: CIAT	
	CIAT offers a wide range of products in the fields of air conditioning, heating, refrigeration and air handling and provides expert guidance in sustainable solutions for comfort, air quality and energy optimisation
Solution type/name: GeoCIAT Access	
Description + picture	
<p>Heating only heat pump integrating the Geo-Cooling and Domestic Hot Water function as standard. GeoCIAT TM Access connects to vertical or horizontal sensors or groundwater thanks to the intermediate ITEX AGEO exchanger. Designed for low energy houses, GeoCIAT TM Access integrates all the components needed for the installation. It can be connected to emitters such as underfloor heating systems, comfort units (fan coil units, DIVIO dynamic radiators) or radiators.</p>	
Applications:	
For low energy houses	
Performance and features:	
<ul style="list-style-type: none"> • Heating capacity of 4.7 kW at 0/-3°C 30/35°C Cooling capacity of 6.12 kW at 10/7°C 30/35°C • Water/water • Scroll R410A compressor. • Brazed plates exchanger • DHW valve integrated as standard (300 litre DHW tank optional). • HomeConnect control with remote control station (remote I/O Homecontrol protocol) • Electronic expansion valve • Very high COP (coefficient of performance) (4.11 0/-3°C 30/35°C) 	
Cost	
Not available	
References:	
<ul style="list-style-type: none"> • http://www.ciat.com 	

Table 26. Characterization table for Clima Veneta



Company name: Clima Veneta	
	Company profile: <p>Climaveneta, a European leader in HVAC and HPAC with 40 years' experience, is in business for a purpose: to provide energy efficient heating, air conditioning and data center cooling solutions that enhance everyone's comfort, improve the profitability of a building and do not contribute to an increase in CO2 levels. They are the 1st European manufacturer and the 5th world group in central air conditioning.</p>
Solution type/name: BWR DHW2 0011-0121	
Description + picture	
<p>Reversible heat pump, total heat recovery, geothermal source 5,00 - 34,0 kW . The PRANA DHW2 heat pumps optimized for geothermal systems are reversible units for all year round operation in any operating mode: single cycle (air conditioning, heating, domestic hot water) as well as combined cycle in total heat recovery (domestic hot water together with cooling). Energy efficiency is highest during the summer cycle, when, thanks to the full recovery of the heat, the production of hot water is free.</p> <p>During the combined use, the DHW exchanger uses the temperature of the discharge gases to gets inside the accumulation sanitary water as high as 65° C. The advanced electronic regulation developed by Climaveneta ensures the highest operational flexibility, fast working condition a significant increase in the overall COP, which go hand in hand with electricity and space reduction.</p>	
Applications:	
PRANA DHW2 is used in residential, hotel and small sector buildings.	
Performance and features:	
<ul style="list-style-type: none"> • Advanced technological choices aimed at reducing energy costs of 50% when compared to traditional systems • High efficiency and low pressure drop stainless steel AISI 316 plate exchangers (at the domestic hot water side). It is positioned next after the compressor and it ensures the domestic hot water production • The low energy consumption ensures a 60% reduction of CO2 emissions than traditional systems based on fossil fuel. 	
Cost	
Not available	
References:	
<ul style="list-style-type: none"> • http://www.climaveneta.com • http://www.climaveneta.com/Country/US/Prana/Products/12/optimized-heat-pumps-for-heating/geothermal-reversible-heat-pumps-with-total-heat-recovery-optimized-for-heating/179/bwr-dhw2-0011-0121.html 	

Table 27. Characterization table for DAIKIN



Company name: DAIKIN	
	<p>Company profile:</p> <p>Daikin was founded in 1924 and has become a leading manufacturer of air conditioning equipment.</p>
Solution type/name: DAIKIN altherma	
Description + picture	
<p>Low temperature heat pump-Integrated heating and hot water unit in one system.</p> <p>Build to withstand most severe winter conditions.</p> <p>Custom-made product for very low heat loads.</p> <p>Max capacity > heat load > min capacity: partial load compressor will reduce its frequency delivering the capacities required by the house, with high operating efficiencies.</p>	
Applications:	
For new builds, as well as for low-energy houses	
Performance and features:	
<ul style="list-style-type: none"> • Liquid injection to avoid too high discharge temperatures when high water temperatures are required at low outdoor temperatures • Plate heat exchangers to maximise the heat exchange surface • The compressor can modulate down to low frequencies to offer the highest efficiencies over the relevant temperature range. • Factory-mounted high efficiency circulating pump already qualifying for future regulations (ErP2015) with an A-energy label ($EEI \leq 0.23$) • COP (coefficient of performance) of up to 5.04 is reached 	
Cost:	
Not available	
References:	
<ul style="list-style-type: none"> • http://www.daikin.com • http://www.recair.fi/pdf/Daikin-Altherma-tuoteluettelo.pdf 	

Table 28. Characterization table for NIBE

Company name: NIBE





	<p>Company profile:</p> <p>NIBE is a Global Group contributing to a more sustainable world with solutions for indoor climate and comfort, as well as components and solutions for measuring, controlling, and electric heating. NIBE has over 60 years of experience in manufacturing products for both residential and commercial use. It all began in southern Sweden, in the province of Småland. Today, NIBE has operations and sales on five continents.</p>
<p>Solution type/name: NIBE™ F1345</p>	
<p>Description + picture</p>	
<p>The NIBE F1345 is one of a new generation of heat pumps, designed to supply heating and tap water needs in a cost-effective, environmentally friendly way. The new NIBE F1345 is more flexible than ever and with its advanced control system it can be adapted to several system solutions. Has to large scroll compressors. In systems with up to nine heat pumps and with a wide range of accessories e.g. for control of oil, gas, pellet fired or electric boilers, you find the full flexibility for your installation. NIBE F1345 is equipped with a multicolour display, multilingual support and simply upgradable software via the built in USB port. NIBE F1345 is manufactured in four sizes; these feature outputs of 24, 30, 40 and 60 kW.</p> <ul style="list-style-type: none"> • High flow temperature (up to 65°C) – means great installation flexibility • The heat pump consists of two units which contain less than 3 kg refrigerant per unit • Scheduling (indoor comfort, hot water and ventilation) • Docking possibility – up to 540 kW in cascade 	
<p>Applications:</p>	
<ul style="list-style-type: none"> • Commercial buildings with high heat demands NIBE F1345 is a ground source heat pump for multi-occupancy buildings, industrial premises, churches and other buildings with a large heat demand. 	
<p>Performance and features:</p>	
<ul style="list-style-type: none"> • A ground source heat pump • High COP – provides savings and shorter payback times 	
<p>Cost</p>	
<ul style="list-style-type: none"> • Can lower energy cost up to 80% 	
<p>References:</p>	
<ul style="list-style-type: none"> • http://www.nibe.eu • http://www.nibe.eu/Products/Ground-source-heat-pumps/NIBE-F1345 	

Table 29. Characterization table for Vaillant

Company name: Vaillant	
	<p>Company profile:</p> <p>Founded in Remscheid 140 years ago, the Vaillant Group today supplies innovative hot water, room heating and cooling solutions to countries all over the world. Company develops high-efficiency products that save energy and conserve resources.</p>
Solution type/name: Geo THERM	
Description + picture	
<p>Heat pumps take up to 75 % of the required energy from the environment. Only 25% of the energy has to be added in the form of electricity.</p> <p>It extracts energy using a geothermal probe or a ground collector and supplies heat in winter, passive cooling during summer plus hot water at all times.</p> <p>It extracts energy using a geothermal probe or a ground collector and supplies heat in winter, passive cooling during summer plus hot water at all times.</p> <p>There is an integrated hot water cylinder, likewise an auxiliary electric heater and a weather-compensating controller.</p>	
Applications:	
Use in single, double, or multi-family houses	
Performance and features:	
<ul style="list-style-type: none"> • Ground source • Emission-free • Efficient: up to 75 % of the energy comes from the environment, only 25 % must be added in the form of electricity • Hot water cylinder, auxiliary electric heater and a weather-compensating controller • The output range from 6 to 17kW supplies single and dual-occupancy houses • The output range from 22kW supplies for multi-family houses, commercial properties and other buildings with up to 400m² floor space 	
Cost	
<ul style="list-style-type: none"> • Simple high-value technology with low maintenance and a long service life 	
References:	
<ul style="list-style-type: none"> • https://www.vaillant.com • https://www.vaillant.com/what-we-do/technologies-to-make-people-feel-good/how-different-technologies-work/heat-pumps/index.en_gb.html 	

COMPETITOR ANALYSIS - Dual source heat pump

Company	PRODUCT	ENERGY SOURCE	APPLICATIONS		PERFORMANCE/ COP(coefficient of performance) / EER (Energy efficiency ratio)	POWER		COMPRESSOR/ REFRIGERANT
			Small resident. build.	Large tertiary build.		Heating	Cooling	
Ciat	GeoCIAT Access	Water / water heat pump	x		Heat pump integrating the Geo-Cooling and Domestic Hot Water function as standard. COP of 4.11 at 0/35°C	4.7 kW at 0/35°C	6.12 kW at 0/35°C	Hermetic Scroll TOR type Compressor - Refrigerant R410A
Clima Veneta	BWR DHW2 0011-0121	Ground source	x	x	Reversible heat pump; single cycle (air conditioning, heating, domestic hot water) as well as combined cycle (domestic hot water together with cooling); Significant increase in the overall COP	5- 34 kW	5- 34 kW	Hermetic Scroll type Compressor equipped with the crankcase heater and thermal protection
Daikin	DAIKIN altherma	Ground source	x		Low temperature heat pump-Integrated heating and hot water unit in one system COP of up to 5.04 is reached EER of 3.37	4-16 kW		Low-capacity: 4-8kW range is equipped with swing compressor High-capacity: 11-16kW range is equipped with scroll compressors

Nibe	NIBET TM F1345	Ground source		x	Heating and tap water needs; COP of up to 4.65 at 0/35 °C.	24 – 60 kW		Two large scroll compressors; Refrigerant R 407 C or R 410 C
Vaillant	GeoTHERM	Ground source	x	x	Evaporator with injection system for increased heat transfer; Weather compensated energy balance control; Maximum flow temperature of up to 62°C for domestic hot water; Multi-stage Sound Insulation (MSI) for ‘whisper quiet’ operation: COP of 4.2	6 – 46 kW		Refrigerant R 407 C
Ochsner	Various types	Ground-brine or Water or Air		x	Heating and cooling EER 2.5 - 6.4	100-960 kW		Semi-hermetically sealed screw Compressor – Refrigerant R410A

8. KEY SUCCESS FACTORS OF GEOTECH SOLUTIONS

In the National Renewable Energy Action Plan (NREAP) from Member States⁷⁴, which indicates the pathways to reach 2020 renewable energy targets for CO₂ emissions reduction, is clearly reflected that exploitation for shallow geothermal energy must grow significantly, in the short and medium term.

Shallow geothermal heat pumps (Ground Source Heat Pumps = GSHP) systems can play a key role in this context, reducing CO₂ emissions.

The official statistics provided by EurObserv'ER⁷⁵ corresponding to the last three years available (2012, 2013 and 2014) show the current number of **GSHP installations in the EU** (Figure 65), reaching a total amount of **1.3 million in 2014**.

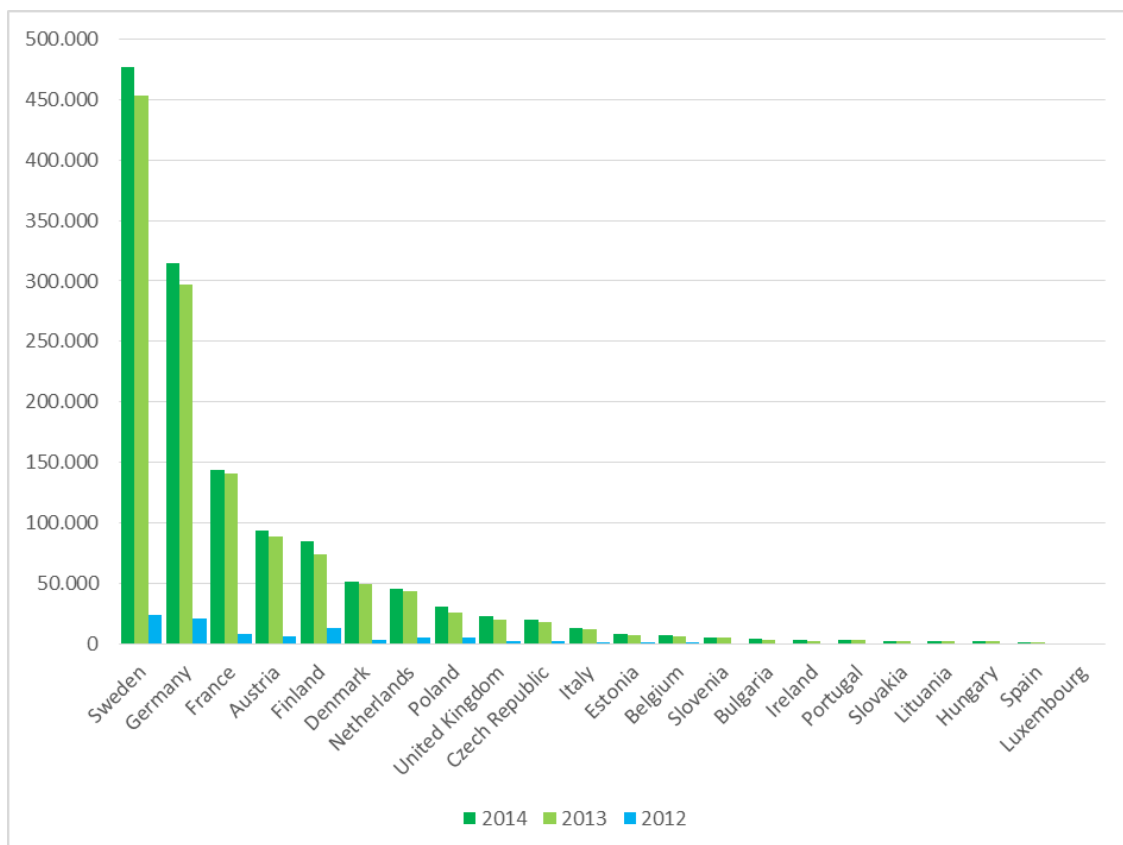


Figure 65. Total number of GSHP in operation in the EU

Mapping out the 2020 trends for the renewable energy output from HPs is a hard task, because measuring renewable energy output from machine bases is problematic without specific studies made by each Member State. Hence the projections are based on questionnaires filled out by the national experts, part of surveys carried out as a part of Eurostat SHARES (Short Assessment of Renewable Energy Sources) project.

EurObserv'ER assesses the renewable energy output produced by HPs at approximately 8 Mtoe in 2014, and estimates that it could be as much as 12.7 Mtoe for 2020 adopting a conservative scenario. EurObserv'ER considers that the current market trend is just in line with the NREAP (National Renewable Energy Action Plan) previsions (Figure 66).

⁷⁴ NREAP data from Member States. European Environment Agency, 2011

⁷⁵ Heat Pumps Barometer - EurObserv'ER 2013-2015

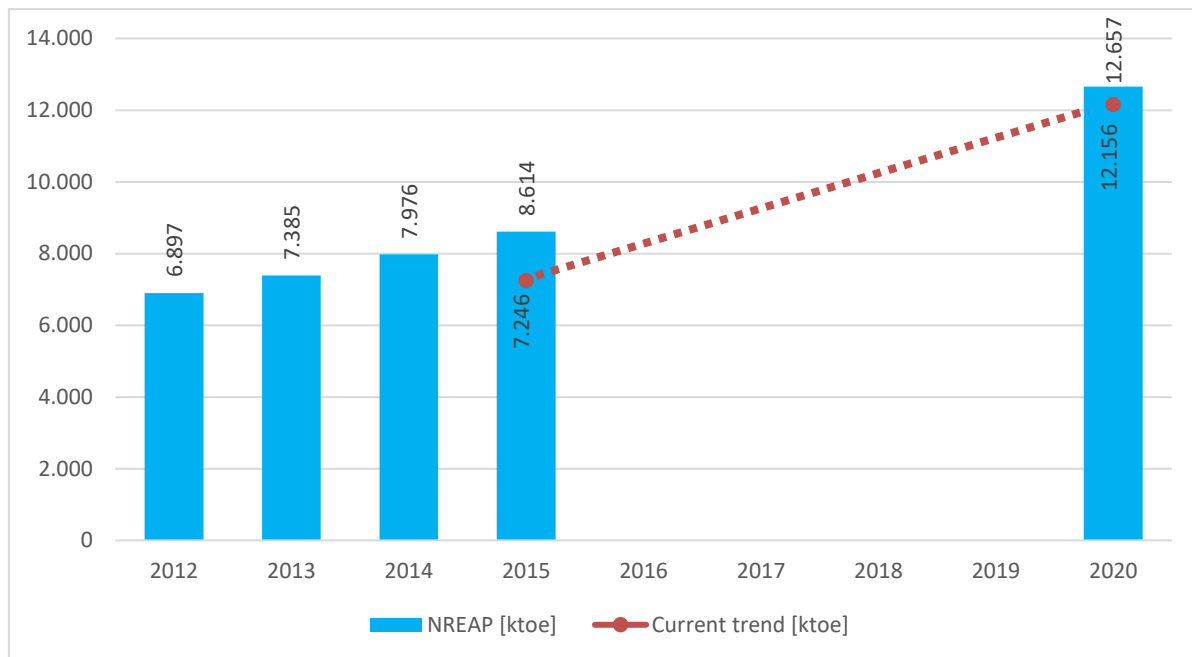


Figure 66. Actual trend from GSHPs compared with the NREAP⁷⁶

However, it is also clear that the current state of uptake of shallow geothermal energy in the EU varies widely across the different countries. Consequently, achieving the targets set in the NREAP for uptake of shallow geothermal heating and cooling technology implies significant industry growth in many Member States, besides a certain number of technical, economic and socio-technical challenges to be met.

According to the JRC (Joint Research Centre)⁷⁷, the **most important challenges** in this field are as follows:

ESTIMATE THE RESOURCE POTENTIAL

It is well known that the heat stored in the Earth's crust is very high. However, the estimation of heat in place would benefit from more direct measurements. An extensive drilling campaign has been proposed by the European Geothermal Energy Council (EGEC) and would bring benefits to the geothermal sector in two ways: first, it would facilitate a more accurate estimate of the resource potential in Europe by establishing temperature gradients and heat flows in the crust and providing a better picture of the geology in the area. Second, due to increased drilling activities in the sector, knowledge and experience would be accumulated quicker.

DRILLING RISKS AND COSTS

Today, drilling costs often constitute more than half of the cost associated with construction and commissioning of a geothermal power plant. Drilling into hydrothermal reservoirs includes drilling into highly heterogeneous materials where hard rocks may alternate with fractures and where complete loss of circulation and collapsing geological formations may be experienced. Loss of circulation can lead to extensive losses of drill muds and cements. Collapsing formations may prevent movement of casings and, in worst cases, lead to the necessity of cutting the drill string, causing the bottom hole assembly, collars and parts of the

⁷⁶ EurObserv'ER, 2015

⁷⁷ 2014 JRC Geothermal Energy Status Report, Institute for Energy and Transport, European Commission, 2015

drill string to be left in the well⁷⁸. An intensive drilling campaign provides the opportunity to develop and test novel drilling technologies in a reasonably short period of time and better direct resource potential. Therefore, drilling development projects are highly complementary.

STIMULATION

Existing stimulation methods need to be refined to increase the rate of success, to improve predictability of results, to remove well and formation damage, to develop and prop fracture networks and to reduce environmental hazards as pollution of aquifer. Research should focus on understanding the underlying processes leading to improved permeability and develop concepts to minimise unwanted side effects.

Currently, building environmental systems that employ shallow geothermal technology are arguably the most efficient in meeting building heating and cooling demands. They are often the second most cost effective solution in extreme climates (after co-generation), despite reductions in thermal efficiency due to ground temperature (the ground source is warmer in climates that need strong air conditioning, and cooler in climates that need strong heating)⁷⁹.

In nearly all Member States, their application can result in the lowest consumption of primary energy resources in delivering heat for buildings of all types. Furthermore, GSHP technology offers the best opportunity for both maximising the benefits of renewable electricity sources and reducing energy consumption from conventional power sources for heating applications⁸⁰.

To illustrate cost assessment and economic efficiency of GSHP systems, an usual but representative example will be presented, namely a family house of 150 m² (Figure 67).

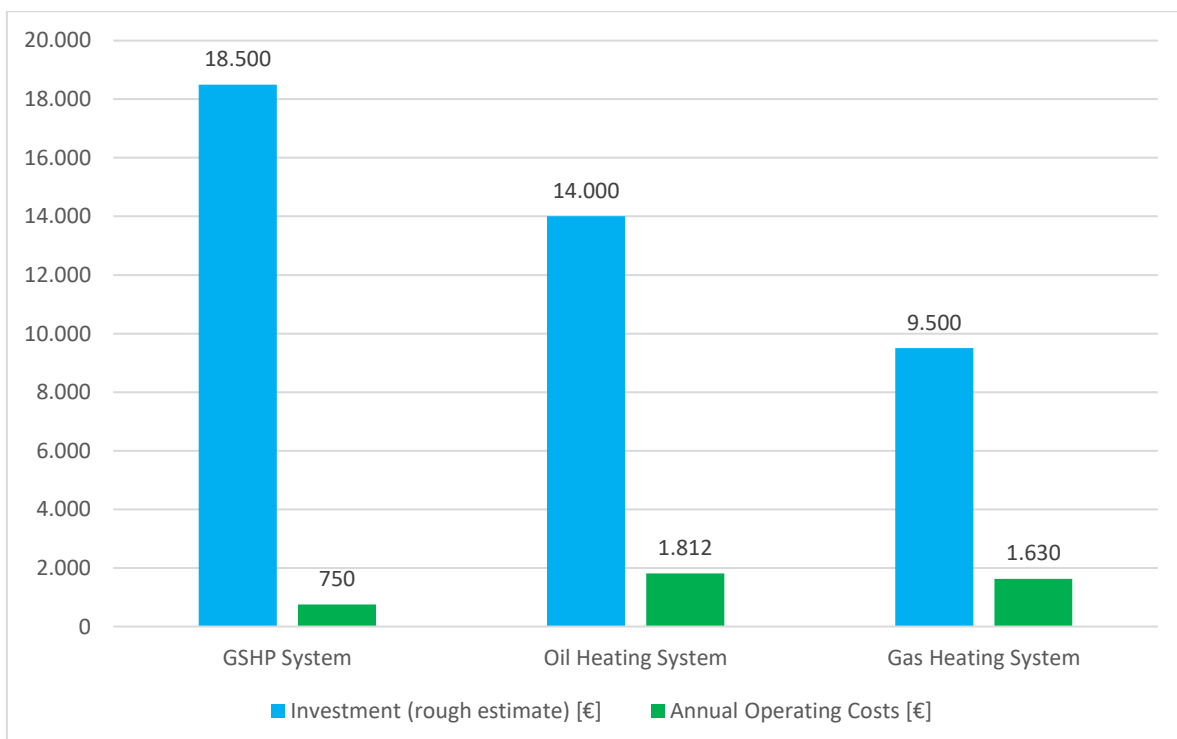


Figure 67. Results-Comparative investment costs for different Heating Systems^{81 82 83}

⁷⁸ Sveinbjornsson & Thorhallsson, 2014

⁷⁹ Bloomquist, R. Gordon. Geothermal Heat Pumps, Four Plus Decades of Experience, 2009

⁸⁰ Ioan David, Camelia Ștefănescu, Ioan Vlad. Efficiency Assesment of Ground-source Heat Pumps in Comparison with Classical Heating System, 2015

⁸¹ Ioan David, Technical University Darmstadt, SGEM, 2015

⁸² Required data for an approximate calculation: (1) Building type: family house 150m² floor area; (2) Energy performance in accordance with EU standards (Energy savings regulation, Low-energy house, Top Low-

Hence, the geothermal probe system saves annually to oil heating 1,062 € and compared to gas heating about 880 €. Thus, the GSHP system pays for itself (payback) accordingly compared to an Oil-heating system within approximately 4.2 years, and compared to Gas-heating system 10.2 years.

The GEOTeCH project will contribute to meet the aforementioned major challenges by advancing in the development of innovative geothermal heating and cooling technologies and new whole-system solutions, besides demonstrating their effectiveness.

Specifically, GEOTeCH project focuses on four key aspects, whose specific innovation will be illustrated in the following subchapters.

8.1 Borehole Drilling Technology

Current Context

The current mainstream drilling technologies being used in Europe for the installation of vertical borehole heat exchangers are known as Down the Hole Hammering (DTH) for drilling in consolidated formations and Rotary Direct Circulation (RDC) for drilling in sedimentary and unconsolidated formations. Other drilling technologies such as sonic drilling, rotary reverse circulation, direct flush or shell and auger, are used as well to a less extent.

A comparison between all the alternatives among drilling technologies, showing their main features, is presented in the Table 30:

Table 30. Current Geothermal Drilling Methods in the EU

Borehole Drilling Technology	Application	Description	EU market relevance
Down the Hole Hammering (DTH)	Rock Consolidated soil	In DTH drilling, the drill string rotates while the drilling hammer continuously strikes down into the rock. Inside the hammer, a piston powered by compressed air gives the drill bit its striking power. This combined with the rotational movement means that the rock is crushed in a very efficient manner. Because the power transfer takes place down in the hole when the piston strikes directly at the bit - hence the drilling method's name - there is minimal energy losses along the drill string. DTH is a reliable method that drills stable holes with exceptional straightness.	High
Rotary Direct Circulation (RDC)	Sedimentary Unconsolidated soil	Rotary drilling does not require force in the form of a hammer blow. Instead, rotary drilling creates a very large compressive force along the drill string, in combination with rotational movement. There are currently two types of rotary drilling: - <u>Rotating cutting drilling</u> : a common method for drilling	High

energy house); (3) Heating demand: calculated in kWh/year and compared to 1m² net used living space; (4) Heating load: calculated in W. Heating load and heating surfaces heat source designed

⁸³ www.heiz-tipp.de/ratgeber

		<p>in softer materials such as sand, clay and soft rock. A drag bit is used instead of a normal drill bit. This bit has 2-4 wings with carbide tips that cut up the material by pressure and rotation.</p> <p>- <u>Rotating crushing drilling</u>: it uses a tri-cone drill bit. This drill bit has tungsten carbide bits designed for drilling in harder materials. The bits crush the rock by means of pressure and rotational movement.</p>	
Sonic Drilling	All types of soil and rock	<p>Sonic drilling is a soil penetration technique that applies the principles of Bingham's findings on the fluidisation of porous materials in combination with the laws of inertia.</p> <p>A sonic drill is more precisely identified as a rotary vibratory drill. It is capable of high drilling speeds as well as accomplishing tasks, such as continuous coring that cannot be carried out by any other equipment.</p>	Low
Rotary Reverse Circulation	All types of soil and rock	<p>The RC method employs dual wall drill rods that comprise an outer drill rod, with an inner tube located inside the drill rod. The inner tubes overlap and seal on the tube below with O-rings when the drill rods are screwed together. These inner tubes provide a continuous sealed pathway for the drill cuttings to be transported from the bit face to the surface.</p> <p>The circulating medium, in most cases high-pressure air, enters the annulus between the rod and tube via the air swivel, which is normally part of the drill string, or sometimes mounted on top of the rotation head. The air travels down the annulus to the drilling tool, which is usually an RC hammer, or can be a blade bit or tri-cone roller bit.</p> <p>The air powers the drilling tool and the exhaust air carries the cuttings. In RC drilling the cuttings are returned to the surface through the inner tubes in the drill string and rotation head.</p> <p>Once through the rotation head, the air and cuttings comprising the sample change direction at the discharge blast box and are transported through the sample hose to the cyclone. The cyclone slows the sample, separates it from the air, and collects it.</p>	Low
Direct Flush	Unconsolidated soil	<p>The wet drilling method uses drilling tools to loosen and excavate the soil materials and it requires a flushing stream for transportation. Cutting tools like tri-cone bits, roller bits or under-reamers are used. When using the direct flushing method, bentonite or polymer suspension is pumped down to the piles tip through the hollow drilling rod. The suspension is then raised up to the piles top in the annulus between drilling rod and borehole wall. This method is most suitable for smaller borehole diameters.</p>	Low

Shell and Auger	Soft soil	This technique, also called “light percussion drilling”, involves driving lengths of steel casing into the ground to stabilise the sides of the borehole as soil is removed using shell and clay cutter tools. Boreholes are usually advanced using 150 mm or 200 mm casing, although holes sizes can be increased to 300 mm diameter if required.	Low
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GEOTeCH Innovation

The drilling technique proposed is a dry-drilling technique based on a hollow stem auger system. The hollow stem auger serves as a casing and, as no additional casing is needed, borehole stability is guaranteed.

The method is applicable in a variety of geological conditions and, as the borehole stability is guaranteed and water circulation, density and pressure are not an issue, it requires less specialist knowledge on the part of the operator, increasing the level of quality that can be routinely achieved.

This concept can be used to drill boreholes up to 50 m deep in the sedimentary geologies that dominate urban areas in a large part of Europe.

Current Identified Drawbacks and GEOTeCH Key Success Factors

Table 31 shows current Identified Drawbacks for each drilling technology and GEOTeCH Key Success Factors able to overcome limits of actual commercial solutions.

Table 31. Comparison between systems currently in use in the EU and the GEOTeCH drilling system

Borehole Drilling Technology	Identified Drawbacks	GEOTeCH Drilling System Key Success Factors
Down the Hole Hammering (DTH)	<ul style="list-style-type: none"> • Noise issues (compressor) • Health & safety with pressurised air (12-20 bar) • Management of arising borehole • Potential borehole instability • Build-up of air pressure in formation • Site cleanliness, working conditions 	<ul style="list-style-type: none"> • Applicable in a variety of geological conditions • Requires less specialist knowledge on the part of the operator
Rotary Direct Circulation (RDC)	<ul style="list-style-type: none"> • Water usage in drilling process • Management of arising sludge/mud • Use of drilling fluid additives • Borehole instability • Site cleanliness, working conditions 	<ul style="list-style-type: none"> • Increases the level of quality that can be routinely achieved • It can be implemented in developing markets more easily
Sonic Drilling	<ul style="list-style-type: none"> • High drilling waste production • Very high vibration • Risk of causing fractures in hard bedrock • Cost ineffective • Noise issues 	<ul style="list-style-type: none"> • Compact equipment capable of working in restricted areas • Very low noise and pollutant emissions

	<ul style="list-style-type: none"> • Contamination risk 	<ul style="list-style-type: none"> • Quick, controlled and reliable installation of the heat exchanger • High stability of borehole capable of drilling near foundations and structures • Low clean water usage • Quick and cheap equipment mobilisation
Rotary Reverse Circulation	<ul style="list-style-type: none"> • High drilling waste production • Inefficient in difficult drilling conditions 	
Direct Flush	<ul style="list-style-type: none"> • Very high waste of clean water • Contamination risk • High drilling waste production 	
Shell and Auger	<ul style="list-style-type: none"> • Auger drilling is restricted to generally soft unconsolidated material or weak weathered rock 	

Moreover, sonic drilling, rotary reverse circulation, direct flush or shell and auger have a standard depth between 80 m and 150 m. Operating so deep, these techniques can only be properly used in designated drilling areas present in well-managed and organised sites of sufficient size.

8.2 Vertical Borehole Heat Exchanger Devices

Current Context

Geothermal systems include a wide variety of designs and operations. These systems may be described by various terms:

- Horizontal Loops
- Vertical Loops
- Pond Loops
- Open loops

All these systems include the same basic operation, circulating a fluid that is in contact with the earth through a heat exchanger, in order to extract heat from the surroundings for heating a structure or to reject heat to the ground when cooling a structure.

The GEOTeCH project focuses on the development of a spiral type concentric heat exchanger that in specific circumstances can provide an alternative to the most widely applied system of vertical borehole heat exchanger in the EU, namely the vertical U-loop system. The U-loop, also known as a closed loop system consists of piping installed in a borehole drilled in the earth through which a heat-transfer fluid circulates. Through pipework the vertical loop is connected to the heat pump. The circulating heat transfer fluid does not come in direct contact with the earth.

Closed-loop systems can be designed to meet a wide range of heating and cooling needs, from those of an individual house to the ones of very large commercial buildings.

The straightforward U-loop, or double U-loop systems, still dominates the market. They are usually made of PE100⁸⁴, having a diameter/wall thickness ratio of 11 (SDR11), and their pressure class is usually PN16.

Following, indicative geometric configurations and average properties are shown in the Table 32.

⁸⁴ Polyethylene Pipe of Minimum Required Strength (MRS) equivalent to 10 MPa, in accordance with ISO 12162

Table 32. Geometric configurations and material properties for the BHE ⁸⁵

Components	Parameters	Specifications
BHE configurations	Borehole	<ul style="list-style-type: none"> • Borehole depth: 80 m • Borehole distance: 6 m • Drill-hole diameters: 121 mm, 165 mm and 180 mm
	U-Pipe	<ul style="list-style-type: none"> • Pipe type: Double-U • Pipe shank spacing: 70 mm • Pipe outer diameter: 32 mm • Pipe wall thickness: 3 mm
BHE properties	Grouts	<ul style="list-style-type: none"> • Grouting thermal conductivity: 2.35 W/m/K • Volumetric water content: 31% • Grouting density: 1.8 g/cm³
	U-Pipe	<ul style="list-style-type: none"> • Pipe thermal conductivity: 0.42 W/m/K
Fluid properties	Heat carrier fluid	<ul style="list-style-type: none"> • Fluid density: 1.11 g/cm³ • Fluid volumetric thermal capacity: 3.8 MJ/m³ /K

GEOTeCH Innovation

The innovation of vertical borehole heat exchanger technologies developed within GEOTeCH project consists on a heat exchanger product, supported by an innovative drilling method and a newly developed dual source heat pump. An integrated approach using all 3 mentioned aspects will allow lower cost drilling and long term high efficiency performance of the GSHP installation.

Moreover:

- New spiral coaxial heat exchanger will allow better thermal performance, especially at low flow conditions
- Dry auger drilling technique will allow quicker overall installation of novel heat exchanger, while retaining installed quality (thermal and environmental)
- Dual source heat pump using intelligent controls will use the ground heat exchanger or outside air as a source depending on building demand, available source temperatures and calendar function

Current Identified Drawbacks and GEOTeCH spiral heat exchanger Key Success Factors

Table 33 shows a comparison between systems currently in use in the EU and the GEOTeCH spiral/co-axial BHE proposed:

⁸⁵ Jin Luo, Joachim Rohn, Manfred Bayer, Anna Priess. Thermal Efficiency Comparison of Borehole Heat Exchangers with Different Drillhole Diameters, 2013

Table 33. Current BHE Systems Drawbacks Vs GEOTeCH Key Success Factors

Current BHE	Identified Drawbacks	GEOTeCH BHE System Key Success Factors
<p>U-loop Double U-loop</p>	<ul style="list-style-type: none"> • Little opportunity to improve thermal resistance or hydraulic resistance. • High thermal resistance at laminar flow conditions • Considerable thermal interaction between up and down pipes • Often designed with to high pressure losses (install depth relatively great) • Greater installation depth, potentially intersecting multiple aquifers and drilling difficulties. • Standard installation type by mud/air rotary drilling, large water usage and potential for cross contamination. 	<ul style="list-style-type: none"> • Improved thermal performance at laminar flow, allowing designs to be delivered using multiple shorter boreholes. • Improved hydraulic performance and lower pump energy costs/emissions. • Improved short-timescale response and enhanced thermal storage capacity. • Complete integration with the innovative dry auger-based drilling technology. • HX installation within casing, reduced risk of failed installation or damage

8.3 Advanced Design and Implementation of Foundation Heat Exchangers

Current Context

Ground source energy can be efficient and economical providing heating and cooling to buildings, especially where the heating load in winter is similar to the cooling load in summer.

Heat exchange with the ground can be achieved via boreholes or via thermo-active foundations.

In thermo-active foundations, foundation piles, also referred to as "thermal piles" or as "energy piles", are used as heat exchangers for supplying low temperature heat to heat pumps.

Fluid is circulated through pipes within the heat exchanger inside the concrete of piled foundations. However, there remain few validated design approaches for determining the heating and cooling capacity of pile heat exchangers. There are also concerns that inappropriate operation may cause extreme temperatures to be developed in the ground, leading to loss of geotechnical performance. As a result, most current designs are conservative and do not fully utilise the thermal capacity of the pile-ground system. Experimental results are showing the pile concrete to be making a substantial contribution to the short term storage of thermal energy⁸⁶. This is significant, as most design methods assume that the pile concrete merely acts to transfer heat to the surrounding ground. This heat storage also acts to protect the ground against larger fluctuations in the fluid temperature and is therefore beneficial for geotechnical performance.

⁸⁶ Loveridge F., Powrie W. Performance of Piled Foundations Used as Heat Exchangers, 2013

Besides, in the sector of thermo-active foundations, a number of promising innovations, such as the use of thermally enhanced concrete, have been analysed using calibrated high detailed 3D-FEM⁸⁷.

GEOTeCH Innovation

Foundation heat exchange technology will be optimised and better design approaches will be developed. Key issues, not currently matured, will be faced and improved, such as:

- Transport
- Material Handling
- Quality Control
- Safety risk
- Coordination with HVAC systems design and operation
- Structural design integrating heat exchangers inside
- Payback
- Life-cycle

The **tertiary building sector** is a **strategic key target for GEOTeCH**. Specific heat exchanger technology will be designed and implemented for this architectural typology, considering its special elements, conditions and scale.

Foundation structures such as piles, screen walls and basement slabs **will become effective geothermal heat exchangers** when implemented with embedded heat exchange devices.

This approach is often the only feasible way to implement geothermal heating and cooling in dense urban locations which do not have enough land available outside the building footprint to install vertical borehole heat exchanger arrays.

It has to be considered that this heat exchange technology will generate important savings because it avoids borehole geothermal drilling, since the structural foundation excavations would also serve for geothermal heat exchange.

⁸⁷ Finite Element Models

Current Identified Drawbacks and GEOTeCH Key Success Factors

Table 34 shows a comparison between foundation heat exchangers systems currently in use in the EU and the GEOTeCH innovative systems proposed.

Table 34. Current Foundation Heat Exchanger Systems Drawbacks Vs GEOTeCH Solutions Key Success Factors

Current Foundation Heat Exchangers	Identified Drawbacks	GEOTeCH Foundation Exchanger Systems Key Success Factors
Thermal Piles (or Energy Piles)	<ul style="list-style-type: none"> • Design methods are either risky or slow to execute and so not suitable for early design stages, because they are based on very simplified approaches or make use of sophisticated numerical analysis methods. • High design and operation knowledge required. • Difficult coordination between the structural and energy specialities, usually belonging to different companies. • High cost of installation. • Integration with the structural elements is not well optimised in relation to thermal, structural and economic factors. • Much of the foundation mass is left thermally inactivated. The current foundation thermal exchangers focus only on structural piles, but all other structural elements in contact with the natural soil are often forgotten. These elements, like screen-walls and foundation-slabs, among others, are powerful elements of heat exchange with the ground. 	<ul style="list-style-type: none"> • More accurate design methods in prediction of thermal behaviour. • Design risk reduction. • Faster process that produces data for early stage cost and performance evaluation. • Higher levels of optimisation regarding structural stability/integrity and thermal performance. • Construction and industrial risk reduction. • Fabrication and installation costs reduction. • Enhanced uptake of the technology for the large tertiary building sector. • Use of all the structural mass foundation present in a building, thereby maximising the energy exchange with the ground without the need for complex boreholes or additional systems or facilities. • Specific application of this technology to the tertiary building sector, from design to control and operation.

8.4 Replicable geothermal heating and cooling System Solutions for Wide-Scale Market Deployment

Current Context

For houses, schools or smaller offices the limited GSHP capacity (10 - 50 kW) coupled to vertical U-loop borehole heat exchangers is a proven robust technology with high energy saving potential.

On the other hand, for large buildings, borehole heat exchangers are usually applied, with the necessary excavation and drilling activity to introduce heat exchanger loops to achieve ground-coupled heat exchange. However, the use of energy foundations and other thermo-activated ground structures is not widely used⁸⁸, except for the energy piles mentioned above⁸⁹.

GEOTeCH Innovation

The innovative aspect of GEOTeCH consists on the integration and optimisation of all elements of the system, devising packaged solutions targeted at particular building types and sizes.

For small building applications:

GEOTeCH technology provides the market with a GSHP concept much more appealing – both for installers and end users – by devising “Plug and Play” packages that can be applied to a large number of small buildings.

These packages will combine a number of innovations and new products, comprising the following elements:

- **Advanced drilling technology**
 - Borehole stability is guaranteed and water circulation, density and pressure are not an issue;
 - It requires less specialist knowledge;
 - It increases the level of quality;
 - It can be implemented in developing markets more easily;
 - Compact equipment capable of working in restricted areas;
 - Very low noise and pollutant emissions;
 - High stability borehole capable of drilling near foundations and structures;
 - Low clean water usage;
 - Quick and cheap equipment mobilisation.
- **Advanced borehole heat exchanger**
 - Quick, controlled and reliable installation of the heat exchanger
 - Improved thermal characteristics at low flow conditions
 - Low pressure loss, reduced pumping cost
 - Quick and lower cost equipment mobilisation.
- **Advanced dual-source heat pumps⁹⁰**
 - Optimise the use of available source temperatures
 - Reduce length of borehole HX and thereby first cost
- **Advanced control device incorporating robust control algorithms**

⁸⁸ Kuppam Thulukkanam, Heat Exchanger Design Handbook, 2000

⁸⁹ Loveridge F., Powrie W. Performance of Piled Foundations Used as Heat Exchangers, 2013

⁹⁰ Renato M. Lazzarin, Dual source heat pump systems: Operation and performance, 2012

- Innovative energy exchange control systems.
- **Design tool for engineering system design**
 - Innovative design simulation methodologies.
- **Training and quality management modules**
 - Training and support activities for all GEOTeCH solutions.

For large building applications:

- Systematic whole-system optimisation and development of advanced control methods for geothermal systems using foundation heat exchangers;
- Coordination between all HVAC devices.

Current Identified Drawbacks and GEOTeCH Key Success Factors

Table 35 shows a comparison between geothermal heating & cooling systems currently in use in the EU and the GEOTeCH innovative systems proposed:

Table 35. Current Geothermal Heating & Cooling Systems Drawbacks Vs GEOTeCH Solutions Key Success Factors

Current GH&C Systems	Identified Drawbacks	GEOTECH Replicable Geothermal Heating and Cooling System Solutions Key Success Factors
<p>Small Buildings: GSHP (10 - 50 kW) coupled to vertical U-loop borehole heat exchangers.</p>	<p><u>Small Building:</u></p> <ul style="list-style-type: none"> ● Design complexity which is difficult for SME installers to deal with. ● Systems are not easy to integrate and potential performance is not always realised. ● Control systems are not robust. ● Drilling is a cost barrier and the messy process is unappealing to both contractors and consumers. ● Overall complexity is unattractive to the new SME installers. 	<ul style="list-style-type: none"> ● More effective approaches to control system integration. ● Drilling process is dry and tidy. ● Optimisation of hybridisation strategies. ● Whole-system solutions that are easier to implement and with lower life-cycle costs and greater CO₂ emission savings potential.
<p>Large Buildings: Energy Piles.</p>	<p><u>Large Building:</u></p> <ul style="list-style-type: none"> ● Integration with building energy management systems is poorly developed. ● Control system integration is very complex. ● Lack of design guidance and optimised fabrication procedures. 	<ul style="list-style-type: none"> ● Better design guidance and optimised fabrication methods. ● System implementation more attractive to developers, design professional and construction businesses.

In conclusion, the **key success factors of the GEOTeCH solutions**, in comparison with the existing systems available in the market, are as follows:

- Less capital-intensive equipment
- Quicker installation and working safety enhancement
- Reduction of environmental risks, complexity and costs of dealing with water supplies and contaminated waste
- Less usage of drinking water for drilling, less waste of water
- Lower thermal resistance compared to conventional U-tube devices
- Cost-effective geothermal systems, alternative to drilling techniques, in large tertiary building sector.

Thanks to its more accurate design methods in prediction of thermal behaviour; faster process that produces data for early stage cost and performance evaluation; higher levels of optimisation regarding structural stability/integrity and thermal performance; specific application to the tertiary building sector of this technology, from design to control and operation.

- Maximum use of the foundation structures that are otherwise required, exclusively for structural and geotechnical purposes in tertiary buildings

Piles, screen walls and basement slabs become effective geothermal heat exchangers, taking advantage of all the structural mass foundation present in a building, maximising the energy exchange with the ground without the need for complex boreholes or additional systems or facilities.

- Optimised hybrid solutions integrating the different geothermal systems in small and large building markets

These solutions will be developed by the GEOTeCH project, expanding the traditional GSHPs market from housing buildings to large tertiary sector buildings.

- Optimisation of geothermal system operation by the implementation of an Energy Management System and the Dual Source Heat-Pumps
- More attractive geothermal heating and cooling standard to design for professionals and construction companies

GEOTeCH solutions are easier to implement and allow savings during installation, requiring less specialist knowledge on the part of the operator. This will allow the entry of construction SMEs in the GSHP market.

9. MARKET OPPORTUNITIES, EU LEGISLATIONS AND MARKET BARRIERS TO APPLICATION OF GEOTHERMAL SYSTEMS IN BUILDING SECTOR

EU Legislations

The EU legislation on geothermal energy is presented next. It is important to say that energy has become an area of shared competence between the EU institutions and the different countries of the EU.

The objectives of the EU in this field are the following:

- Ensure the functioning of the energy market
- Ensure security of energy supply in the Union
- Promote energy efficiency and energy saving and the development of new and renewable forms of energy

Such a provision, therefore, entitles EU decision-makers to legislate on a number of issues that can directly or indirectly affect the shallow geothermal sector.

Hence, it is worth providing a **general overview of the main EU legislation relevant to shallow geothermal energy** and to the **objectives of the GEOTeCH project**.

- **Directive 2009/28/EC** on the promotion of the use of energy from renewable sources (RES directive). This directive aims at increasing the share of renewable energies in the overall energy mix within the EU, leading towards reaching a share of 20% renewable by the year 2020. In addition to setting the target share of RES to be reached by Member States (MS) it also aims at reducing final energy demand as well as GHG emissions and therefore securing a stable independent energy supply within the EU on a long-term basis. The RES Directive also delivers a common framework of guidelines as a support tool for MS to reach the defined targets. These guidelines touch topics such as eligibility, statically transfer, joint projects, guarantees of origin, administrative procedures, information, and training.
- **Recast Directive 2010/31/EU** on energy performance buildings (EPBD). This directive focuses on the improvement of energy performance of buildings, building elements and technical systems via a set of minimum requirements. The directive centres on topics such as providing a framework for the calculation of energy performance, the share of nearly-Zero-Energy-Buildings (nZEB), energy certification of buildings and regular inspections of heating and air-conditioning systems.

The directive has already been transposed into national law by Member States. It includes obligatory reporting on the process, which is handed to the Commission who can then assess the progress the MS are making. Upon request, the Commission can also provide guidance to MS for a quicker implementation.

- **Directive 2012/27/EU** on energy efficiency, aims at increasing the efforts currently made by Member States to use energy more efficiently throughout all stages of the value chain. It therefore contributes directly to the 20/20/20 target of 20% primary energy reduction by 2020. However, according to current energy demand it is necessary for the European Union to more than double its energy saving efforts in order to achieve this ambitious target. The EED was adopted in summer 2012 and will replace both the Cogeneration Directive (2004/9/EC “CHP Directive”) and the Energy Services Directive (2006/32/EC “ESD”). The new directive will cover and regulate all sectors with energy savings potential.

In order to improve the energy efficiency of products and installations, measures must be taken to achieve the non-binding target by 2020. The progress will be re-assessed in 2014. If Member States fail to reach the non-binding targets, binding targets will come into force. Among other things, the EED states that Member States should set indicative national energy efficiency targets that are based either on primary or final energy consumption or energy intensity. Furthermore, Member States are obliged to renovate 3% of the total floor area of heated and/or cooled buildings owned and occupied by their government each year. National energy efficiency obligation schemes, achieving annual savings of 1.5% will have to be put in place and policies promoting the use of efficient heating and cooling systems (using high efficiency cogeneration at local and regional level) will need to be adopted. In this context, a cost-benefit analysis by the Member States based on climate conditions, economic feasibility and technical suitability will need to be performed in order to identify saving potentials. Member States will also have to take on authorisation criteria for new electricity production taking CHP and district heating into consideration (incl. urban and rural spatial planning requirements). Member States should create certification schemes for providers of energy services, energy audits and other energy efficiency improvement measures and installers of building elements (e.g. heating, cooling, and hot water). This will help advance the energy services market and ensure access for small and medium-sized enterprises to this market.

- **Recast Directive 2009/125/EC** establishing a framework for the setting of Ecodesign requirements for energy-related products. The framework for the setting of Ecodesign requirements for energy-related products (recast) (Directive 2009/125/EC) aims at establishing Ecodesign requirements for several product groups of the heating sector, where Lot 1 encompasses products like heat pumps, boilers, output capacity as well as heating and combi-systems, Lot 2 covers water heater and Lot 10 includes air-conditioning units below 12 kW.
Through the implementation of this directive consumers will have direct insight into the energy consumption of various heating installations and giving them the opportunity to take the energy efficiency into consideration when choosing such a system. The requirements are based on a common methodology and the result will be visualised on a label in the same way as it is already done for several other appliances, starting with a grading system from A+ to G, which will then later be upgraded to A+++ to D in order to take into account expected technical progress. Through this rating system the energy label will function as an advertisement for efficient products for a tenant or buyer. Once implemented, the Ecodesign Directive will have far reaching implications for manufacturers, importers, consumers, contractors, consultants and architects. It is linked to the EPBD and will promote innovation in design and marketing of boilers.
- **Recast Directive 2010/30/EC** on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products. It applies to all energy-related products with significant direct or indirect effect on the consumption of energy and other essential resources during their use.
Similar to the Ecodesign Label discussed prior, the energy label will include the energy performance of a product (with a rating system A to G). Currently, a delegate act for an energy label applicable to heat generators is being developed simultaneously to the implementation process of the energy related products.
- **Directive 2000/60/EC** establishing a framework for Community action in the field of water policy.
- **Directive 2006/118/EC** on the protection of groundwater against pollution and deterioration.

- **EU Energy Roadmap 2050.** The European Commission has issued a roadmap for moving to a competitive low carbon economy in 2050 (COM(2011) 112 final) to ensure that the political measures in place to achieve the 2020 targets are continued to deliver beyond 2020. For instance it is expected that GHG emissions will be reduced by about 40% in 2050. The “Energy Roadmap 2050” presents different pathways towards a low-carbon energy sector, while at the same time keeping Europe competitive and securing the energy supply. The political measures to achieve the 2020 targets will continue to deliver beyond 2020.

The Commission identifies four main components of decarbonisation for the energy sector on which it bases its scenario development:

- Energy Efficiency (mostly impact on demand side)
- Renewable Energy Sources
- Nuclear Energy
- CCS (impact on supply side)

Within the Roadmap these components are combined into two current trend scenarios and the following five decarbonisations scenarios:

- High Energy Efficiency scenario, which eventually leads to 41% decrease in energy demand in the building sector by 2050 (compared to 2005 levels)
- Diversified Supply Technologies scenario, all energy sources compete on a market basis, decarbonisation is led by carbon pricing
- High Renewable Energy Sources scenario
- Delayed CCS scenario
- Low Nuclear scenario

Opportunities

The renewable contribution of geothermal heat pumps to the heat produced is calculated according to the EU Directive 2009/28/EC “Renewable Energy”, Annex VII, by the equation:

$$E_{RES} = Q_{usable} \cdot (1 - 1/SPF)$$

According to the Directive only heat pumps with $SPF > 1.15 \cdot \eta$ can be considered for statistics purposes. In the Decision 2013/114/EU, is reported that the average power system efficiency at European Level is set up at 45.5%, so that the minimum SPF for a heat pump to harvest renewable energy is 2.5.

Geothermal heat pumps can easily exceed (and in some cases even double) the threshold imposed by the Commission.

Each Member State set up its own targets for geothermal heat pumps (and heat pumps in general) for 2020, and inserted in the National Renewable Energy Action Plans (NREAP). Table 36 resumes the targets (including Iceland and Norway that realised the NREAP on a voluntary basis)⁹¹.

⁹¹ extrapolation by NREAPs of Member States <https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans>

Table 36. Summary of 2020 targets for the heat pumps in the heating and cooling sector)

NREAP - heat pumps	Aerothermal			Geothermal			Hydrothermal			Total		
	2015	2020	Increase	2015	2020	Increase	2015	2020	Increase	2015	2020	Increase
	ktoe	ktoe	%	ktoe	ktoe	%	ktoe	ktoe	%	ktoe	ktoe	%
Austria	55	105	90.91%	14	26	85.71%	68	131	92.65%	137	262	91.24%
Belgium	77.5	168	116.85%	67.8	147	116.85%	16.1	35	116.85%	161	350	116.85%
Bulgaria	n.a.	n.a.		n.a.	n.a.		n.a.	n.a.		0	0	0.00%
Croatia	36	76.5	112.50%	0	0	0.00%	5.1	19.1	274.51%	41.1	95.6	132.60%
Cyprus	n.a.	n.a.		n.a.	n.a.		n.a.	n.a.		1.61	2.97	84.47%
Czech Republic	n.a.	n.a.		n.a.	n.a.		n.a.	n.a.		88	157	78.41%
Denmark	135	170	25.93%	166	199	19.88%	0	0	0.00%	301	369	22.59%
Estonia	n.a.	n.a.		n.a.	n.a.		n.a.	n.a.		0	0	0.00%
Finland	n.a.	n.a.		n.a.	n.a.		n.a.	n.a.		530	660	24.53%
France	1080	1280	18.52%	425	570	34.12%	n.a.	n.a.		1505	1850	22.92%
Germany	338	547	61.83%	400	521	30.25%	62	77	24.19%	800	1145	43.13%
Greece	104	229	120.19%	23	50	117.39%	n.a.	n.a.		127	279	119.69%
Hungary	2	7	250.00%	28	107	282.14%	7	29	314.29%	37	143	286.49%
Iceland	0	0	0.00%	0	0	0.00%	0	0	0.00%	0	0	0.00%
Ireland	n.a.	n.a.		n.a.	n.a.		n.a.	n.a.		51	84	64.71%
Italy	1566	2175	38.89%	145	522	260.00%	146	203	39.04%	1857	2900	56.17%
Latvia	n.a.	n.a.		n.a.	n.a.		n.a.	n.a.		1	4	300.00%
Lithuania	n.a.	n.a.		n.a.	n.a.		n.a.	n.a.		6	14	133.33%
Luxembourg	n.a.	n.a.		n.a.	n.a.		n.a.	n.a.		4.2	13.1	211.90%
Malta	n.a.	n.a.		n.a.	n.a.		n.a.	n.a.		0	0	0.00%
The Netherlands	81	117	44.44%	177	242	36.72%	6	11	83.33%	264	370	40.15%
Norway	n.a.	n.a.		340	400	17.65%	85	100	17.65%	425	500	17.65%
Poland	n.a.	n.a.		n.a.	n.a.		n.a.	n.a.		72	148	105.56%
Portugal	n.a.	n.a.		n.a.	n.a.		n.a.	n.a.		0	0	0.00%
Romania	1	4	300.00%	2	8	300.00%	0	0	0.00%	3	12	300.00%

Slovakia	1	3	200.00%	2	4	100.00%	1	3	200.00%	4	10	150.00%
Slovenia	7	14	100.00%	26	38	46.15%	5	5	0.00%	38	57	50.00%
Spain	7.4	10.3	39.19%	23.4	40.5	73.08%	0	0	0.00%	30.8	50.8	64.94%
Sweden	100	150	50.00%	544	815	49.82%	54	80	48.15%	698	1045	49.71%
United Kingdom	194	1301	570.62%	354	953	169.21%	n.a.	n.a.		548	2254	311.31%
All	3730	6252	67.61%	2723	4617	69.53%	387	562	45.16%	7594	12513.47	64.78%

The following Table 37 shows the percentage of heat pump contributions with respect to total energy consumption for heating and cooling at 2020.

Table 37. Expected contribution at 2020 of heat pumps with respect to the total energy consumptions for heating and cooling

NREAP - heat pumps	Expected energy consumption for heating and cooling at 2020 (energy efficiency scenario)	Percentage of heat pumps contributions	Percentage of geothermal heat pumps contribution
	ktoe	%	%
Austria	12,802	2.05%	0.20%
Belgium	21,804	1.61%	0.67%
Bulgaria	4,538	0.00%	0.00%
Croatia	3,084	3.10%	0.00%
Cyprus	499	0.60%	0.00%
Czech Republic	16,586	0.95%	0.00%
Denmark	7,653	4.82%	2.60%
Estonia	1,579	0.00%	0.00%
Finland	15,300	4.31%	0.00%
France	60,000	3.08%	0.95%
Germany	93,139	1.23%	0.56%
Greece	9,674	2.88%	0.52%
Hungary	9,719	1.47%	1.10%
Iceland	838	0.00%	0.00%
Ireland	4,931	1.70%	0.00%
Italy	61,185	4.74%	0.85%
Latvia	2,612	0.15%	0.00%
Lithuania	2,684	0.52%	0.00%
Luxembourg	1,268	1.03%	0.00%
Malta	72.73	0.00%	0.00%

Netherlands	24,989	1.48%	0.97%
Norway	4,307	11.61%	9.29%
Poland	34,700	0.43%	0.00%
Portugal	8,371	0.00%	0.00%
Romania	18,316	0.07%	0.04%
Slovakia	5,613	0.18%	0.07%
Slovenia	2,029	2.81%	1.87%
Spain	29,849	0.17%	0.14%
Sweden	16,964	6.16%	4.80%
UK	51,500	4.38%	1.85%
All	526,605.73	2.38%	0.88%

As reported in the tables, the expected contribution in the heating and cooling sector of geothermal heat pumps is very limited. Even countries with mature markets, such as Sweden or Netherlands, expect an impact of geothermal heat pumps lower than 5%.

Some further considerations are necessary:

- Many Member States could not provide clear statistics nor provisions of heat pumps and their contributions to reach 2020 targets. Moreover, some Member States could provide a general overview of heat pumps, but they were unable to distinguish among different types
- Some Member States provided high values of hydrothermal heat pump contributions. Since, by definition of EU 2009/28/EC, hydrothermal energy means energy stored in the form of heat in surface water, its contribution is expected to be extremely limited and including only a few numbers of applications. The rest should be covered by groundwater heat pumps

Figure 68 reports a comparison between the objectives 2015 and 2020 for GSHP, the objectives 2020 for all heat pumps, and a preliminary rough evaluation of renewable energy contribution of GSHP at 2015, based on the statistics of installed capacity of ground source heat pumps provided in the European Geothermal Congress 2016⁹² following the calculation procedures of EU Directive 2009/28/EC and the Decision 2013/114/EU.

⁹² Antics, M., Bertani, R. & Sanner, B. (2016): Summary of EGC 2016 Country Update Reports on Geothermal Energy in Europe. - Proc. EGC 2016, 16 p., Strasbourg

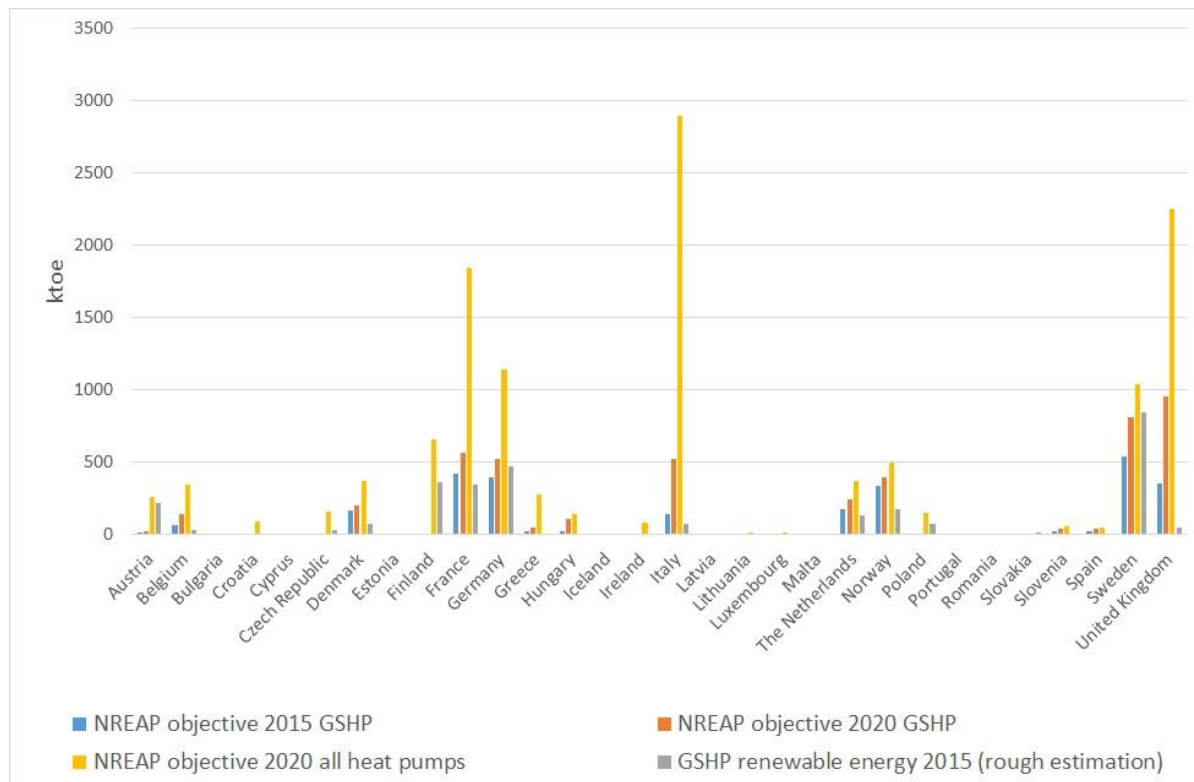


Figure 68. Comparison among NREAP objectives and a rough estimation of renewable energy provided by GSHP in 2015

The Member States are acting individually to reach their targets for energy efficiency and renewable energy. The measures to support the growth of geothermal heat pumps are contained in the NREAPs. The main measures are:

- Certification of installers
- Awareness raising and training programs for citizens and Public Body technicians
- Mandatory renewable energy targets for new buildings (geothermal heat pumps are encouraged because of the high quota of renewable energy provided, according to the Directive 2009/28/EC)
- Support schemes to use renewable thermal energy in building renovation projects (generally not exactly focused on geothermal heat pumps, even if they are often included)

Table 38 presents the support schemes for geothermal heat pumps existing in different Member States:

Table 38. Support schemes for geothermal heat pumps in different Member States⁹³

Member State	Small heat pumps	Large heat pumps
Austria	<p>€ 85 per kW for 0 to 80 kW.</p> <p>€ 45 per kW for every additional kW to max. 400 kW.</p> <p>A maximum of 30 % of environment-relevant investment costs is however supported.</p>	<p>The support volume amounts to 15 % of the environment-relevant investment costs. The application must be made before the beginning of a project and environment-related investment costs must amount to at least € 10,000. In addition, a minimum performance number</p>

⁹³ Legal Sources on Renewable Energy” <http://www.res-legal.eu/>

	An award of € 300 is granted for using energy efficiency consulting.	of 4.0 is requested.
Belgium	<p>Tax reduction on energy savings.</p> <p>Premium for geothermal heat pumps installed in existing buildings:</p> <p><i>Flemish Region</i>: the premium amounts to € 210 per kVA compressor capacity (min. € 850, max. € 1,680).</p> <p><i>Walloon Region</i>: a premium of € 1,500 is granted when a heat pump is installed for heating purposes, and a premium of € 2,250 is granted when an integrated heat pump system (space heating/domestic hot water) is installed.</p> <p><i>Brussels Capital Region</i>: a premium for heat pump systems of € 1,500 per installation (lump sum) is granted, and in the case of an integrated heat pump system (space heating/domestic hot water), a premium of € 2,250 per installation (lump sum) is granted per housing unit. Alternatively, a premium of € 750 per installation (lump sum) is granted for the installation of a heat pump for the generation of domestic hot water.</p>	
Bulgaria	The Bulgarian Energy Efficiency Fund is available. All RES technologies are eligible.	
Croatia	<i>Stable support schemes not available</i>	
Cyprus	<p><i>Non-economic activity</i>:</p> <p>Maximum grant for installation of heat pumps with heat exchanger for heating/cooling reaching 55% of eligible expenditures for a maximum grant amount of € 20,000.</p> <p><i>Economic activity</i>:</p> <p>Maximum grant of 35% for a maximum of € 100,000</p>	<p><i>Non-economic activity</i>:</p> <p>Maximum grant for installation of heat pumps with heat exchanger for heating/cooling reaching 40% of eligible expenditures for a maximum grant amount of € 200,000.</p> <p><i>Economic activity</i>:</p> <p>Maximum grant of 15% or 25% for a maximum of € 100,000</p>
Czech Republic	Tax reduction on energy savings	
Denmark	<p>Tax reduction on electricity for heat pump owners.</p> <p>Subsidies for the substitution of inefficient oil fired boilers (objective: 0 oil-fired boilers up to 2030).</p>	
Estonia	Investment support for building renovation by the use of heat pumps (all types). The support is between 1,000 and € 30,000 and it cannot be lower than € 7,340 per flat.	No support schemes.
Finland	State grant for investments in RES facilities. It can cover 30% of the entire cost. Only for companies, municipalities and communities.	
France	<p>Subsidies for social housing renovation projects "habiter mieux". General subsidies for all RES.</p> <p>Tax reduction on energy savings.</p>	
Germany	Investment support for geothermal heat pumps in building renovation projects up to 100 kW.	Low-interest loans for geothermal heat pump projects > 100 kW.

Greece	Subsidies for renovation projects of enterprises, varying from 15% to 50% according to the climatic zone and the size of enterprise. Tax reduction.	
Hungary	EEEOP funding: call for tenders for renewable energy projects.	
Ireland	Tax reduction on energy savings.	
Italy	Rotating fund for building renovation interventions (eligible capacity of geothermal heat pumps below 1,000 kW). Tax reduction on energy savings.	
Latvia	<i>Stable support schemes not available.</i>	
Lithuania	<i>Stable support schemes not available.</i>	
Luxembourg	Subsidies specific for geothermal heat pumps. <i>Subsidy for residential users:</i> The subsidy amounts to 50% of the eligible costs, subject to a maximum of € 8,000 in a single-family house. For multi-family houses, the subsidy amounts to 50% of the eligible costs, subject to a maximum of € 6,000 without exceeding a maximum support of € 30,000 per house. The following expenses are eligible: the heat pump, additional needed devices, geothermal drilling and installation costs. <i>Subsidy for companies:</i> Grants may cover up to 45% of the additional costs arising from the use of renewable energy as compared to non-renewable sources. The grant may increase by 20 percentage points for small enterprises and by 10 percentage points for medium-sized enterprises.	
Malta	Stable support schemes not available.	
Netherlands	Loans at low interest by banks “green found”, for geothermal and solar thermal projects. Tax reduction in energy efficiency projects.	
Poland	Low interest loans. For geothermal heat pumps, the maximum eligible amount is € 12,520. The loan should cover 80% of the total investment cost. Subsidies for geothermal energy. The amount is equal to the 20% of the loan received.	
Portugal	<i>Stable support schemes not available</i>	
Romania	<i>Economic sector:</i> Subsidies for renewable energy to cover heating and cooling needs in the farms. Subsidies from 30% to 50% of the project. <i>Non-economic sector:</i> Subsidies covering up to € 1,800 of geothermal heat pump projects.	<i>Economic sector:</i> Subsidies for renewable energy to cover heating and cooling needs in the farms. Subsidies from 30% to 50% of the project.
Slovakia	Subsidies depending on the European Regional Development Fund. General grants for renewable energy.	

Slovenia	Low interest loans for projects of energy savings.	
Spain	The program “Geotcasa” was available for the financing of geothermal heat pump projects. The companies realising the installation receive the grant, and then they act as an ESCo.	
Sweden	Tax deduction of installation works. Tax reduction on energy savings. Exemptions of nitrous oxide tax.	
United Kingdom	<p>Green Deal. Loan for building renovation projects.</p> <p><i>Domestic renewable heat incentive.</i></p> <p>For ground source heat pumps: p 19.3 (€ct 23.17) per kW_{th}</p> <p><i>Non-Domestic renewable heat incentive.</i></p> <p>For ground source heat pumps:</p> <p>In Great Britain (Tariff rates from 1 July 2016)</p> <p>Shallow geothermal: First 12 months: p 8.9 (€ct 10.68) per kW_{th}</p> <p>In Northern Ireland: Capacities below 20 kW_{th}: p 9.1 (€ct 10.92) per kW_{th}</p> <p>Capacities between 20 kW_{th} and above up to but not including 100 kW_{th}: p 4.7 (€ct 5.64) per kW_{th}</p>	<p>Green Deal. Loan for building renovation projects.</p> <p><i>Non-Domestic renewable heat incentive.</i></p> <p>For ground source heat pumps:</p> <p>In Great Britain (Tariff rates from 1 July 2016).</p> <p>Shallow geothermal: First 12 months: p 8.9 (€ct 10.68) per kW_{th}</p> <p>Afterwards p 2.6 (€ct 3.12) per kW_{th}</p> <p>In Northern Ireland (Tariff rates until 18 November 2015): Capacities of and above 100 kW_{th}: p 1.3 (€ct 1.56) per kW_{th}</p>

Regarding the legal framework for the exploitation of the natural resource, there is not a common framework at European level and the permissions, rules and timing vary accordingly to the different situations. This is particularly impactful for open loop geothermal systems. In case of closed loop geothermal systems, like borehole heat exchangers, the procedures are generally simplified, even if a detailed geological study is usually requested.

In all Member States, and generally at European level, the Administrative Bodies have begun to set up online tools to request installation permits. All the data are then managed in database formats. An example of this database (with integrated GIS for the localisation of ground heat exchanger) can be found for the City of Stockholm⁹⁴.

These tools and databases are useful to:

- Verify the quality certifications of installers
- Verify the compatibility of the geothermal project with the urban environment
- Issue the installation permit
- Improve the statistics on geothermal heat pump installations
- Include the new geothermal installation in management system to protect the geothermal resource and to guarantee the final users

⁹⁴ <http://varmepumpar.stockholm.se>

Barriers

The market **barriers for the application of geothermal systems in building sector** can be summarised as follows:

- Lack of available space in built urban environment to install individual systems for single family houses or condominium
- Lack of suitable (efficiency/economic) concepts with higher end temperatures for existing building stock that requires renovation
- Regulations and permits on the underground use different from area to area and depending on the geological, hydrogeological and soil pollution conditions
- Low energy classes of the existing building environment, which:
 - imply a considerable amount of thermal capacity provided by the GSHP and then a large surface area needed for the installation of ground heat exchangers
 - cause low efficiency of the system because of high temperatures of the circulating fluid. With energy vector costs (electricity and natural gas) variable and unstable, low efficiency of GSHP can lead to working costs comparable to working costs of natural gas boilers and so reducing the convenience of the investment
 - make end-users incline for insulation interventions respect to plants interventions
- In multifamily houses, need to find proper agreements among households to substitute the central heating system. Lack of appropriate financing schemes for groups of final users
- High cost of a GSHP solution with respect to alternatives. In the mind of end-users, the medium-long term savings generally do not justify the investment

The market **barriers for the application of GSHP in building sector** can be theoretically tackled by a combination of:

- Connection of single and multifamily buildings through thermal networks, linked to ground heat exchanger fields, located in proper available areas; the heat pumps can be located both near the GHE field and inside the single buildings
- More emphasis on the thermal storage capability of ground source systems and their integration in to smart grid applications
- Elaboration of new schemes of financing for activation of energy efficiency projects by groups of end-users

A proposal of a new financing scheme comes from Italy. The financing scheme is proposed expressly to tackle the barrier of difficult management of energy efficiency interventions in multifamily buildings.

In Italy currently a tax deduction exists, comprising 65% of the investment for the energy efficiency interventions, divided in 10 years after the intervention. This support scheme, even if very successful for small interventions in single family houses, is currently almost ineffectively for large interventions in urban environment, because of different economic possibilities of end-users and also different maximum quota of tax deduction per year.

The new proposal for 2017 is to create a rotating fund that would finance 90% of the interventions for single and groups of end-users. The end-users all assign their 65% tax deduction to the fund, which therefore will get back of the money in 10 years. The end-user will pay the remnant 25% in instalments, through the monthly energy bill. The new proposal should encourage the direct intervention in energy efficiency projects of energy utilities that manage the energy networks and sell the energy vectors to end-users.

By increasing the economic possibilities for energy rehabilitation projects in multifamily houses and in urban environment in general, most barriers for the installation of GSHP should be overcome⁹⁵.

Finally, GSHP must face another type of barrier: the competition with air-to-air heat pump systems, especially in Southern Europe and in temperate climate in general. Air-to-air heat pumps, even if less efficient, are undoubtedly cheaper and they can provide some quota of renewable energy as well, so they can represent an alternative in building rehabilitation projects.

For both small and large projects, GSHP systems should integrate with AHP systems, instead of competing, with the aim to find an optimum energy and economic balance for the end-user, result of the integration of two technologies.

⁹⁵<http://www.ilsole24ore.com/art/norme-e-tributi/2016-10-07/condomini-eco-e-sisma-bonus-fino-75-80percento-222039.shtml?uuid=ADzQIBYB>

10. PRELIMINARY IDENTIFICATION OF FINANCING MODELS FOR POTENTIAL BUYERS OF BOREHOLE DRILLING SYSTEMS

Market Conditions

The **EU heat-pumps market** differ largely, while it is popular in Northern Europe, it still has major growth potential in many European countries, particularly in major economies such as the UK where the penetration rate is low.

Climate dictates the use made of HPs. In the north of Europe, HPs are basically used for heating. In areas where the climate is warmer, as Italy, Spain or France, the reversible HP market is bigger, as it is based on the cooling function. In some Southern European regions, the demand for cooling in summer easily outstrips the demand for winter heating.

This issue raises problems when making statistical comparisons between the various EU markets.

According to EurObserv'ER, the HP market, including all uses and technologies taken together, contracted in 2014, with recorded sales of about 1.7 million units compared to almost 2 million in 2013. Because the slowdown essentially stems from a sharp slump in the Italian market, and, to a lesser extent from the French market, it is not quite as dramatic as the figures suggest. If France and Italy are left out of the equation, the 2014 HP market would have registered a slight growth of about 2%.

The construction sector is one of the most important industrial and economic sectors in the EU. According to Eurostat data, its annual turnover was estimated at € 1.2 trillion in 2009, providing 7.1% of all employment and 29% of industrial employment in the EU. Investment in construction represented over 51% of all fixed capital investments. New building activity is assumed to be 1% of the total living area per year, reaching about 2.1 million of new buildings per year. But the existing building stock still represents the biggest market and it is also the one with greatest potentiality for energy saving.

GEOTeCH solutions for small buildings can be applied in both new buildings and retrofitting projects and in almost any geological environments. In the medium term, it can be estimated a **potential market of 3.68 billion Euro per year in the small buildings retrofit sector**⁹⁶. Similar assumptions can be made for the small buildings market on new buildings.

The large tertiary market constituted by new buildings represents an important target for the project as well. It is estimated that there were about 210 million buildings in the EU in 2010⁹⁷. As regards the large tertiary market on new buildings, considering 2.1 million new buildings per year in the EU, considering moreover that commercial buildings represent 30% of the building stock and that 5% of these buildings could be targeted as market for large systems, **GEOTeCH solution would generate an additional cumulative annual turnover of 4.73 billion Euro for large systems in the new buildings market**⁹⁸.

According to the 2015 Heat Pumps Barometer, the total number of Geothermal Heat Pumps in function in the European Union in 2014 is 1,340,906.

Current growth prospects are better as the construction sector indicators now give more grounds for hope. Growth should be about 1.8% in 2015, 2.0% in 2016 and 1.7% in 2017.

⁹⁶ Assuming an average market price of 50,000 Euro for a small-scale shallow geothermal energy solution

⁹⁷ Source: Eurostat, 2014

⁹⁸ Assuming an average market price of 150,000 Euro for a large-scale shallow geothermal energy solution

European directives are also contributing, by implementing more stringent energy performance regulations in the building sector. Moreover, HP type heating solutions are patently encouraged.

Indeed, adoption of the proposed solution will result in important economic savings for building owners, directly related to the energy savings achieved. The design and installation complexity and the associated cost and risks of current geothermal heating and cooling solutions constitute a barrier to wider uptake in the market, particularly for inexperienced SME installers in developing markets as well as end-users.

In addition to improved technical and economic performance, the approach taken in GEOTeCH will result in less complex solutions that have proved reliability and performance and are simpler to integrate into the construction process. These will be more appealing to both consumers and installers and so will address some of the non-technical barriers to market growth. Furthermore, the development of installation guides and quality control procedures, that are part of the GEOTeCH activities, will contribute addressing these barriers.

GEOTeCH aims to significantly contribute to EU energy and environmental policies, representing a versatile solution for both new and existing buildings, both residential and commercial, guaranteeing energy saving and GHG emission reductions.

Potential Customers

GEOTeCH project focuses on four key aspects as already mentioned: (1) Innovating borehole drilling technology; (2) Innovating vertical borehole heat exchanger devices; (3) Advanced design and implementation of foundation heat exchangers; and (4) Replicable geothermal heating and cooling system solutions for wide scale market deployment. Hence, the goal should be not only selling an innovative drilling system to specialised companies and installers, but addressing also other actors' needs. The most important agents of the construction and design process must be involved in the process, in order to know advantages of GEOTeCH solutions, as well as public entities related to energy and building market.

The professionals or entities that can be considered within GEOTeCH project as key target customers (or related agents) are as follows:

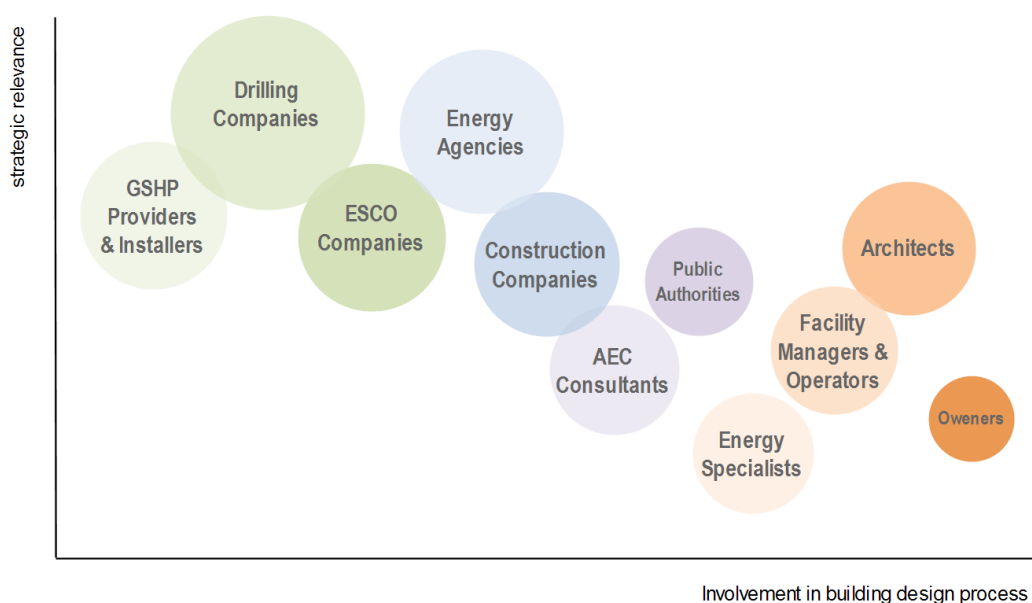


Figure 69. GEOTeCH project solutions key target customers

A catalogue of the most important companies, representative of the GSHP market in the EU in 2015 is shown below:

Table 39. Companies representative of the GSHP market in the EU, 2015⁹⁹

Company	Brand	Country	Capacity Range
BDR Thermea	De Dietrich	France	5.7 - 27.9 kW
	Baxi	UK	4.0 – 25.0 kW
	Sofath	France	2.8 - 14.2 kW
	Brötje	Germany	5.8 - 28.5 kW
Bosch Thermotechnology	Bosch Thermotechnology	Germany	5.8 - 28.5 kW
Daikin Europe	Rotex	Germany	6.0 – 17.0 kW
Danfoss	Thermia Värme AB	Sweden	4.0 – 84.0 kW
	KH Nordtherm	Denmark	Up to 42.0 kW
Nibe	Alpha Innotec	Germany	5.0 – 160.0 kW up to 540.0 kW
	Nibe Energy Systems Div.	Sweden	5.0 – 22.0 kW
	Tecchnibel	France	5.0 – 58.0 kW
Vaillant Group	Vaillant	Germany	3.0 – 64.0 kW
Viessmann Group	Viessmann Group	Germany	7.3 – 240.0 kW
Ochsner Wärmepumpen	Ochsner Wärmepumpen	Austria	5.0 – 1,000.0 kW
Stiebel Eltron	Stiebel Eltron	Germany	4.7 – 56.0 kW
Waterkotte	Waterkotte	Germany	4.0 – 491.0 kW
Wolf Heiztechnik	Wolf Heiztechnik	Germany	6.0 – 16.0 kW

⁹⁹ Source: EurObserv'ER, 2015 (Non exhaustive list)

FINANCIAL SUPPORT TO GEOTHERMAL HEATING

Support schemes are crucial tools of public policy for geothermal field to compensate for market failures and to allow the technology advancing along its learning curve. By definition, they are temporary and shall be phased out as this technology reaches full competitiveness. Innovative financing mechanisms should be adapted to the specificities of geothermal technologies, according to the level of maturity of markets and technologies.

Several mechanisms for supporting investments in geothermal energy exist at European and national level, among Member States. These mechanisms can address different project stages and can come from different sources.

A European Geothermal Risk Insurance Fund (EGRIF) is seen as an appealing public support measure for overcoming the geological risk. As costs decrease and markets develop, the private sector will be able to manage project risks with, for example, private insurance schemes, and attract private funding.

While designing a support scheme, policy-makers should take a holistic approach, which goes beyond the LCoE¹⁰⁰ and includes system costs and all externalities. As an alternative, there is the chance to offer a bonus to geothermal use for the benefits it provides to the overall electricity system: flexibility and base-load.

Geothermal heat technologies are heading for competitiveness, but support is still needed in certain cases, notably in emerging markets and where a level-playing field does not exist. In addition, there is a need for an in-depth analysis of the heating sector, including the best practices to promote geothermal heat, the synergies between energy efficiency and renewable heating and cooling, and barriers to competition. Operational aid similar to a feed-in tariff system is now beginning to be explored in some Member States, partly because of the inclusion of the sector into the European regulatory framework (20% target).

The **instruments and incentives** to bring favourable conditions for **shallow geothermal development** are the following:

- Grants
- Feed-in Tariff & Feed-in Premium
- Geological Risk Coverage with risk insurance schemes
- Additional measures like portfolio standards, tax credits, public support (EU, governmental, local, etc.)

Regarding Geological Risk Coverage in shallow geothermal energy, one system exists in France called AQUAPAC. It is an insurance to cover the geological risk associated with aquifers up to 100 m depth. This scheme concerns only heat pumps with a capacity above 30 kW.

In relation to geothermal heat pumps, support schemes are here more for removing barriers like awareness. They can play a role in the promotion of geothermal. Financial incentives schemes are not available in all European countries for supporting GSHP, although the competition on the heating sector can be considered as unfair with fossil fuels still receiving subsidies. Financial support is still required in emerging markets where they should be tailored for both individual and collective installations. Possible schemes are grants, tax reduction, loans with zero interest rate. They should have a link with quality, certification etc.

¹⁰⁰ Levelised Cost of Energy

The Table 40 below gives some non-exhaustive examples of financial mechanisms in force for GSHP:

Table 40. Financial support schemes for geothermal H&C in selected EU countries¹⁰¹

NATURE	AREA
Investment Grants	France (Fonds chaleur renouvelable), tertiary buildings Germany Hungary Greece Poland Romania Slovakia Slovenia Spain
Feed-in tariff	Italy (Conto termico) Netherlands (SDE+) UK (Renewable heat incentive)
Tax rebate/VAT reduction	France (VAT reduction for DH) individual housings Hungary Italy Netherlands
Low or zero interest loans	France, for individual housings Germany Hungary Netherlands Poland Slovenia Spain
CO₂ tax	Finland Sweden Denmark

¹⁰¹ European Geothermal Energy Council (EGEC), 2013

In the United Kingdom the Renewable Heat Incentive provides a financial incentive for generation of renewable heat based on metered readings on an annual basis (for 20 years) for commercial buildings. The domestic Renewable Heat Incentive was due to be introduced in spring 2014 for seven years and be based on deemed heat¹⁰².

In Germany, BAFA (Federal Office for Economic Affairs and Export Control) encourages HP market expansion via the Market Incentive Programme¹⁰³. In the case of GSHPs, the minimum funding amount is 4,500 € for <45 kW units. Very high performance GSHP are eligible for “Innovationsförderung” (innovation support), with minimum funding of 6,750 €¹⁰⁴.

The Swedish HP market is mature, since HP technology has long been in demand from households. The thermal regulations encourage installation of this type of technology in new buildings.

Innovative financial schemes:

For heating systems of buildings, both small and tertiary big facilities, it occurs that, if a competitive renewable source of energy, such as geothermal, is planned to be installed but it has high capital costs, this barrier can be removed with the following measure:

- An ESCO takes the responsibility of the investment (for example, the boreholes for 26 individual or collective buildings, and eventually the Heat Pumps)
- Then, it sells to the customer the heat extracted from the borehole heat exchangers, via an adapted accounting system, at a fixed sale price, which is added to his energy invoice

Support schemes could cover the feasibility and design of such systems, while another possible innovative measure for geothermal heat pumps is the possibility of receiving discounts on the price of electricity.

¹⁰² 2010 to 2015 government policy: low carbon technologies. British Department of Energy & Climate Change, 2015

¹⁰³ Marktanzreizprogramm (MAP)

¹⁰⁴ Heat Pumps Barometer, EurObserv'ER, 2015

11. CONCLUSIONS

11.1 Summary of achievements

The purpose of this deliverable has been identified with a preliminary assessment of the European market for the developed GEOTeCH solutions, aiming at ensuring the future successful commercial exploitation of the key results of the project in the two reference market segments of small residential and large tertiary building sectors.

Main results and achievements can be summarised in the following points:

- The conventional heating and cooling market is fragmented and heterogeneous, being composed by many different technologies, and updated statistics show that the **level of efficiency of the installed stock is low**: hence **modernisation of existing conventional heating and cooling systems is strongly needed in Europe**
- In comparison with the traditional heat and cool (H&C) systems that use oil and gas, **shallow geothermal energy has the potential to save up to 70% of energy**, but current state of deployment of such renewable energy is very heterogeneous across Member States
- **European mature markets** of geothermal installations are **Sweden, Germany, France, Switzerland and Norway**, which account for **around 70% of all installed capacity** of the continent (to evaluate the geothermal potential it is important to consider ground conditions but also political/economical factors as well as construction trends)
- **Profitable markets** have been identified with **The Netherlands, Denmark, Poland, Belgium, the UK and Germany** for their large percentages of territory suitable for application of GEOTeCH drilling technology
- Competitors present in the EU market are starting to offer innovative products for geothermal applications with some advanced features similar to GEOTeCH solutions, however the **dry drilling technology** developed within the project is actually **beyond the state of the art**
- Application of **GSHPs** suffers **competition with ASHPs** which are more commercialized in the market due to their easiness of installation, lower price and less space occupancy (big price differences between the regions are the result of diversified incentive policies). **GSHPs provide higher efficiencies**
- Current EU legislations are aiming to reduce GHG emissions by requiring new and renovated housing to be low/zero energy buildings: it is envisaged that **heat pumps will play an important role** in space heating and DHW production in all EU member states, reducing requirements for primary energy
- Main **market barriers** for the application of geothermal systems in building sector can be identified with: lack of available space in built urban environment for installation, different regulations and permits, lack of appropriate financing schemes, high cost of GSHPs and needed certifications respect to alternatives, lack of awareness and knowledge about geothermal systems
- Opportunities in the market can be exploited and barriers overcome through the **key success factors** characterizing GEOTeCH solutions such as: less capital-intensive compact equipment, reduction of environmental risks, complexity and costs, better integration between heat exchange elements during installation, maximum use of the foundation structures, optimized hybrid solutions integrating the different geothermal systems, cost-effective geothermal systems, safety enhancement

11.2 Relation to continued developments

The work performed in the present deliverable will represent the basis for activities to carry out within Tasks 7.3, 7.4 and 7.5.

The market assessment will allow identifying most profitable markets for creation of successful business models for the main exploitable results developed within GEOTeCH.

12. ACRONYMS AND TERMS

SPF	Seasonal Performance Factors
COP	Coefficient of Performance
GSHP	Ground Source Heat Pump
ASHP	Air Source Heat Pump
BTES	Borehole Thermal Energy Storage
ATES	Aquifer Thermal Energy Storage
EPC	Energy Performance Coefficient
UTES	Underground Thermal Energy Storage
FHX	Foundation Heat Exchanger
DHW	Domestic Hot Water
BHE	Borehole Heat Exchanger

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