IGEIA
Integration of Geothermal Energy into Industrial Applications

DELIVERABLE 17:
ADVANTAGES OF GEOTHERMAL ENERGY FOR THE INDUSTRY

With the support of:

Intelligent Energy Europe

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1. PROJECT DESCRIPTION

Industrial applications represent a small sector of direct geothermal energy use even though the industrial sector offers a very attractive target for geothermal applications. The IGEIA project aims at promoting the integration of geothermal heating and cooling applications into industrial sites in some countries, and convincing industrials that geothermal energy could offer solutions to their energy issues.

The project objectives consist of:

- Identifying energy needs in the industrial sector. Investigating industrial sites where the use of geothermal applications are possible and evaluating its energy usage
- Presenting local conditions allowing installation of geothermal heating. Identify new energy savings in heating & cooling on sites
- Stuying the feasibility of the geothermal application
- Developing a European solution customized by country
- Informing the industrial sector on geothermal potential and advantages (everywhere, every time)

Some of the covered themes:

- Research and listing of local conditions for geothermal energy in each country involved in the project
- Investigation on specific industrial sites to determine the status quo: energy use and quantify the potential energy saving.
- Study of financial aspects, subsidies and financial aids granted to industries using geothermal energy in each country.
- Evaluation of technical conditions when proposing an alternative solution using geothermal energy/RES supply.
- Identification of energy savings and supply optimal conditions by comparing energy use for different sources: existing versus geothermal (RES), for specific industrial sites in 3 countries.
- Comparison of studies carried out by several industrial partners on energy use, identification of energy savings optimal conditions and proposing geothermal applications as alternative energy saving solutions for the studied sites, and extrapolation to all 5 countries.

Partners:

- Saunier & Associés (France)
- UBeG (Germany)
- Sweco (Sweden)
- ESTSetúbal (Portugal)
- EnPro (Estonia)

All produced material is available at www.saunier-associes.com/igeia

2. GEOTHERMAL TECHNICS

Geothermal energy helps to reduce the usage of fossil fuels and electricity which leads to the reduction of CO_2 as well as other environmentally hazardous gas emissions, like SOX and NOX.

There are several schemes where the underground is used for UTES (Underground Thermal Energy Storage) depending on factors such as geological and hydrogeological site conditions. The two most promising options are storage of energy in aquifers (ATES) and through borehole heat exchangers in a soil or rock mass (BTES). These two concepts are already introduced as commercial systems on the energy market in several countries.

2.1. LOW TEMPERATURE STORAGE IN AQUIFERS (ATES)

In ATES (Aquifer Thermal Energy Storage) systems, groundwater carries the thermal energy into and out of an aquifer. Water wells are used for the connection to the aquifer. However, these wells are normally designed with double functions, both as production and infiltration wells.
The energy is partly stored in the ground water itself but to a larger extent in the grains forming the aquifer (or porous rock mass). Heat is transferred from the ground water to grains as it flows by. This results in the formation of a thermal front between different parts of an aquifer having different temperatures. This front will move in a radial direction from the well during charging of energy and then turn back while discharging, see figure here below.

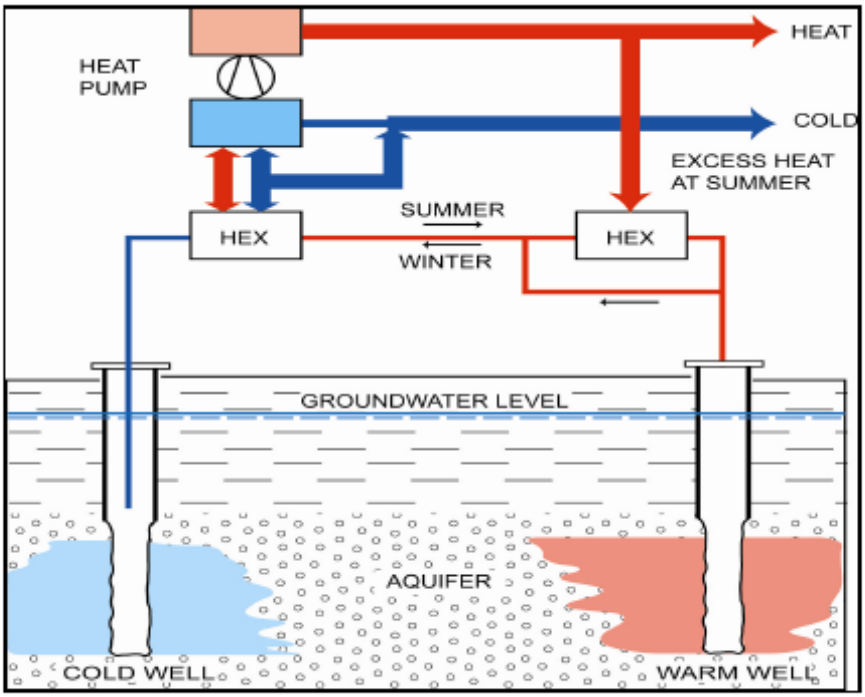


Figure 1 - The most common ATES configuration

Hundreds of these systems are in operation worldwide, with the Netherlands (more than 200 plants) and Sweden (some 60 plants) as dominating countries of implementation. Practically, all systems are designed for low temperature applications where both heat and cold are seasonally stored. Normally the cold side of the aquifer can be directly used for “free cooling”, while the warm side will act as an excellent source of energy for the heat pump. Typically the cold side of these systems will work at a

temperature level of 4-8 °C, while the warm side will reflect the return temperature from the cooling loop, normally in the range of 12-14 °C.

2.2. LOW TEMPERATURE STORAGE IN BOREHOLES (BTES)

BTES (Borehole Thermal Energy Storage) systems consist of a larger number of closely spaced boreholes, normally 50 – 200 m deep. These boreholes are used to exchange heat with the underground and consequently are connected to a Borehole Heat Exchangers (BHE), typically found as a single U-pipe. Several configurations can be found on the market. Figure 2 illustrates the type normally used in Sweden and Europe.

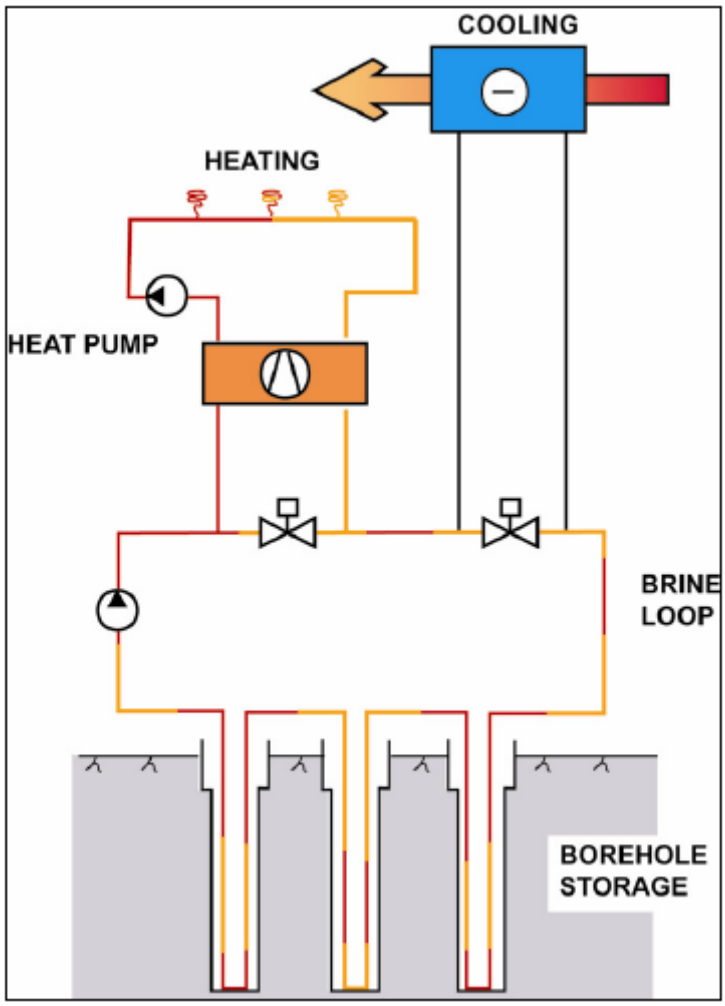


Figure 2 - The most common BTES configuration in Europe

In some countries, boreholes are backfilled with a sealing grout after BHE installation. In Sweden, it is common practice to leave boreholes without grout and boreholes can be naturally filled with groundwater. The backfilling of boreholes with grout results in a decrease of boreholes thermal efficiency. However, it helps protecting the groundwater from contamination.

2.3. HIGH TEMPERATURE STORAGE IN BOREHOLES (HT BTES)

The concept is similar to the BTES heat pump supported one, but the heat pump is replaced by solar collectors or a waste heat source, see figure 3

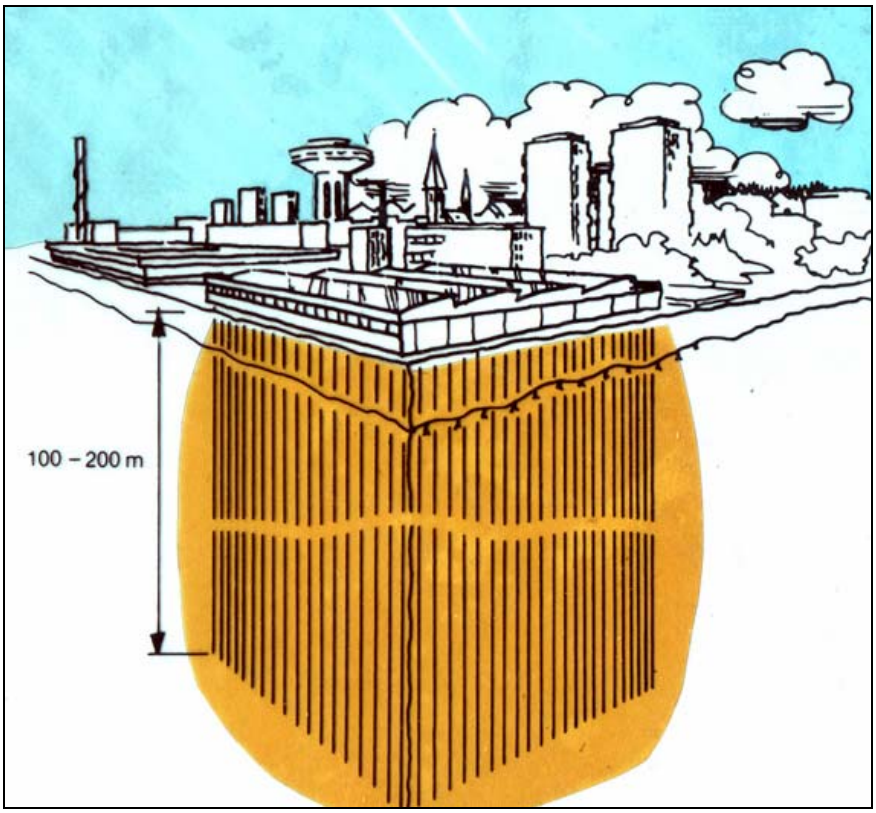


Figure 3 - The principal for HT BTES systems, in this case with storage of solar energy.

Typically heat is seasonally stored at temperature levels up to around 70oC. Since there are storage losses the temperature will drop making the recovery temperature considerably lower. However, the heat losses will decrease with the size of the storage. Therefore the most efficient applications, with losses less than 30 %, are large scaled.

In Europe there are still only some 10 of these plants existing and the technology is still in an early commercial stage with a large market potential.

3. GEOTHERMAL APPLICATIONS

3.1. GENERAL RULE ON TEMPERATURE LEVELS

Generally, when using geothermal energy, temperature levels are limited either by the temperature of the exploited aquifer, or by temperature limits at the condenser outlet for a heat pump application.

This constraint influences directly all types of geothermal applications: for a building heating, heat transmitters should properly work at relatively low temperature levels; whereas for an industrial application, the industrial process must necessarily consume energy but at relatively low temperature levels as well.

The first step consists thus in selecting applications that can operate at low temperature levels (less than 70°C).

Also, for building heating systems using geothermal energy and heat pumps, it is preferable to design the distribution systems for low temperatures (30-40°C) as this will increase the energy efficiency. Such systems could bee floor heating, low temperature convectors or others.

The opposite could be said about the cooling distribution system, as high temperatures as possible should be used for cooling. As an example, it is more efficient to design the cooling loop for 12/17°C instead of 7/10°C. Cooling systems with higher distribution temperatures will be able to utilize much more of the free cooling energy available in the ground.

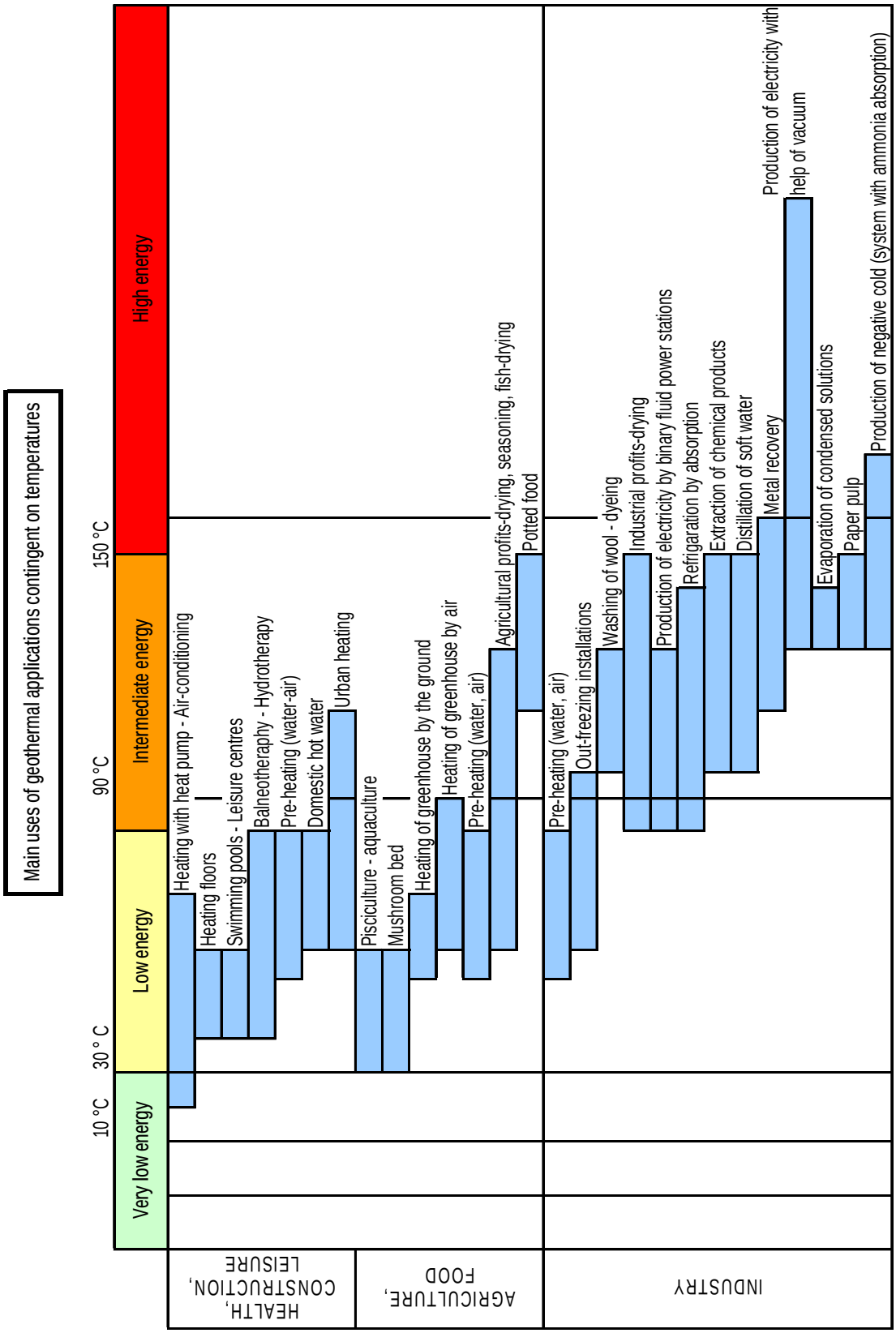


Figure 3 - Temperature Levels necessary for various industrial processes (source: BRGM)

3.2. COVERAGE OF HEATING/AIR-CONDITIONING NEEDS IN BUILDINGS

The main advantages for using geothermal systems for heating/air-conditioning building are:

- The same geothermal device can provide both heating and cooling energy.
- At least , a part of the cooling energy can be provided without using a chiller (geocooling)
- Energy can be efficiently stored, diurnally or seasonally

3.3. INTEGRATION OF GEOTHERMAL ENERGY INTO AN INDUSTRIAL PROCESS

Geothermal energy can be integrated into an industrial process in two applications: either as a means for storage, for energy otherwise dissipated in the surrounding air, or as energy well to provide the process directly with heating or cooling.
Industrial processes represent an interesting target for geothermal energy application because power needs are generally high, just like operating periods.

3.3.1 Waste energy storage

Most of the heat released by industrial processes is generally evacuated into the surrounding air using heat exchange systems. No energy recovery is achieved due to two factors principally:

- Lack of heat recovery systems.
- Non-simultaneity between heat production and possible use of heat produced

Geothermal applications are of interest since they offer the possibility of storing the released heat in order to re-use it later. The recovered heat can be restored using a heat pump that allows reaching higher temperature levels.

Waste heat recovery is only interesting when a user of that energy is available. This is most commonly done via a District Heating network.

3.3.2 Heat supply in an industrial process

Geothermal energy can be used to supply heat for an industrial process, either by drawing heat from the ground, or by recovering heat previously stored.
The temperature level needed for the process is a crucial design parameter (cf. Figure 1) and in most cases is a limiting factor: Because of limited temperature levels, geothermal energy does not cover the entire energy demand of the process. However, it allows a pre-heating in the process chain.

3.3.3 Cold supply

Geothermal energy offers other opportunities such as supplying cold for an industrial process chain. The interesting parts of this solution are primarily:

- Developing a stock of cold that might have been created additionally, during a geothermal heat production.
- Avoiding the use of cooling towers, that are potential sources of Legionella development and are energy and water consuming

4. ADVANTAGES OF GEOTHERMAL ENERGY FOR THE INDUSTRY

The main advantages of geothermal energy for the industry are:

- It allows drastic cost reductions on the energy bill
- It makes the industry less sensible to future evolution of fossil energy prices
- It allows a important reduction of CO_2 emissions
- It reduces the risk of Legionella contamination through open air chillers

4.1. ESTONIAN SITUATION

4.1.1 Water resource

The Estonian territory is covered with sedimentary rock layers, with a maximum thickness reaching 700 m (Fig.3). Therefore no crystalline base rock is found. The geothermal gradient is low and is typically in the range of 12-16 ºK/km.

Underground aquifers have temperature around 5-8 ºC. The thermal conductivity of most sedimentary rocks saturated with water, varies between 2 and 3 W/m ºK and for clay rock between 1 and 1, 5 W/m ºK.

Average air temperatures vary between –2 and –7 ºC in January, and +16 and +17,4 º in July, depending on the region. These low temperatures induce important heating needs for buildings. The heating season covers the period lasting from the end of September till the end of May.

The largest water resource that can be easily used as geothermal energy source is the water pumped from underground oil-shale mines in the North-East of Estonia. However, the number of consumers in this region remains insignificant.

Concerning ATES systems, the existing procedures for receiving permissions from local Environmental Offices are rather complicated.

4.1.2 Incentives

In Estonia, there are currently no state subsidies to support companies, who wish to integrate geothermal energy systems in their applications and industries.

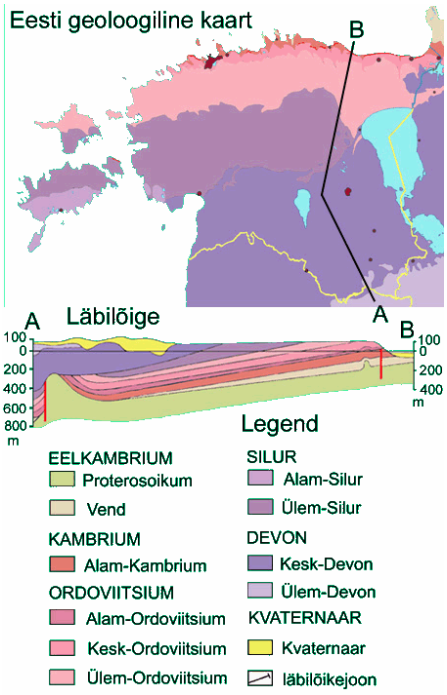


Figure 4 - Estonian Geological Map

4.1.3 Some ideas of potential industrial sectors

All industries with a heating/cooling demand are almost potential users for geothermal energy. Industries with especially high potentials include:

- Office buildings
- Shopping centres
- Supermarkets
- Hotels
- Spas
- District heating systems
- Food processing industry
- Chemical industry and others with high amounts of waste heat

4.1.4 Example of pay back period calculation

Geographic situation:	Shopping center, Paide, Estonia
Industrial Sector:	Shopping Hall
Role of geothermal system:	Heating of building
Type of application:	BTES
Wells depth:	90 m
Number of wells:	10 (partly used)
Geothermal capacity	
heating:	80 kW
cooling:	100 kW (condenser` heat storage)
Investment costs:	50 000 €
Annual savings:	10 000 € (electricity consumption)
Simple payback period:	5 years

4.2. FRENCH SITUATION

4.2.1 Water resource

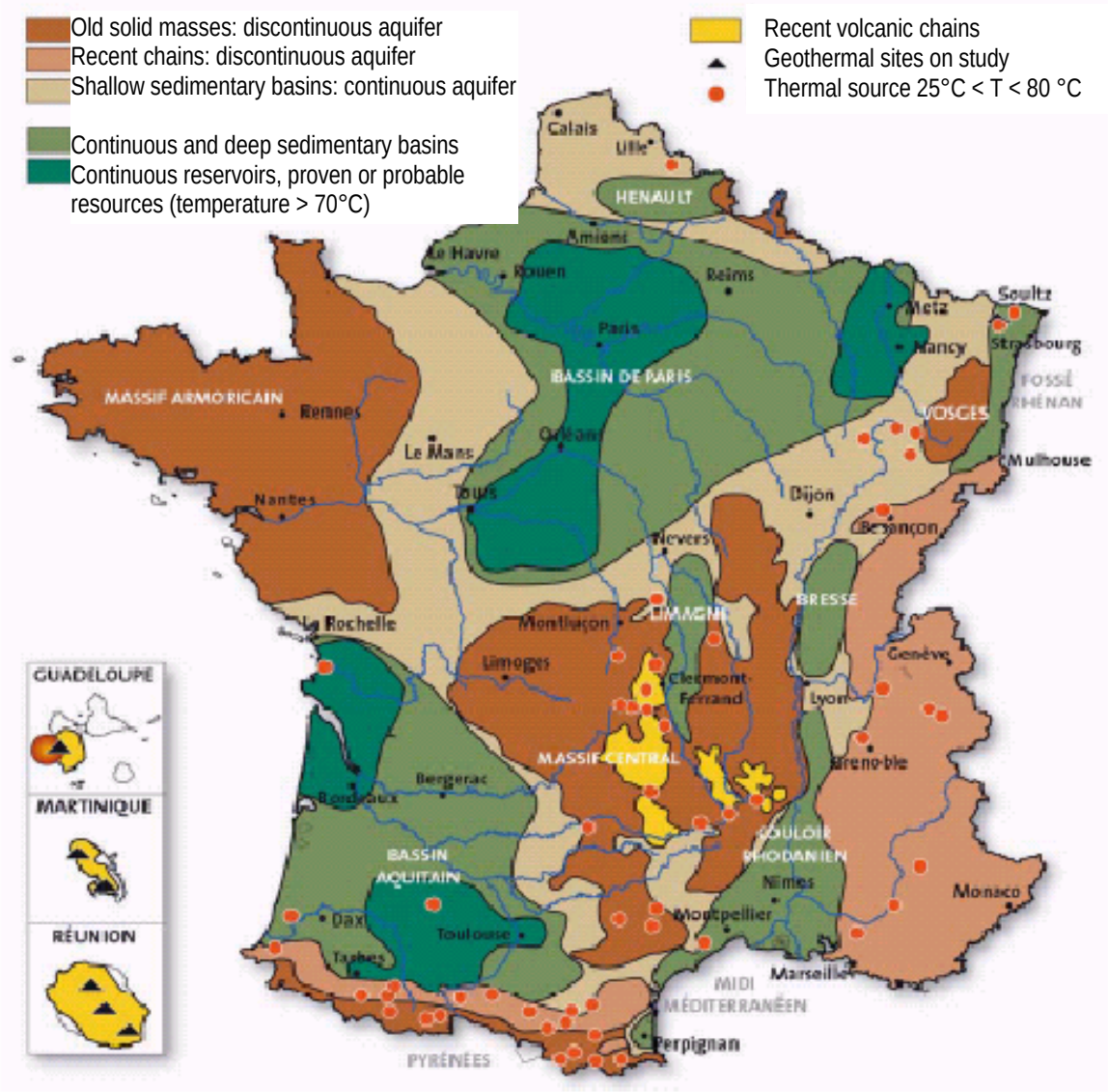


Figure 5 - Sedimentary basins in France (source: BRGM)

Basically, all green zones are favourable to the development of ATES systems. BTES systems can be implemented almost anywhere.

4.2.2 Incentives

Industrial applications are potentially eligible to various incentives systems. New favourable incentives programs should be implemented in 2009 (for more information: www.saunier-associes.com/igeia).

4.2.3 Some ideas of potential industrial sectors

Regarding the coverage of heating/air-conditioning needs in buildings, all of the industrial sectors can be potentially equipped with geothermal systems.

Within this project, some industrial sectors with a great potential for geothermal energy have been identified. These sectors are well developed in France, and part of their process needs could be provided by geothermal systems:

- food industry (farming)
- district heating
- chemical industry
- shopping complex (wholesale and retail trade)

4.2.4 Example of pay back period calculation

Geographic situation:	Ile-de-France
Industrial sector:	pharmaceutical
Role of geothermal system:	pre-heating of chemical products before distillation/cooling of distillate
Type of application:	ATES (aquifer system)
Wells depth:	40 m
Number of wells:	2
Water flow rate:	30 m^3/h
Geothermal capacity	
heating:	220 kW
cooling:	980 kW
Investment costs:	245 000 €
Annual savings:	80 800 € (water and electricity consumption)
Pay back period:	3 years (with constant energy prices, and no subsidies included)

4.3. GERMAN SITUATION

4.3.1 Geological background

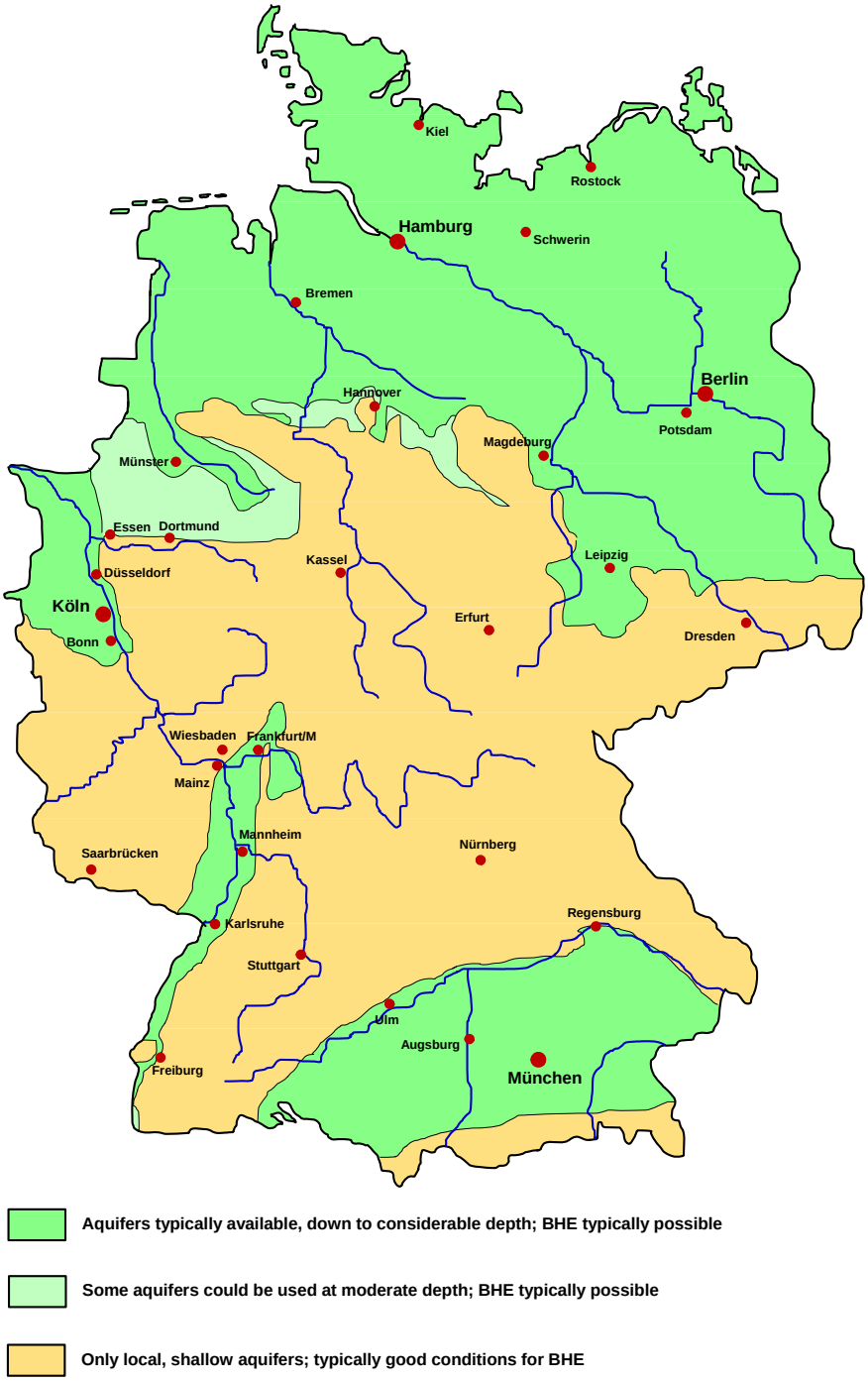


Figure 6 – Main areas in Germany suited for aquifer storage and BHE; deep geothermal (hydrogeothermal) potential can be found in the green areas only

4.3.2 Incentives

Industrial applications can be supported in the framework of the “Marktenreizprogramm” of the Federal Minster of Environment (BMU). There is both an option for deep geothermal (>400 m depth), and for shallow geothermal heat pumps. The latter is, however, limited to smaller projects not to be found in the

industrial, more in the commercial sector. Of the German states (Länder), only Baden-Württemberg currently offers a specific incentive scheme for geothermal uses. For more information, please consult the relevant report at: www.saunier-associes.com/igeia .

4.3.3 Some ideas of potential industrial sectors

Basically, all buildings requiring heating/air-conditioning (offices, shops, etc.) in all industrial sectors might be equipped with geothermal systems. The feasibility on a specific site depends upon the best suited technology (groundwater, BHE, deep geothermal) for the geological conditions and project size, the heat and/or cold demand, the supply temperature needs for heat and cold, the possibility to get the required water/mining licenses, etc.

Within this project, some industrial sectors with a great potential for geothermal energy have been identified for Germany. In most of them, already some projects have been demonstrated, and for offices, geothermal heating and cooling already is a standard option:

- office buildings of all type
- supermarket, shopping malls
- food industry (farming, processing)
- logistics (facilities for storage, handling, etc.)

4.3.4 Example of pay back period calculation

Geographic situation:	Rhein-Main area
Industrial sector:	Transport
Role of geothermal system:	Base load for heat and cold, cooling of IT server facility
Type of application:	Borehole heat exchangers
BHE depth:	100 m
Number of BHE:	80
Geothermal capacity	
heating:	330 kW
cooling:	300 kW
Investment costs:	680 000 €
Annual savings:	62 000 € (electricity consumption)
Pay back period:	11 years (with constant energy prices, and no subsidies included)

4.4. PORTUGUESE SITUATION

4.4.1 Water resource

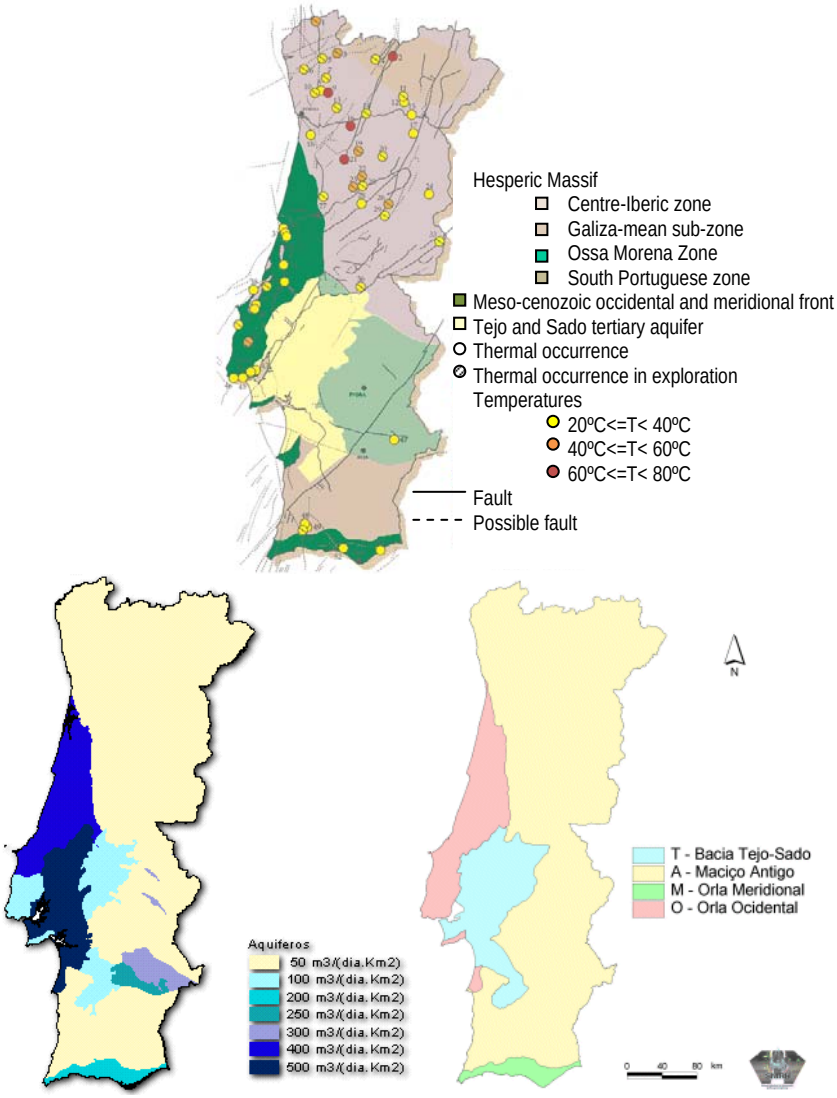


Figure 7 - Geological map with thermal occurrences and Aquifers maps in Portugal (Source: INETI, Portugal and Instituto do Ambiente)

4.4.2 Incentives

In Portugal, financial incentives promoting the use of renewable energy sources in industry are rather scarce. Currently, the only way to obtain a financial aid is by submitting a project proposal to the National Strategic Reference Board (QREN – Quadro de Referência Estratégico Nacional).

This Board has defined 3 frameworks for investments in industry: Incentive Systems to Investment in Industries: Incentive System to Investigation and Technological Development (SI I&DT), Incentive System to Qualification and Internationalization of SME (SI Qualificação PME) and Incentive System to Innovation (SI Inovação). (for more information: www.incentivos.qren.pt)

4.4.3 Some ideas of potential industrial sectors

Low enthalpy geothermal energy (heating and cooling) can be used in many industrial applications and systems.
After studying energy demands and type of energy needed, some industrial sectors have been identified. In Portugal there is no application example, but potential industries include:

- food industry
- district heating
- chemical industry
- shopping and supermarkets
- Greenhouses and farms fish

4.4.4 Example of pay back period calculation

In Portugal, as previously mentioned, there is no example application, only some theoretical studies, using a software that were especially developed to study the pay-back period in some examples of acclimatization in a building.

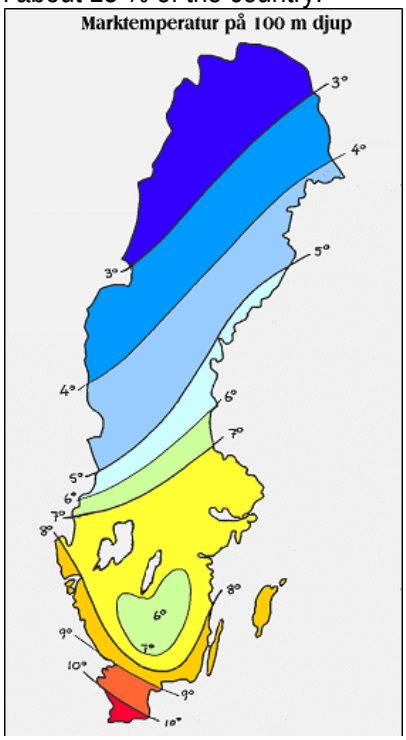
Geographic situation:	Lisbon
Role of geothermal system:	Acclimatization
Type of application:	GSHP
Wells depth total:	1285 m
Project Geothermal capacity	
heating:	82.8 kW
cooling:	89.7 kW
Investment costs:	52 900 € (production equipment and boreholes)
Annual savings:	9 824 €
Pay back period:	5 years (with constant energy prices, and no subsidies included)

4.5. SWEDISH SITUATION

4.5.1 Geological resources

The underground in Sweden provides an excellent source for supplying and storing heating and cooling energy. Furthermore, systems can favourably be combined using surface water and/or outdoor air.

Having high thermal conductivity, the Swedish bedrock is generally favourable for BTES and HT-BTES systems. Aquifers are found in eskers and sedimentary bedrock. They are available for about 30 % of the population but are found only in about 15 % of the country.



Swedish ground temperatures at 100 m depth (°C)

4.5.2 Incentives

There are currently no eligible incentives specifically addressed to Swedish companies who wish to integrate geothermal energy in their applications.

4.5.3 Some ideas of potential industrial sectors

Most industries with a heating/cooling demand are potential users of geothermal energy systems. Examples of industries with especially large potentials are:

- Shopping centres
- Supermarkets
- Hotels
- Airports
- District heating / cooling companies
- Manufacturing industries with cooling needs and a large amount of waste heat

4.5.4 Example of pay back period calculation

Geographic situation:	Kalmar, Småland
Company	Atlas Copco
Industrial Sector:	Manufacturing industry
Role of geothermal system:	Cooling of industrial processes (ovens)
Type of application:	ATES (aquifer system)
Wells depth:	50 m
Number of wells:	5
Water flow rate:	36 m^3/h
Geothermal capacity	
cooling:	1 000 kW (800 ovens; 200 AC)
heating:	300 kW (preheating ventilation air)
Annual Energy savings	520 MWh electricity (Cooling)
	200 MWh district heating
Investment costs:	- 60 000 € (additional investment compared to conventional)
Annual savings:	Approximately 45 000 €
Pay back period:	-1,3 years (with constant energy prices, and no subsidies included)