


> MARKET REPORT ON THE GEOTHERMAL APPLICATIONS POTENTIAL IN THE GERMAN RETAIL INDUSTRY

With the support of :

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Umwelt Baugrund Geothermie Geotechnik

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1 Introduction

This market report reviews the legal, economic, technical, and geological boundary conditions for geothermal energy applications in industry in Germany, for some selected sectors. In particular the food retail sector is considered, as the industrial partner to UBeG GbR in this project is active in that field, and as this sector offers perfect opportunities to create geothermal energy solutions in a number of sizes.

For the statistical data, whenever possible values from the year 2007 were selected. Only in few cases, where the statistical data need longer evaluation and preparation periods, timelines end already in 2006. The main source for statistical data is the relevant German Federal Office, ministries, and industrial associations. The acronyms of the main sources that are used throughout the report are listed below:

Stat. BA	Statistisches Bundesamt	Federal Office of Statistics
BDI	Bundesverband der Deutschen Industrie	Association of the German Industry
HDE	Hauptverband des Deutschen Einzelhandels	Association of German Retailers
BMWi	Bundesminister für Wirtschaft etc.	Federal Minister of Economics
BMU	Bundesminister für Umwelt etc.	Federal Minister of the Environmnet

In the year 2006, a total of ca. 350 MTOE of primary energy have been consumed in Germany (figure 1), the majority from oil and gas. The share of renewables in the total number was 5,8 %, coming mainly from biomass (figure 2). By 2020, the mandatory target set for Germany will be 18 % renewables, substantially more than the current nuclear energy share. Of the final energy, 43,5 % go to industrial and commercial consumption (figure 3).

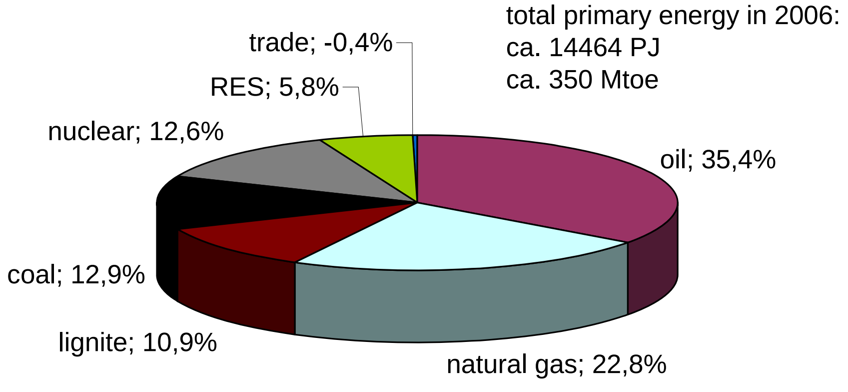

Figure 1 : Primary energy consumption in Germany 2006 (after data from BMWi)

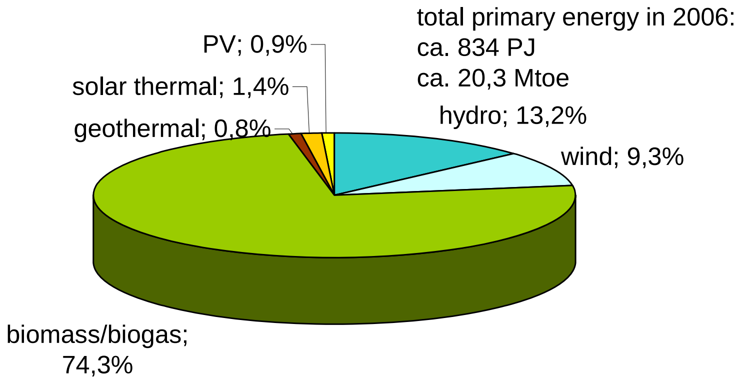

Figure 2 : Renewable primary energy in Germany 2006 (after data from BMWi)

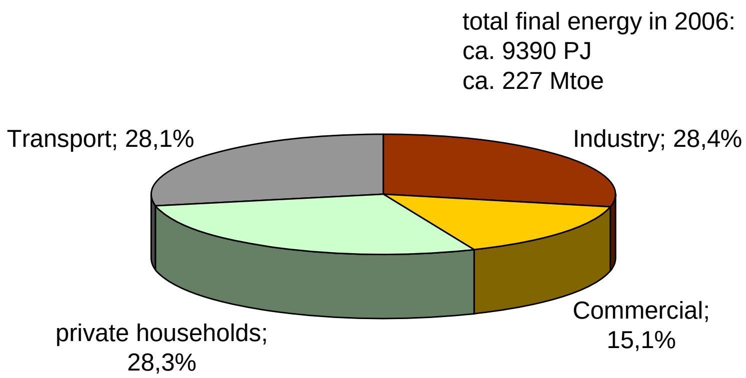

Figure 3 : End energy consumption in Germany by sector 2006 (after data from BMWi)

2 Legal and technical conditions for geothermal applications

2.1 Legislation for geothermal energy in Germany

In Germany, Geothermal Energy is understood as the *"energy stored in form of heat beneath the surface of the solid earth"*. Laws exist both on the federal level (*Bund*) and on the state level (*Länder*). Geothermal energy in Germany is governed by the Federal Mining Act (*Bundesberggesetz*, or BBergG for short).

According to § 3 BBergG ("Bundesberggesetz"; Federal Mining Act), geothermal energy is not a property of the land owner, but belongs to the federal administration (bergfreier Rohstoff). Exploration and exploitation of this kind of resources, like coal, various types of ore, oil, or natural gas, is regulated by the authorities and is granted to an applicant, usually with a certain regular payment to be made according to the amount of the resource exploited (*Förderzins*). However, for geothermal energy, because of the still poor economics and the wish to foster environmentally benign energy, a royalty payment is not required.

The first application is for exploration, after proving the resource, a license for exploitation is given. The license for exploration and, if the resource has been proven, for exploitation gives a rather strong legal position to its holder. If necessary, even the (temporary) right for land use against the will of the owner can be obtained through court order, of course with fair financial compensation. The extension of a mining field according to such license is delineated on the earth surface and shown in a map (fig. 4), and in the vertical dimension it always starts at the ground surface and extends downward (theoretically down to the centre of the earth). When a mining license is given, other aspects like water protection and environmental issues are dealt with by the mining authorities in collaboration with the relevant offices, and the necessary approvals are included in the mining license. The further use (heating, power plant) is not governed by mining law.

An exception is stated in the mining act for the use of a "bergfreie" resource, if it is used on the same lot where it is exploited, and is used only for the construction and operation of buildings on that lot, belonging to the owner of the lot (§ 4 BBergG). In this case no license is required.

However, even here the mining authorities might come into the play again, if § 127 BBergG is fulfilled, asking for a specific approval for boreholes which penetrate into the underground more than 100 m. Use of this exception is made for most of the ground-source heat pump (GSHP) plants in the residential sector, and this fact is the explanation why so many borehole heat exchangers for heat pumps in Germany have a depth of 99-100 m.

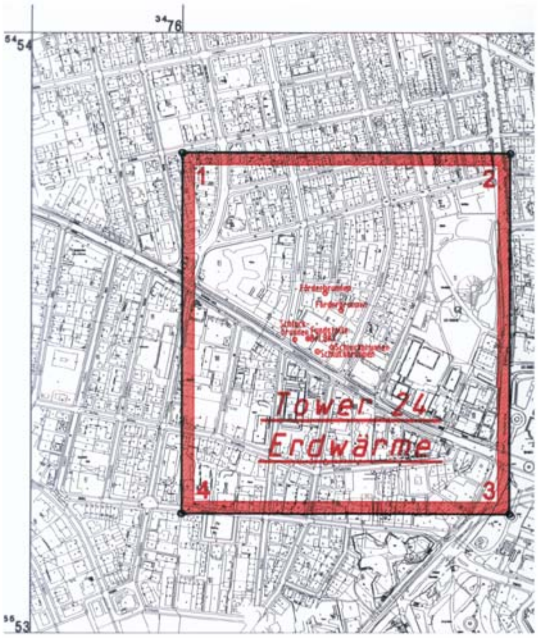

Figure 4 : Example of an exploration mining field on geothermal energy for a large office building right in a city centre

For shallow geothermal systems, usually the exception of § 4 BBergG takes care. In this case, the water authorities need to give a license according to § 3 and § 7 WHG ("Wasser-haushaltsgesetz"; Water Framework Act), and the relevant state laws (water law is governed by the states)

In cases where the mining law is not applicable, other authorities ascertain that there is no harm done to the environment by a geothermal application. Thus shallow geothermal energy is mainly governed by the water law. The Federal Water Household Act (*Wasserhaushaltsgesetz* WHG) only gives a framework, and the relevant state laws handle the details. Water authorities are purely state authorities; on the federal level, there is only a regular coordination group of the states (*Länderarbeitsgemeinschaft Wasser* LAWA).

According to WHG and the state water laws, the use of groundwater requires a license from the water authorities (in a mining license, the right to use groundwater is included, if it is part of the exploitation). The case is obvious for ground water heat pumps; however, by definition even borehole heat exchangers use ground water, if the physical properties of the groundwater are changed (i.e. the water is heated or cooled). Another area of concern is possible groundwater pollution, which may occur during drilling operation, by connecting different aquifers, or in the case of a leakage of antifreeze from a borehole heat exchanger. Most of the states (Bayern, Baden-Württemberg, Rheinland-Pfalz, etc.) already have guidelines how the licensing procedure should be handled (figure 5).

Figure 5 : Examples of state guideline brochures for licensing of shallow geothermal plants in Germany

In general, the guidelines require standard VDI 4640 to be followed for the technical part. The basic technical requirements for sound design, safe construction and reliable operation of shallow geothermal installations (down to about 400 m) are given in the guideline VDI 4640 of the Association of German Engineers (*Verein Deutscher Ingenieure*, VDI). To facilitate the site-specific design of smaller plants, the

Geological Survey of Nordrhein-Westfalen has compiled a database of ground thermal parameters down to 100 m depth for the whole area of the state, available on CD-ROM. Similar work is under way in other states also to increase the use of GSHPs.

Licences for exploration and production are given, upon submitted programs, for specified licence areas (*Erlaubnisfelder*). Herein the surface area is delimited without a depth limitation. Legally, the right to use the geothermal heat resides with the owner of the mining license, no matter what the depth of that use will be. In the worst case, the owner of a mining license for a shallow borehole heat exchanger could prevent the construction of a deep geothermal plant, and vice versa.

2.2 Technical options for geothermal energy in Germany

Both shallow and deep geothermal technologies are known in Germany and have already been demonstrated. The delineation between these realms typically is drawn at a depth of about 400 m.

2.2.1 Deep geothermal systems

Deep geothermal systems exploit warm to hot water from greater depth. Depending on water temperature, steam production and subsequent electric power is possible, with lower temperature covering space heating and process heat demands.

Two basic systems can be used for harassing the heat from deep below. In areas with permeable layers also in greater depth, the hydrothermal method is preferred (the deep groundwater is directly extracted by a pump, figure 6 right). In areas with low permeability, artificial cracks and fissures are created in order to allow for pathways for the geothermal water (“Enhanced Geothermal System”, left). Areas with a potential for deep, warm aquifers are shown in figure 17.

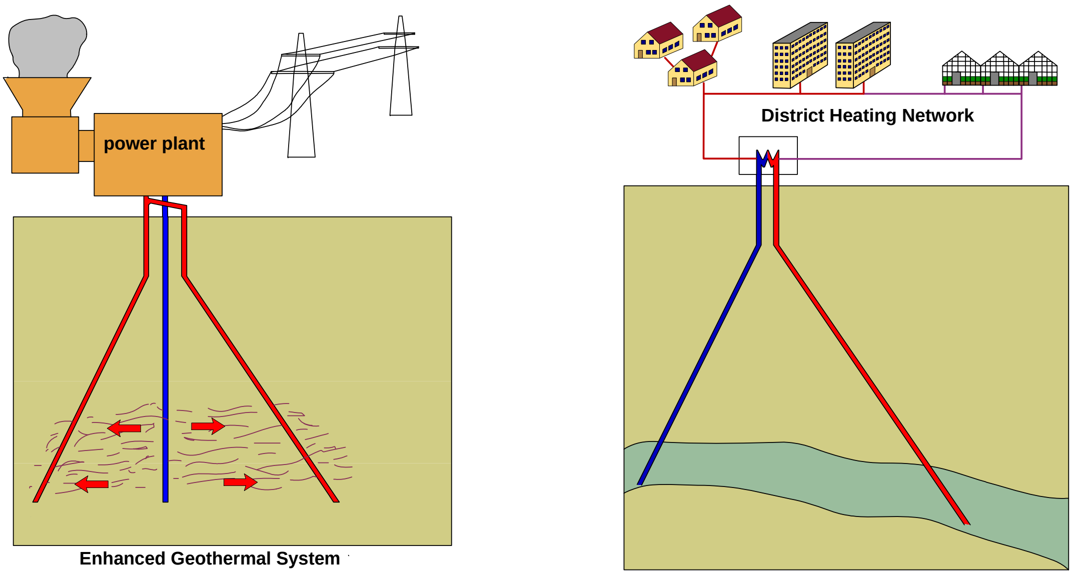

Figure 6 : Schematics of deep geothermal technology options; “Enhanced Geothermal System” to the left, hydrothermal plant to the right.

Figure 7 shows the already existing deep geothermal plants in Germany. Currently larger wells for geothermal district heating systems are under construction in the Munich area. With sufficient temperature, the connection to industrial process heat might be considered. This kind of industrial application already has been demonstrated in other countries, in particular in the agricultural and food industry (drying processes). Projects in Germany had been already planned (e.g. for a leather factory, a sugar refinery, greenhouses), but no project of that type has actually been done yet.

Figure 7 : Existing deep geothermal heating plants in and around Germany (blue: District Heating, green: Combined Heat and Power), cut from a map by EGEC

2.2.2 Shallow geothermal systems

Shallow geothermal systems are very versatile and can be adapted to almost every subsurface condition. Typically the ground system links a heat pump for achieving sufficiently high temperatures. Ground systems can be classified generally as open or closed systems, with a third category for those not truly belonging to one or the other.

To choose the right system for a specific installation, several factors have to be considered: Geology and hydrogeology of the underground (sufficient permeability is a must for open systems), area and utilisation on the surface (horizontal closed systems require a certain area), existence of potential heat sources like mines, and the heating and cooling characteristics of the building(s). In the design phase, more accurate data for the key parameters for the chosen technology are necessary, to size the ground system in such a way that optimum performance is achieved with minimum cost. The individual types of ground systems are described in more detail on this and the following pages.

Open systems

This type is characterised by the fact that the main heat carrier, ground water, flows freely in the underground, and acts as both a heat source/sink and as a medium to exchange heat with the solid earth. Main technical part of open systems are groundwater wells, to extract or inject water from/to water bearing layers in the underground („aquifers"). In most cases, two wells are required („doublette"), one to extract the groundwater, and one to re-inject it into the same aquifer it was produced from.

With open systems, a powerful heat source can be exploited at comparably low cost. On the other hand, groundwater wells require some maintenance, and open systems in general are confined to sites with suitable aquifers. The main requirements are:

- Sufficient permeability, to allow production of the desired amount of groundwater with little drawdown.
- Good groundwater chemistry, e.g. low iron content, to avoid problems with scaling, clogging and corrosion.

Open systems tend to be used for relatively larger installations.

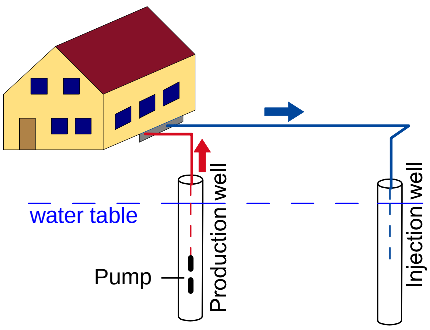

Figure 8 : Groundwater heat pump (open system, doublette)

Closed systems

a) horizontal

The closed system easiest to install is the horizontal ground heat exchanger (synonym: ground heat collector, horizontal loop). Due to restrictions in the area available, in Western and Central Europe the individual pipes are laid in a relatively dense pattern, connected either in series or in parallel.

For the ground heat collectors with dense pipe pattern, usually the top earth layer is removed completely, the pipes are laid, and the soil is distributed back over the pipes. In Northern Europe (and in North America), where land area is cheaper, a wide pattern („loop") with pipes laid in trenches is preferred. Trenching machines facilitate installation of pipes and backfilling.

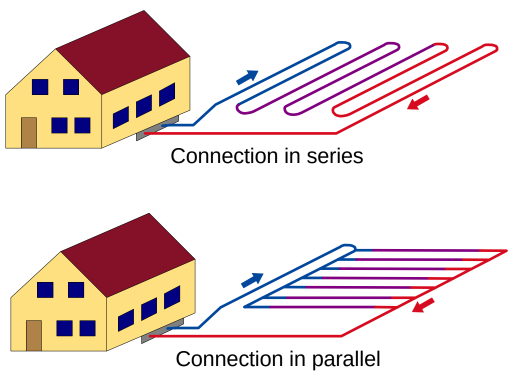

Figure 9 : Horizontal ground heat exchanger (European style)

To save surface area with ground heat collectors, some special ground heat exchangers have been developed. Exploiting a smaller area at the same volume, these collectors are best suited for heat pump systems for heating and cooling, where natural temperature recharge of the ground is not vital. Hence these collectors are widely used in Northern America, and one type only, the trench collector, achieved a certain distribution in Europe, mainly in Austria and Southern Germany. For the trench collector, a number of pipes with small diameter are attached to the steeply inclined walls of a trench some meters deep.

The main thermal recharge for all horizontal systems is provided for mainly by the solar radiation to the earth´s surface. It is important not to cover the surface above the ground heat collector, or to operate it as a heat store, if it has to be located e.g. under a building.

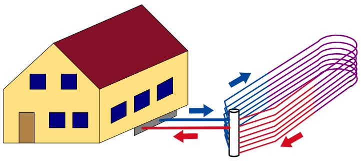

Figure 10 : Horizontal ground heat exchanger (European style)

b) vertical

As can be seen from measurements dating as far back as to the 17th century, the temperature below a certain depth („neutral zone“, at ca. 15-20 m depth) remains constant over the year. This fact, and the need to install sufficient heat exchange capacity under a confined surface area, favours vertical ground heat exchangers (borehole heat exchangers).

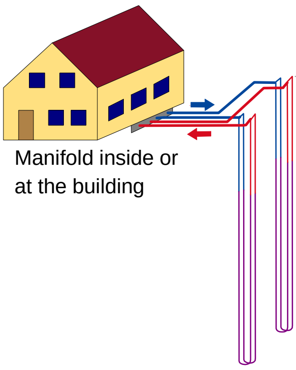

Figure 11 : Borehole heat exchangers (double-U-pipe)

In a standard borehole heat exchanger, plastic pipes (polyethylene or polypropylene) are installed in boreholes, and the remaining room in the hole is filled (grouted) with a pumpable material. In Sweden, boreholes in hard, crystalline rock usually are kept open, and the groundwater serves for heat exchange between the pipes and the rock. If more than one borehole heat exchanger is required, the pipes should be connected in such a way that equal distribution of flow in the different channels is secured. Manifolds can be in or at the building, or the pipes can be connected in trenches in the field.

Several types of borehole heat exchangers have been used or tested; the two possible basic concepts are:

- U-pipes, consisting of a pair of straight pipes, connected by a 180°-turn at the bottom. One, two or even three of such U-pipes are installed in one hole. The advantage of the U-pipe is low cost of the pipe material, resulting in double-U-pipes being the most frequently used borehole heat exchangers in Europe.
- Coaxial (concentric) pipes, either in a very simple way with two straight pipes of different diameter, or in complex configurations.

Ground source heat pump plants of every size have been realised with borehole heat exchangers, ranging from small houses with just one borehole to large buildings, requiring whole fields of borehole heat exchangers. One of the highest number of boreholes for a single plant in Europe have been installed for the head office of the German Air Traffic Control (Deutsche Flugsicherung), with 154 borehole heat exchangers each 70 m deep.

The heat source for thermal recovery of borehole heat exchangers is solar heat (in the upper part) and the geothermal heat flux (in the lower part), with some influence from flowing ground water or percolating water. However, the influence of groundwater in most cases is not very big, and the thermal conductivity of the ground is the main parameter.

The borehole filling and the heat exchanger walls account for a further drop in temperature, which can be summarised as borehole thermal resistance. Values for this parameter usually are on the order of 0.1 K/(W/m); for a heat extraction of 40 W/m, this means a temperature loss of 4 K inside the borehole. Thermally enhanced grouting (filling) materials have been developed to reduce this losses.

A special case of vertical closed systems are „energy piles“, i.e. foundation piles equipped with heat exchanger pipes. All kind of piles can be used (pre-fabricated or cats on site), and diameters may vary from 40 cm to over 1 m.

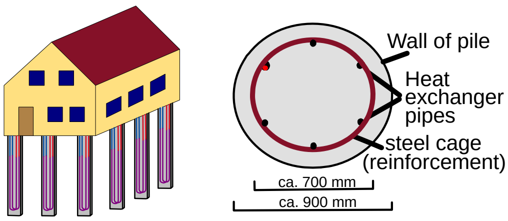

Figure 12 : Energy Piles

A variation of the horizontal ground source heat pump is direct expansion. In this case, the working medium of the heat pump (refrigerant) is circulating directly through the ground heat collector pipes (in other words, the heat pump evaporator is extended into the ground; fig. 13). The advantage of this technology is the omission of one heat exchange process, and thus a possibility for better system efficiency. Direct expansion requires good knowledge of the refrigeration cycle, and is restricted to smaller units. Also heat pipes as heat source have been tested (fig. 13); they work well for heat extraction, but not at all for heat injection.

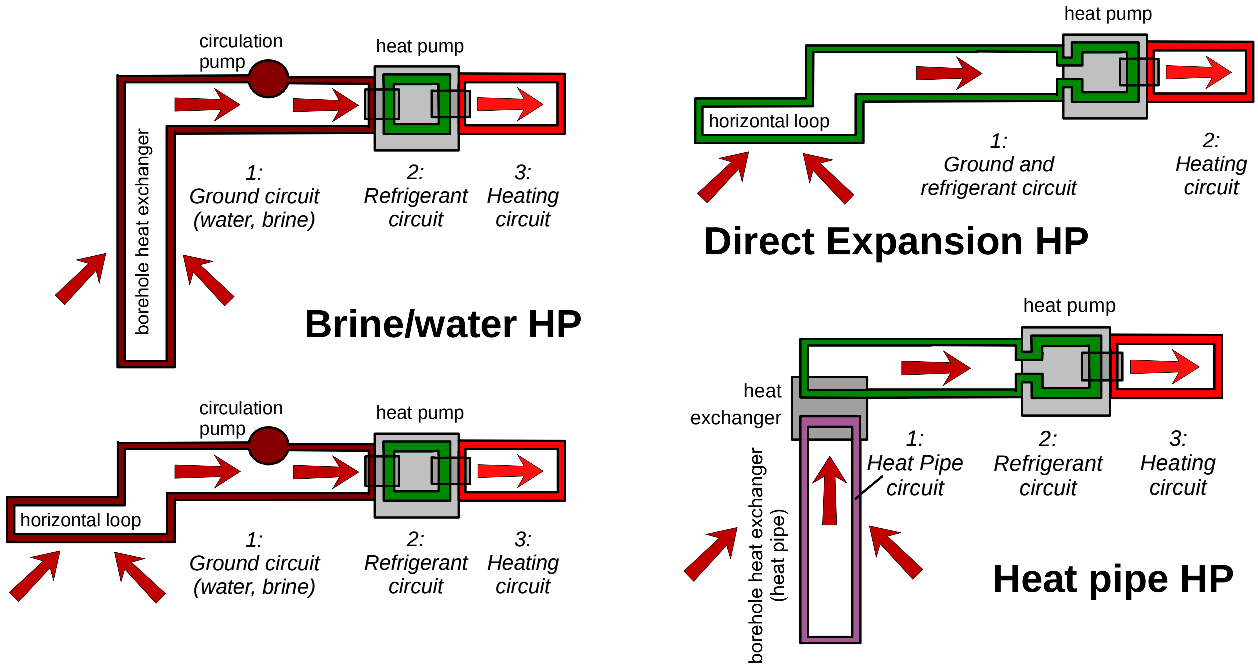

Figure 13 : Ground side connection options for ground source heat pumps

With the classical brine (liquid) system, the ground can easily be used for cooling, also. Heat is rejected into the ground, either by running the heat pump in reverse (figure 14), or by directly coupling the building circuit to the ground circuit. All the installation (heat pumps, manifolds) and the drilling operation for industrial applications is much larger than for residential houses (figure 15).

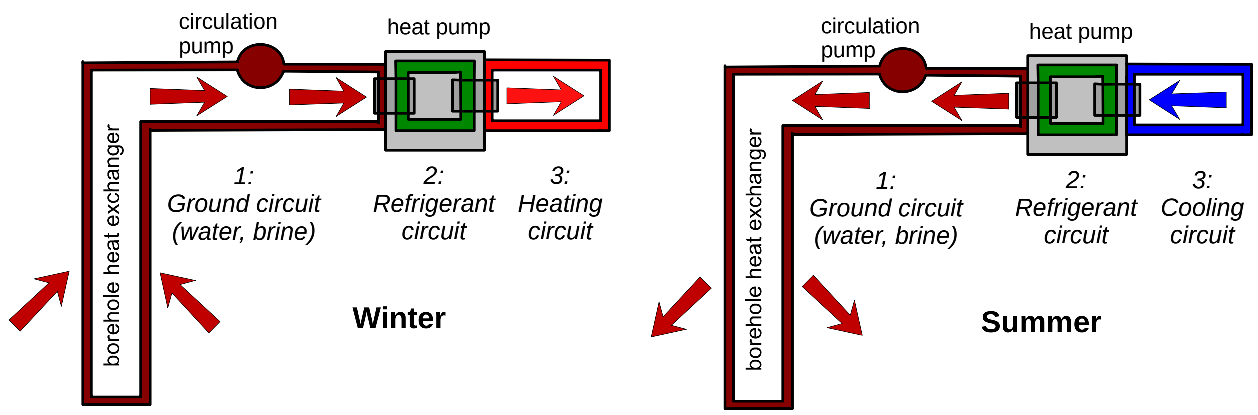

Figure 14 : Reversible ground source heat pumps for heating and cooling

Figure 15 : Large ground source heat pump (ca. 400 kW), manifold and drilling for larger project

3 Climatic and geological conditions for geothermal applications

3.1 Climatic situation in Germany

Most of Germany is located in a moderate climate with mild winters and not too warm summers. Only in high elevations (e.g. Harz, Black Forest, Alpes) cold and long winters can be found. The temperature difference summer-winter is more pronounced in the East, where a transition to continental climate can be experienced. From the climatic viewpoint, no specific problems have to be expected.

According to meteorological standard DIN 4710, Germany is divided into 15 different climatic zones (figure 16). The main parameters (temperature, precipitation) for each zone are given in table 1.

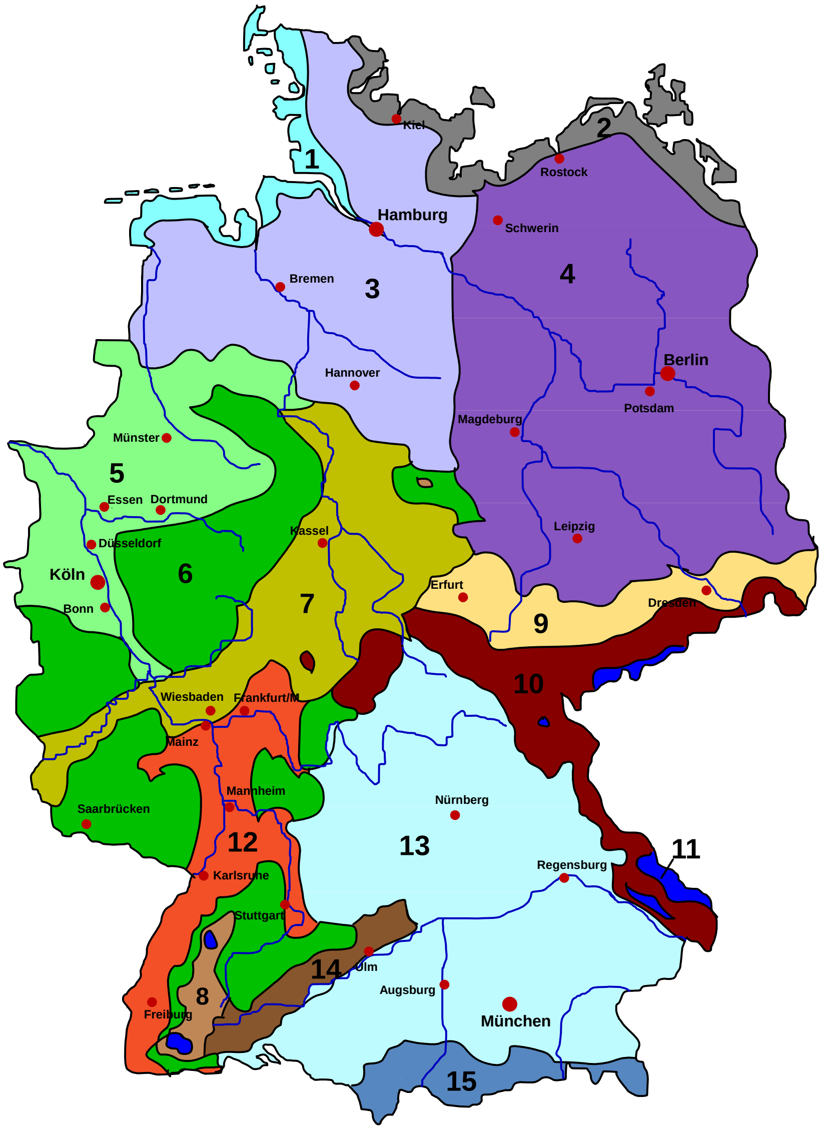

Figure 16 : Climatic zones in Germany (after DIN 4710)

Table 1: Climatic zones according to DIN 4710 (conf. fig. 16)

Zone No.	Annual Average (°C)	Amplitude (K)	Precipitation (mm/a)
1	9,0	7,9	741,4
2	8,4	8,3	589,0
3	8,5	8,1	770,3
4	9,5	10,3	573,9
5	8,1	6,5	733,0
6	6,8	8,4	1168,7
7	8,8	8,6	698,4
8	6,0	8,3	1263,8
9	7,6	8,9	700,7
10	6,3	9,2	742,0
11	3,8	15,0	1117,7
12	10,2	9,1	667,6
13	7,9	9,9	636,6
14	6,8	8,9	1068,5
15	6,8	9,4	1363,5

3.2 Geological situation in Germany

For deep geothermal, only the larger basins in the North and in the Bavarian Molasse basin, and the Upper Rhine Graben, allow for hydrothermal projects (figure 17 gives an overview).

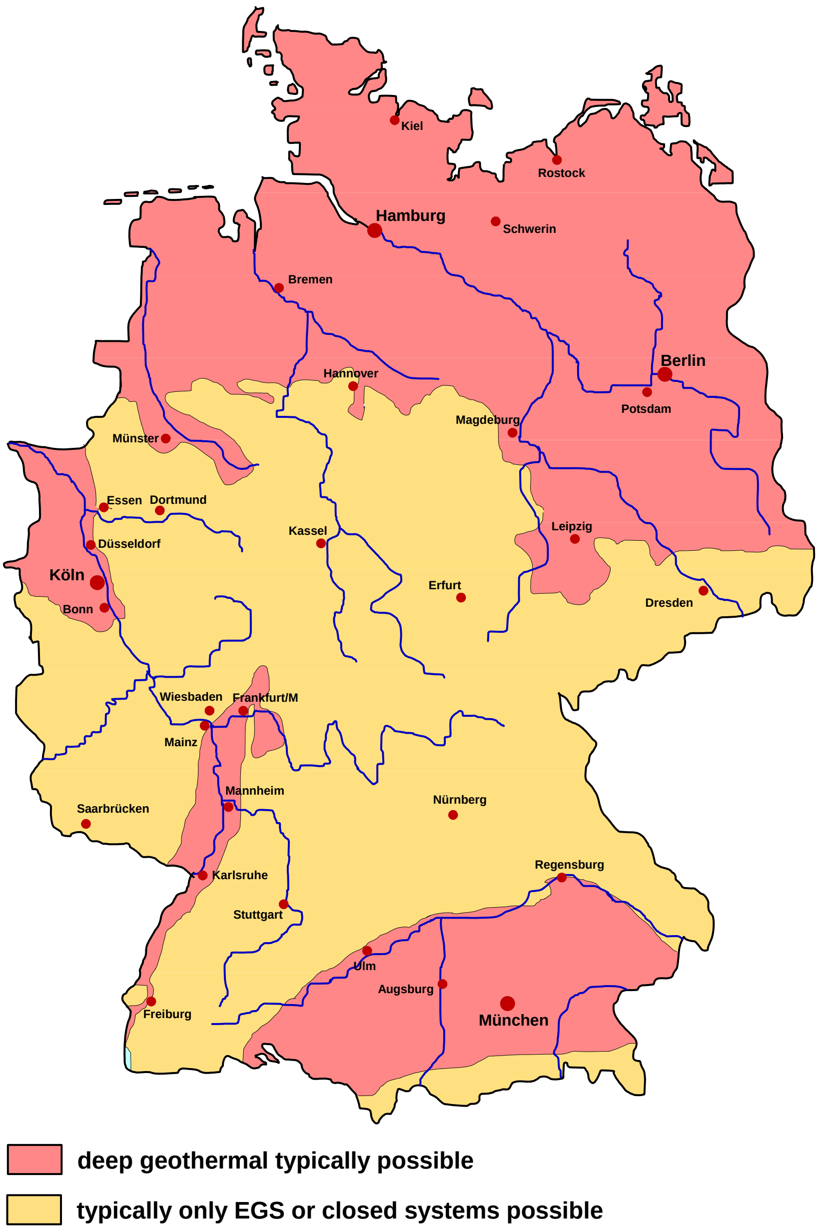

Figure 17 : Sites with deep geothermal potential in Germany

A similar map can be shown for open systems in the shallow geothermal field (figure 18), and in figure 19 a map is presented with relevant ground parameters for shallow geothermal closed systems (BHE). It should be noted that the maps can only give a first assessment of the potential on site, and further investigation (hydrogeology, well test for open systems and thermal response test for closed systems) needs to be done.

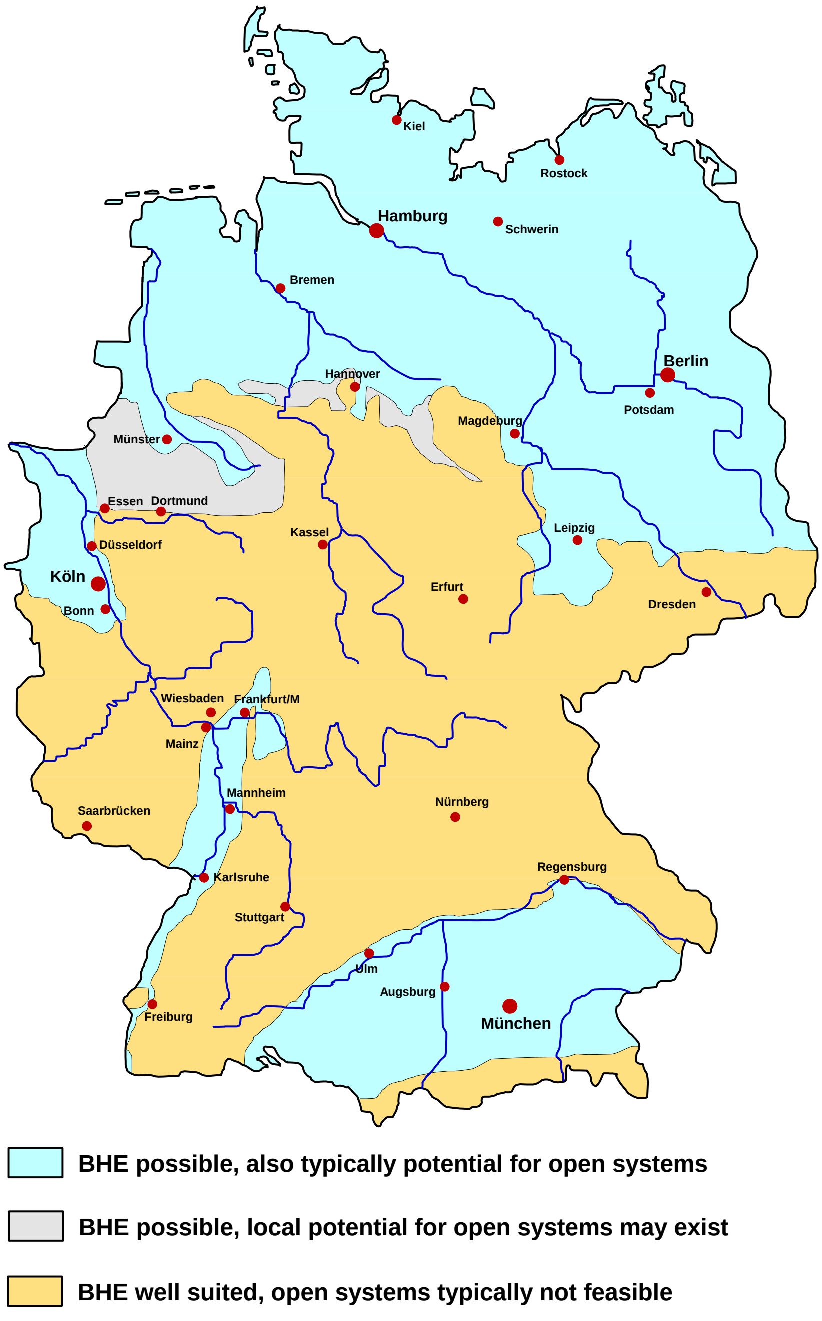

Figure 18 : Sites with open / closed system shallow geothermal potential in Germany

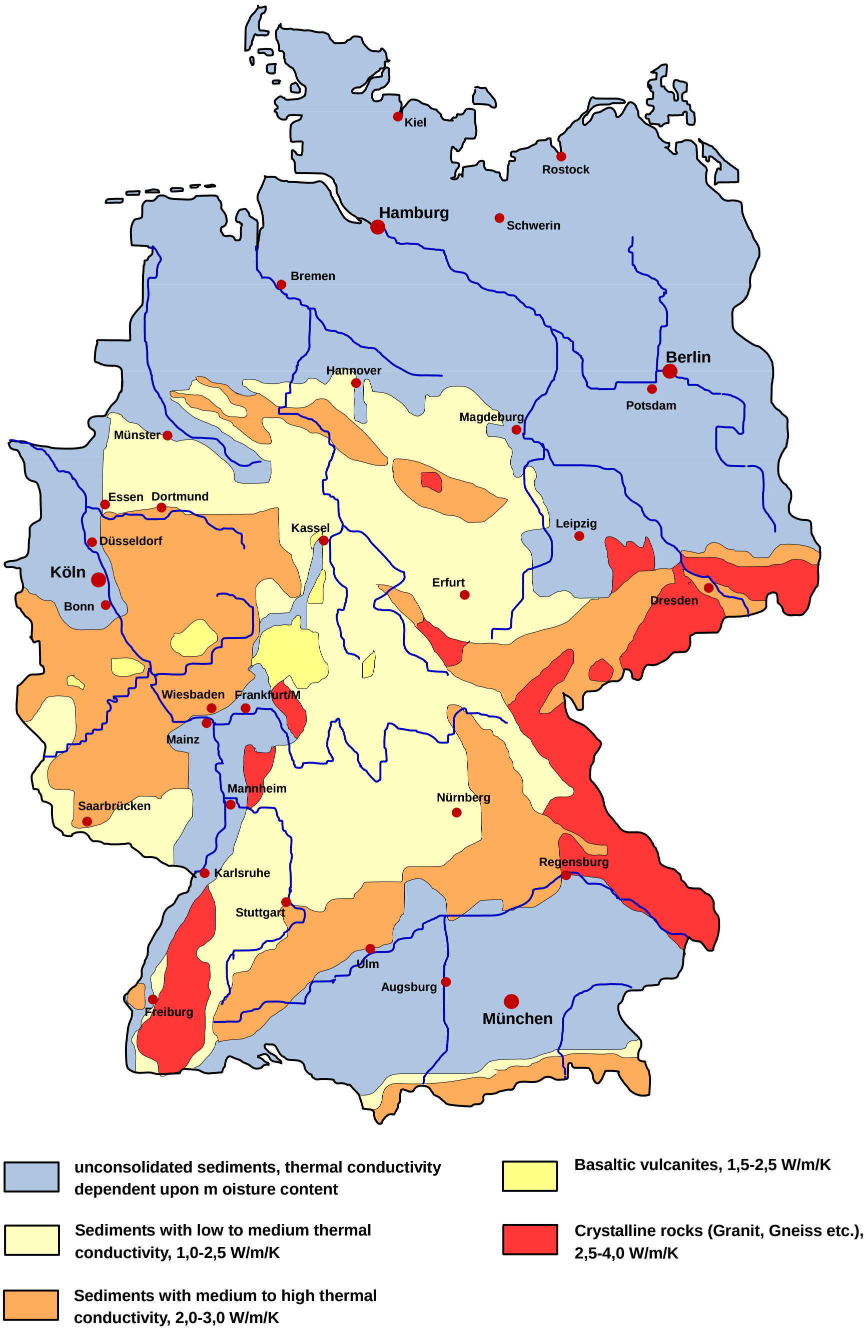

Figure 19 : rock type and thermal conductivity for closed systems

4 Energie consumption in industry

The demand in heat for space heating, hot water and process heat amounted in 2006 in both the commercial and industrial sector combined ca. 3000 PJ (fig. 20). In the commercial sector the majority is for space heating, in the industry sector for process heat. Geothermal energy can provide both, depending upon geological conditions. Also electricity production from geothermal sources has already been demonstrated in Germany (cf. fig. 7); as the electric power prices for industry in Germany are also increasing (fig. 21), this might be an additional incentive to apply geothermal energy also in the power generation field.

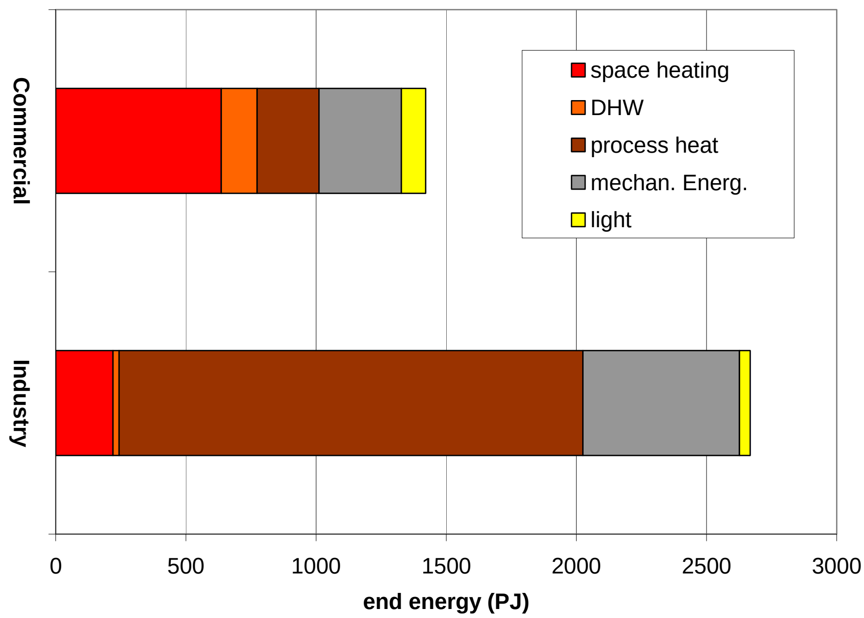

Figure 20 : end energy use in industry and commerce in Germany for 2006 (from data from BMWi)

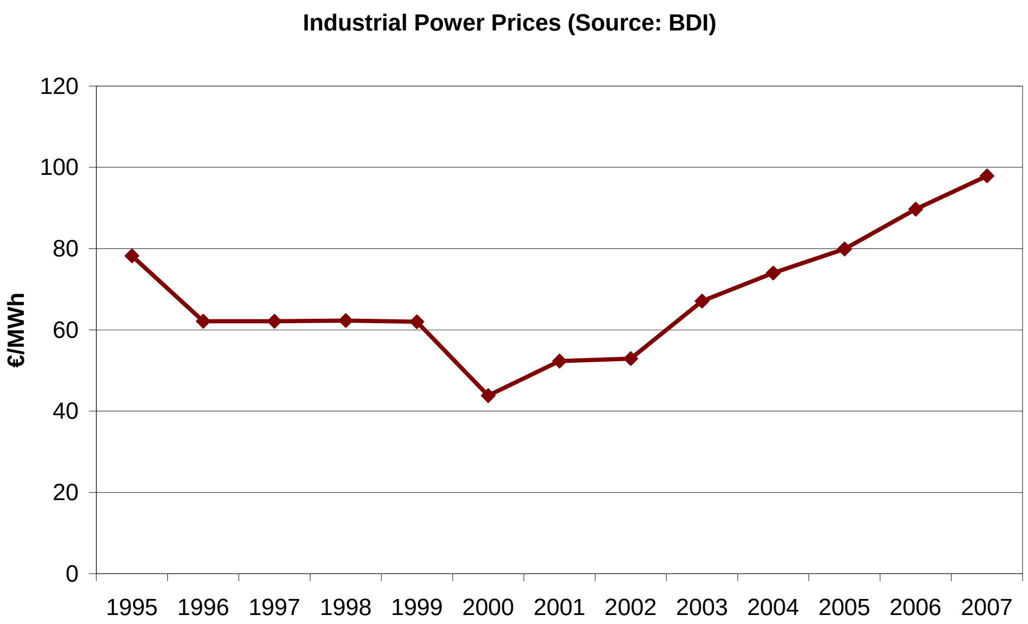

Figure 21 : Mean electric power prices for industry (after data from BDI)

4.1 Chosing potential application fields from ISIC industry classification

From the standard classification developed by the United Nations (which is called the International Standard Industrial Classification - ISIC), the classes listed in table 2 can be considered as a potential target for geothermal energy applications.

Table 2: Industrial classes suitable for geothermal energy applications

A - Agriculture, forestry and fishing	This field offers a tremendous variety of geothermal energy applications, which are already demonstrated world-wide. A specific brochure in FP6-project "RESTMAC" gives more details: http://www.egec.net/target/Brochure%20DISTRICT%20HEATING.pdf
B - Mining and quarrying C - Manufacturing	These are the fields with the highest demand in process heat, for which geothermal energy can contribute
D - Electricity, gas, steam and air conditioning supply	The classical energy related industry; geothermal can help much towards their needs
G - Wholesale and retail trade, repair of motor vehicles and motorcycles	In the food retail sector, cooling of the products accounts for the major energy consumption. Geothermal systems can help to increase efficiency and to use the resulting heat for space heating.
I – Accommodation and Food service activities K - Financial and insurance activities M - Professional, scientific and technical activities N - Administrative and support service activities O - Public administration and defence, compulsory social security P – Education Q - Human health and social work activities R - Arts, entertainment and recreation	Buildings for these industry fields are more or less like offices and residential buildings, and geothermal energy applications for heating and cooling does not significantly deviate from these well-known systems. Also economic situation and site requirements are similar, so these fields are not considered in the current study on specifc industrial applications.

Following the above considerations, the most interesting fields for additional market penetration of geothermal energy will be the classes B, C, D and G. While in B, C and D larger systems with high energy output (and typically higher temperatures) will prevail, class G calls for smaller systems at low to medium temperatures. As the industrial partner in the IGEIA project in Germany is active in the food retail sector, field G now will be investigated in some more detail.

4.2 Size of chosen sector G: retail

From fig. 22 we can see that almost 3 Million people work in the retail sector (G), with a rather stable development. The producing sectors B and C have many more employees, however, the number is continuously decreasing. The annual turnover in fig 23 tells in addition that the value created by the workers in the retail sector is much smaller, being about ¼ of the amount in sectors B and C (with only about double the workforce).

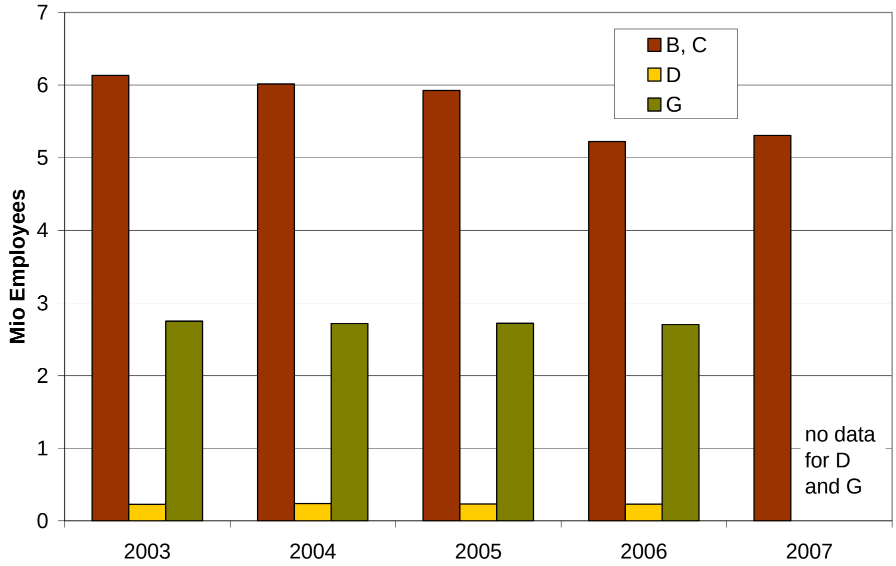

Figure 22 : Number of employees in sectors B,C, D and G (after data from Stat. BA)

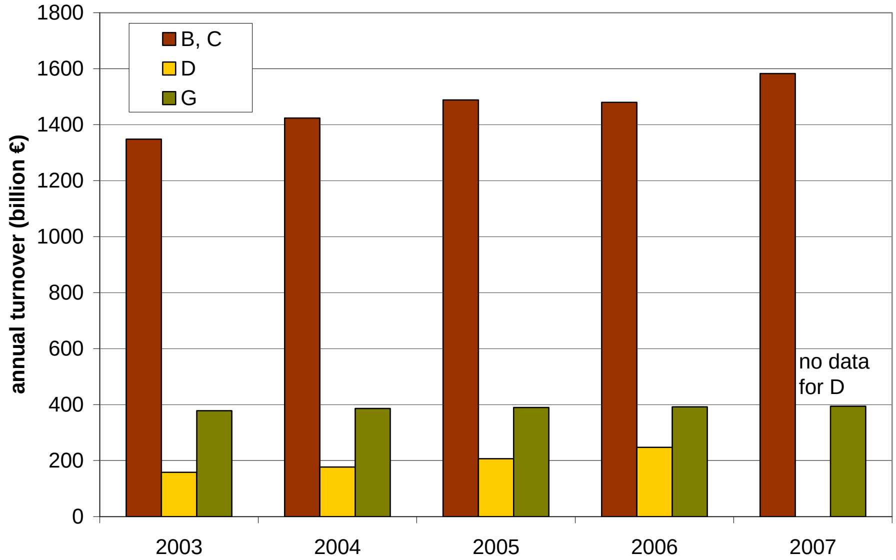

Figure 23 : annual turnover in sectors B,C, D and G (after data from Stat. BA)

5 The food retail sector

5.1 Structure and growth of the sector

The food retail sector, where the UBeG GbR industry partner in IGEIA is active, shows a slow, but steady growth. The sales area is increasing continuously (fig. 24), while sales force is diminishing (Fig. 25). The result is more shop with less service people, and as figure 25 shows, also in higher turnover with less workforce. That asks for an increased application of renewable energies, in order to have reduced energy cost alongside the reducing of staff cost.

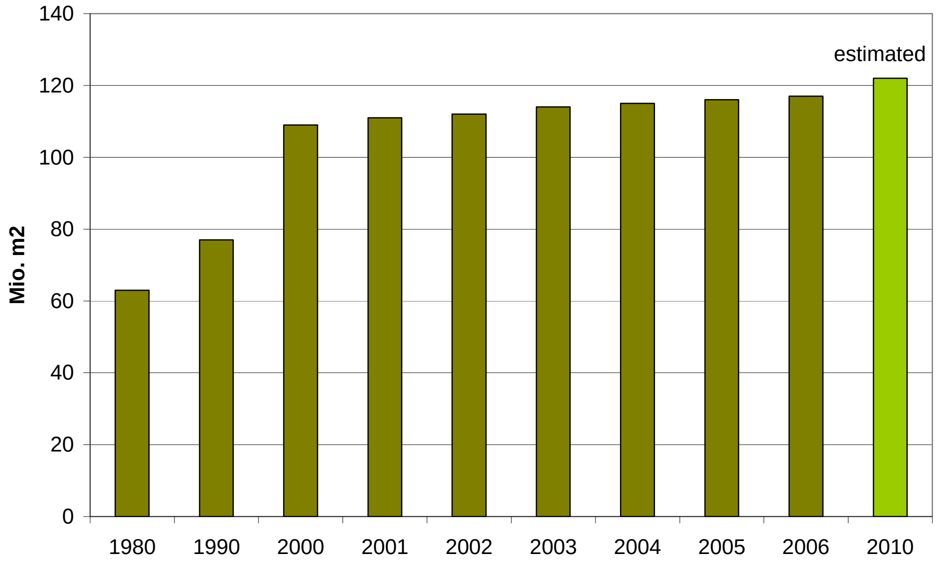

Figure 24: Development of retail sales area in Germany (after data from HDE)

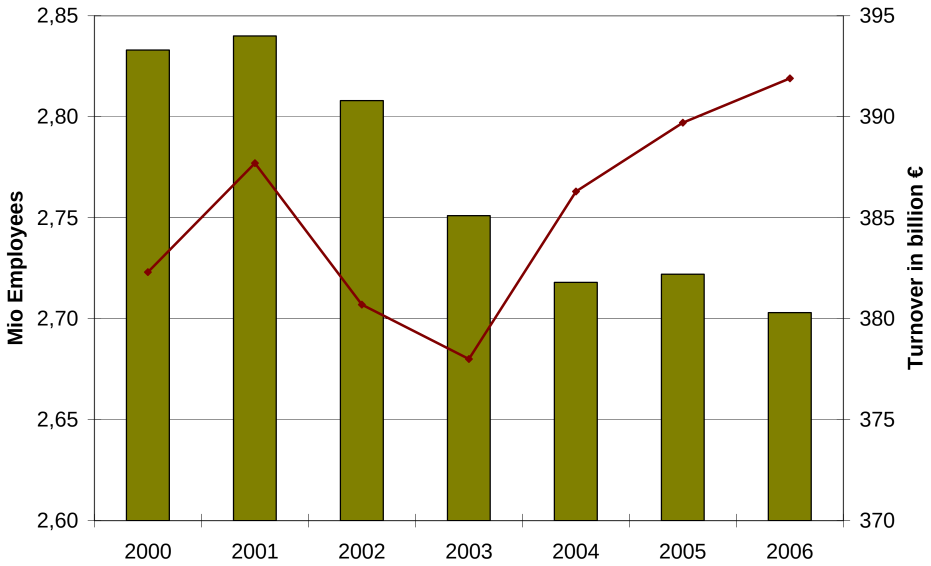

Figure 25: Development of number of employees and annual turnover in retail in Germany (after data from HDE)

The retail sector is built up of a large number of small individual commercial entities (figure 26), with about 90 % of all counted shops having less than 10 employees. A geothermal energy system most probably would be suitable for larger installations; those with 10 employees and more in 2005 counted to 81562 units.

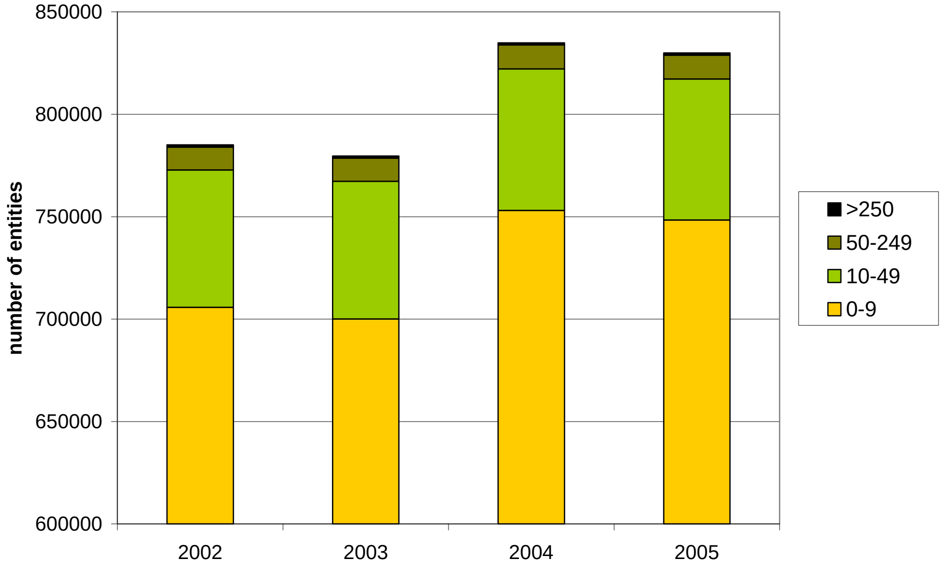

Figure 26 : Number of individual commercial entities in sector G, classified for number of employees (after data from Stat. BA)

5.2 Floor area and buildings

As already was shown in fig. 24, there is a steady growth of the sales area in retail, amounting to an annual increase of close to 1 % for the years 2004-2006. However, there is no statistic about the number of supermarket buildings. A survey from published data of the largest supermarket chains in Germany gives the results shown in figure 27, with a total of about 33'000 buildings of these large chains alone!

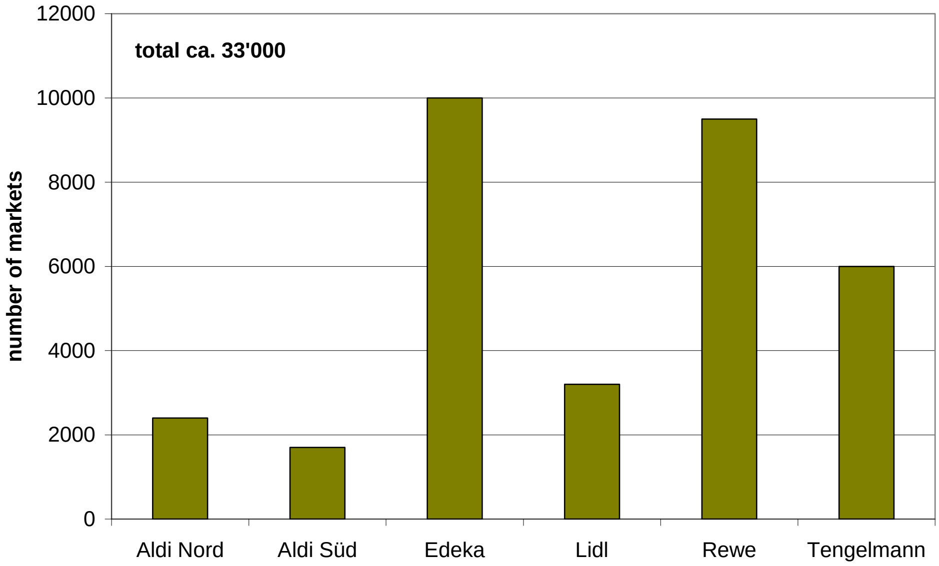

Figure 27 : Number of supermarkets of the large chains in Germany (after data from company publications)

As most of the supermarkets shown in figure 27 will be in the range of >10 employees, this matches well with the total number of entities of that size in retail of >80’000, so that supermarkets (food retail) will account of some 40 % of the total retail.

Considering the fact that most supermarket buildings are destined for a lifetime of some 20-30 years, about 4 % of the buildings will have to be replaced or built new each year. The annual growth in retail area not necessarily will add to this number, as most of the new supermarkets tend to be somewhat larger than the ones they are replacing. In general, a slight decrease in the number of supermarkets with a simultaneous increase in the total sales area can be expected. In any case, the number of 4 % can serve as a meaningful approximation, and with a basis of 33’000 supermarkets of the large chains alone, will result in some 1300 new supermarket buildings each year – a considerable demand potential for geothermal energy solutions.

Comparing the market share of shallow geothermal systems in the countries in Europe with the most developed markets, Germany still has a minor role in terms of installations per capita, and also is far from a top place in terms of installations per area (figure 28). As Germany is among the leaders in total numbers, this fact is of course a result of the large population size (80 Mio) of Germany. In consequence, to reach a GSHP density like in Switzerland (more than 1 installation per km^2), there is still plenty of room for new shallow geothermal installations, and ample opportunity to fulfil the energy needs of supermarkets from geothermal sources.

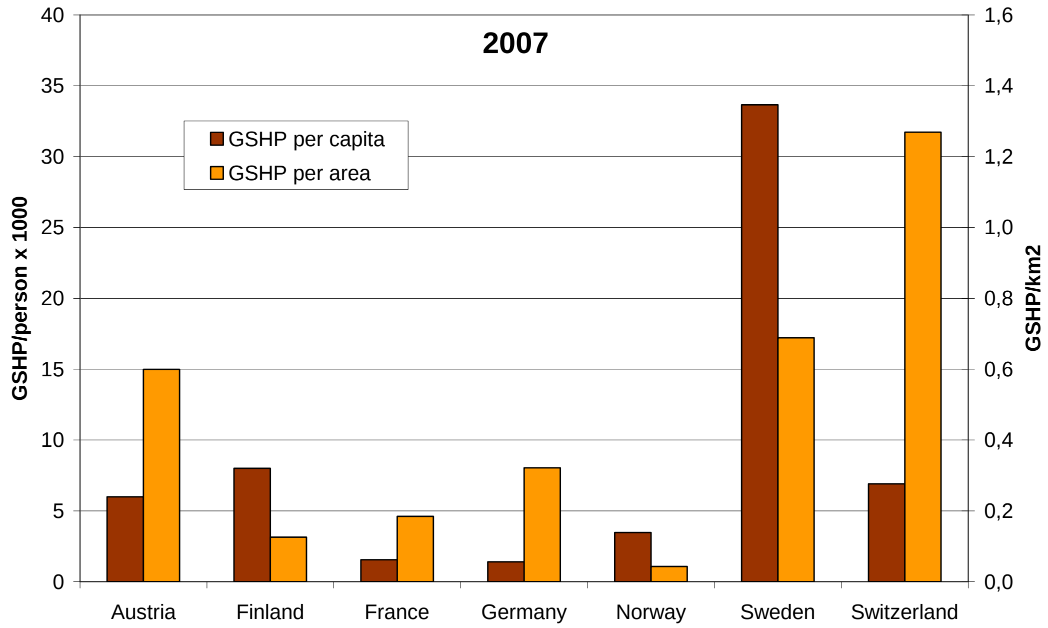

Figure 28 : Number of shallow geothermal installations (ground source heat pumps – GSHP) per capita and per area in some European countries (calculated after data from EHPA)

6 Conclusions

The renewable energy sector in Germany is a real job machine, representing ca. 214’000 jobs in 2006 (fig. 29), with geothermal playing a small, but increasing role. Of the total turnover of the RES sector in Germany in 2006 of about 22 billion €, geothermal energy accounted for just 3 %. In total terms, this is a number of 660 Mio €, nevertheless.

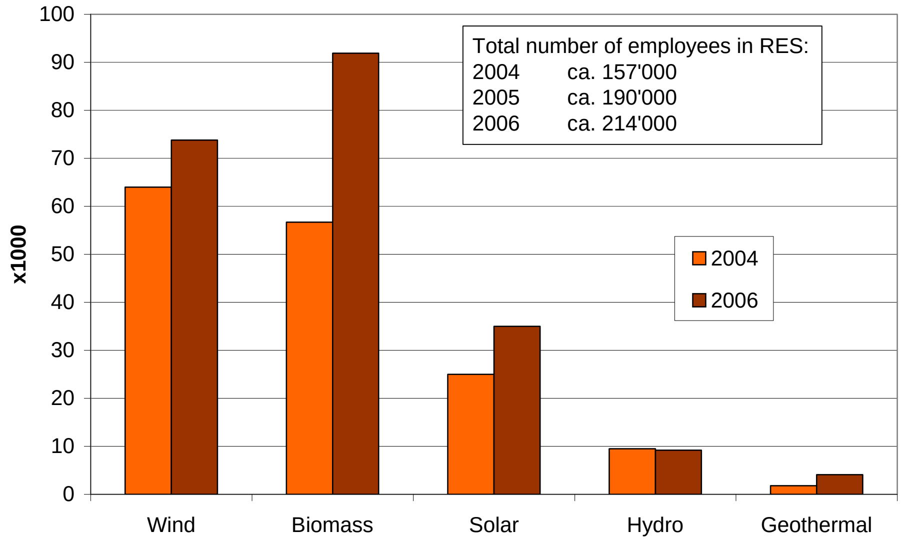

Figure 29 : Development of workforce in RES sector (after data from BMU)

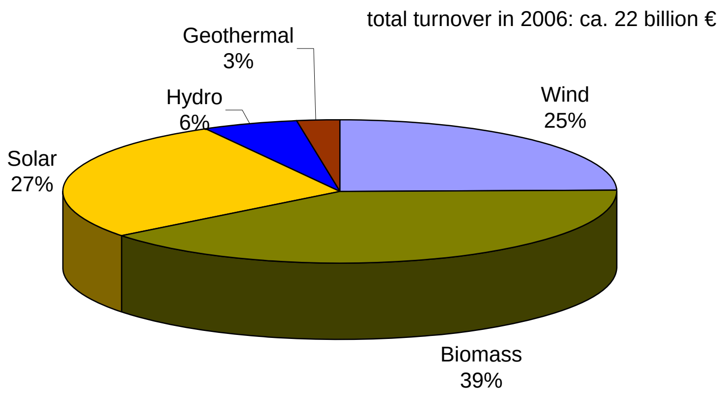

Figure 30 : Turnover of RES sector in 2006 (after data from BMU)

For geothermal applications in industry, a considerable potential is given in Germany both for shallow and for deep geothermal technologies (deep in selected regions, shallow everywhere). The most promising sectors are manufacturing, agriculture, and retail.

In the retail sector in Germany, supermarkets for food retail with the need for heating and cooling and for food refrigeration and cooling are an interesting target. With an estimated construction of more than 1000 new supermarkets each year, shallow geothermal technologies could help in saving energy and reducing emissions at a substantial scale, just in this sub-sector alone.