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Geothermal Energy Use in Germany

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ABSTRACT

At present, 162 geothermal installations for direct use of geothermal energy are operating in Germany. The installed capacity of these plants amounts to roughly 255 MW_t. The installations comprise centralized heating units (district heating), space heating in some cases combined with greenhouses, and thermal spas. Most of the centralized plants are located in the Northern German Basin, the Molasse Basin in Southern Germany, or along the Upper Rhine Graben. In addition to these large-scale plants there are numerous small- and medium-size decentralized geothermal heat pump units (ground coupled heat pumps and groundwater heat pumps). Their installed capacity exceeds 2230 MW_t. By the end of 2009 direct thermal use of geothermal energy in Germany amounted to a total installed thermal capacity of about 2500 MW_t with a pure geothermal contribution of 1800 MW_t.

Three geothermal plants for power generation are working in Germany, two of them combined with district heating. These plants are located in the North German Basin at Neustadt-Glewe, in the Rhine Graben at Landau and in the Molasse Basin at Unterhaching. The Unterhaching and Landau projects have triggered a boom in deep geothermal energy use in the Munich region and the Rhine Graben.

The Renewable Energy Sources Act (Erneuerbare Energien Gesetz, EEG) guarantees system operators fixed payment rates for electricity fed into the main grid. These are laid down over years, ensuring economical operation. The EEG will presumably stimulate the build-up of a geothermal power industry in Germany and will open new opportunities for geosciences and for the drilling and service industry.

In collaboration with the “KfW Bankengruppe” (group of banks) the BMU has created a new loan programme for the long-term financing of deep geothermal drillings. The loan programme helps to hedge the discovery risk.

1. INTRODUCTION

Due to a lack of natural steam reservoirs geothermal energy cannot be converted in Dry Steam or Flash Steam power plants into electric power in Germany. At present only Kalina or Organic Rankin Cycle (ORC) power plants can be used for electrical power generation. At Neustadt-Glewe the first German geothermal plant for electrical power generation is working since November 2003 with an installed capacity of about 230 kW_e. In 2008 and in 2009 power plants at Landau and at Unterhaching started to convert geothermal energy into electric power, each with a capacity of about 3.0 MW_e.

A successful development of the hydraulic stimulation technique in sediments and crystalline rocks (Hot Dry Rock technology) would change the situation in Germany fundamentally. An HDR geothermal power plant is in realisation at Groß Schönebeck. New innovative technologies are currently being developed for converting the heat of deep seated hot aquifers into power. Innovative projects are in realisation in Bruchsal and Insheim (Upper Rhine Graben), as well as in Garching, Sauerlach and Unterföhring (Molasse Basin). The plants for combined power generation and district heating are scheduled to be completed in the years 2010 and 2011.

This paper describes the existing geothermal resources and potentials followed by the status of geothermal utilisation in Germany by the end of 2009, and the contribution from each type of installation: geothermal power production, large-scale centralised and small scale decentralised units. Future perspective of the use of geothermal energy in Germany will be discussed.

2. GEOTHERMAL RESOURCES AND POTENTIAL

The potential for geothermal power production in Germany was investigated in a study published in 2003 by the “Office of Technology Assessment at the German Parliament (Paschen et al. 2003)”, whereas the resources for direct use of geothermal energy in Germany were estimated in two European atlases: the “Atlas of Geothermal Resources in the European Community, Austria and Switzerland” (Haenel and Staroste 1988), and the “Atlas of Geothermal Resources in Europe” (Hurter and Haenel 2002).

2.1 Potential for Geothermal Power Production

Organic Rankine and Kalina cycle techniques allow efficient electricity production at temperatures down to 100°C and makes geothermal power production feasible even for countries like Germany lacking high enthalpy resources at shallow depth. The geothermal resources for geothermal power production in Germany were estimated in a study performed in 2002 (Jung et al. 2002). Three types of reservoirs were considered: hot water aquifers (Fig. 1), faults (Fig.2) and crystalline rocks (Fig. 3) with temperatures above 100°C and at depths down to 7000 m.

Assuming realistic values for the recovery factor and the efficiency factor the accessible electrical energy was calculated. The electrical energy was estimated to 10 EJ (1 EJ = 10^{18} J) for the hot water aquifers, to 45 EJ for deep reaching faults, and to 1,100 EJ for crystalline rock. In comparison to these potentials the annual power consumption in 2007 for Germany was 1.9 EJ (BMWi 2009). To recover at least part of this huge resources further research and developments are necessary especially in accessing heat from faults and crystalline rocks.

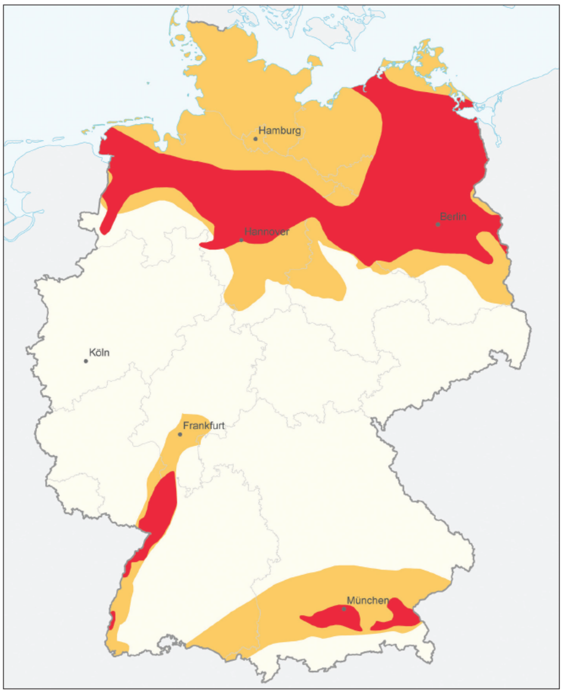

Figure 1: Red areas: Hot water aquifers for geothermal power production, temperature above 100°C. Yellow areas: Hot water aquifers direct use of geothermal energy, temperature above 60 °C. (Schulz et al. 2007). From North to South: Upper Rotliegend (Upper Permian) sand stone aquifer in the North German Basin; Upper Muschelkalk and Buntsandstein (Middle and Early Triassic) aquifers of the Upper Rhine Graben; Malmkarst (Upper Jurassic) aquifer in the South German Molasse Basin.

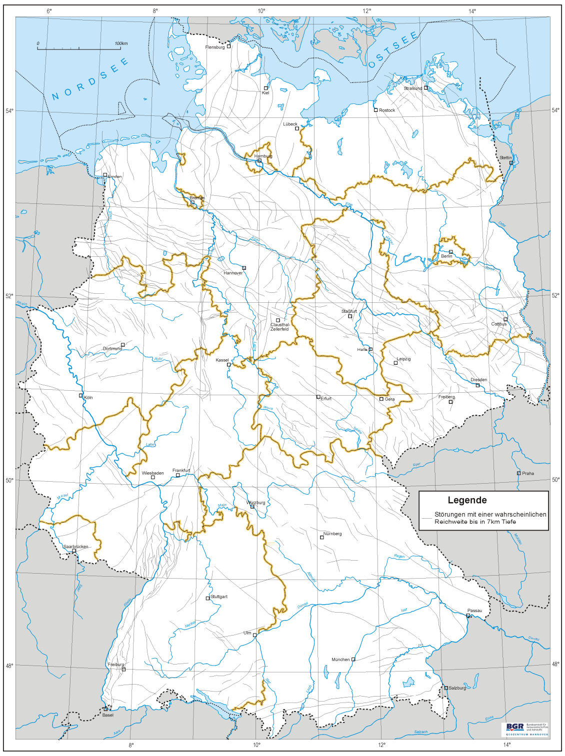

Figure 2: Deep-seated fault systems with a possible extension up to 7 km depth.

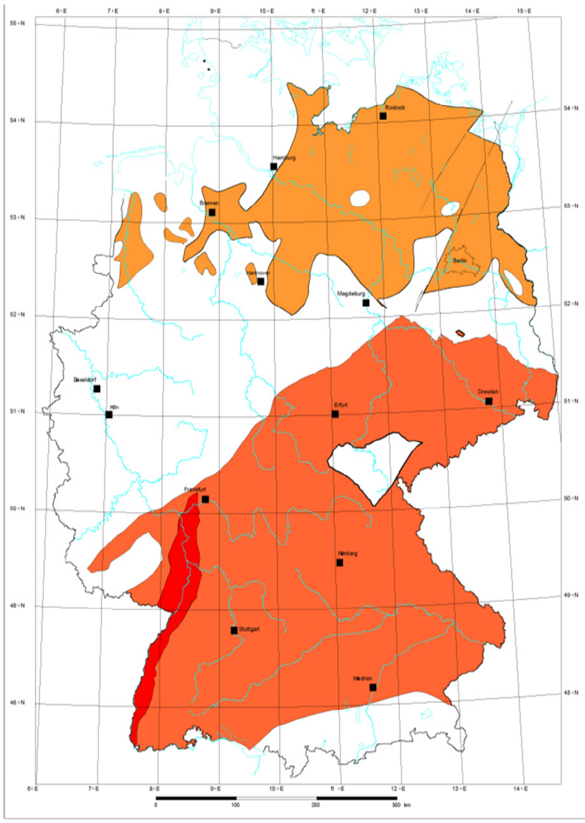

Figure 3: Crystalline rocks for geothermal power production in Germany. Red area: crystalline rock at 3 km depth and with a mean temperature of 100°C; dark red area: crystalline rock in the Upper Rhine Graben at 3 km depth and with a temperature of 130°C; orange area: Rotliegend (Permian) volcanic rock with temperatures exceeding 100°C.

2.2 Resources for Direct Use of Geothermal Energy

The geothermal resources for most European countries have been estimated and compiled in the Atlas of Geothermal Resources in Europe (Hurter and Haenel 2002), a companion volume to the Atlas of Geothermal Resources in the European Community, Austria and Switzerland (Haenel and Staroste 1988). The German contributions to these two atlases display the resources for direct use of geothermal energy in Germany. All aquifers of interest are located in the North German sedimentary basin, the Molasse Basin in southern Germany, and along the Upper Rhine Graben.

The North German Basin is the central part of the Central European Basin. The present-day sediment thickness ranges from 2 km - 10 km. Halokinetic movements of the Zechstein layers are responsible for the intense and complex deformation of Mesozoic and Cenozoic formations (Franke et al. 1996). These movements were active up to recent times. This tectonic disturbance strongly influences the local conditions of the geothermal reservoirs.

The Mesozoic deposits of the North German Basin are made up of sandstones, clay and carbonates, with evaporite intercalations. Six Cretaceous, Jurassic and Triassic sandstone aquifers are of interest for direct use of geothermal energy: Valendis-Sandstein, Bentheimer Sandstein, Aalen, Lias and Rhät, Schilfsandstein, and Buntsandstein. Because of the salt tectonics, great variations of depth and thickness, exceeding locally 1000 m, occur along short distances. Therefore, the temperature and energy content of the geothermal resources vary strongly on a regional scale. Table 1 shows the resources of these aquifers.

The Molasse Basin in southern Germany is an asymmetrical foreland basin associated with the uplift of the Alps. It extends over more than 300 km from Switzerland in the southwest to Austria in the east.

The basin is made up mainly by Tertiary, Upper Jurassic (Malm) and Triassic sediments. Eight aquifers of these sedimentary layers are of interest for direct use of geothermal energy: Burdigal-Sande, Aquitan-Sande, Chatt-Sande, Baustein-Schichten, Ampfinger Schichten, Gault/ Cenoman-Sandsteine, Malm and Upper Muschelkalk. The Malm (karstic limestone aquifer of the Upper Jurassic) is one of the most important hydro-geothermal energy reservoirs in Central Europe because the aquifer is highly productive and present throughout almost the whole Molasse Basin. The Malm aquifer dips from north to south to increasing depths and temperatures. The estimate of resources of the Molasse aquifers is listed in Table 1.

The Upper Rhine Graben belongs to a large rift system which crosses the north-western European plate (e.g. Villemin et al. 1986). Between 30 and 40 km wide, the graben runs from Basel, Switzerland, to Frankfurt, Germany. The structure was formed in the Tertiary at about 45-60 Ma by up-doming of the crust-mantle boundary due to magmatic intrusions in 80-100 km depth. The induced thermo-mechanical stress results in extensional tectonics with a maximum vertical offset of 4.8 km.

Six aquifers (Tertiary, Jurassic, Triassic and Permian) are of interest for direct use of geothermal energy: Hydrobien-Schichten, Grafenberg-Schicht, Hauptrogenstein, Upper Muschelkalk, Buntsandstein and Rotliegend. The resources of these aquifers are listed in Table 1.

3. STATUS OF GEOTHERMAL ENERGY USE

Geothermal energy (Bertani 2005, Lund et al. 2005) is worldwide the most extensively used renewable energy besides hydro-power and biomass (direct use). Due to the lack of natural steam reservoirs geothermal energy got little attention in Germany in the past. The use of geothermal energy in Germany is actually restricted to a relatively small number of centralised installations and numerous small decentralised units (heat pump units). Geothermal power production has just started. But the new payment rates for power production by the Renewable Energy Sources Act had a positive effect, several plants for combined power generation and district heating are under construction.

3.1 Geothermal Power Production

Three geothermal plants for power generation are working in Germany (Table 2), two of them combined with district heating. These plants (Fig. 4) are located in the North German Basin at Neustadt-Glewe, in the Rhine Graben at Landau and in the Molasse Basin at Unterhaching. The major use at Landau is the power generation whereas the major use at Neustadt-Glewe and at Unterhaching district heating is. The total capacity of these plants is about 6.6 MW_e for power generation and additional 55 MW_t for district heating (Table 2). The power production of 50,200 MWh/a (6.6 MW_e * 7600 h, estimated) will provide about 13,200 households with electric power (with 3,800 kWh/household per year).

The first geothermal plant for electric power generation in Germany is working since November 2003. The power plant is situated in the eastern part of the North German Basin at Neustadt-Glewe (Fig. 4). The installed capacity is about 230 kW_e (Table 2) to generate power. In addition 17 MW_t are used for district and space heating. An Organic Rankin Cycle (ORC) is used for the electrical power generation. The thermal water enters the ORC-system with a temperature of 98°C and is cooled down to 72°C. For the thermodynamic realisation at these low temperatures perfluoropentan gas (C5F12) is used, which starts boiling at 31°C at normal pressure (Kranz 2003).

Table 1: Resources of Germany (Schellschmidt et al. 2002).

Reg.	Aquifer	A km²	T_t °C	Resources 10^{18} J	GJ/m²
A	Valendis Sst.	143	50	0.11	0.79
	Bentheimer Sst.	361	54	0.28	0.78
B	Aalen	66250	43	80.83	1.22
	Lias and Rhät	68125	38	102.87	1.51
	Schilfsandstein	63125	48	37.88	0.60
	Buntsandstein	67500	49	70.88	1.05
C	Garfenberg-Schicht	597	28	0.29	0.48
D	Hydrobien-Schicht.	2117	30	5.72	2.70
	Ob. Muschelkalk	2060	137	3.17	1.53
	Buntsandstein	2746	137	45.72	16.65
	Rotliegendes	2117	110	89.79	42.41
E	Hauptrogenstein	332	79	0.49	1.47
	Ob. Muschelkalk	1616	75	1.11	0.69
	Buntsandstein	1688	85	9.78	5.80
F	Aquitan-Sande	3776	48	6.79	1.80
	Chatt-Sande	2564	72	9.05	3.53
	Baustein-Schichten	880	45	0.36	0.41
	Malm	7740	69	11.79	1.52
	Ob. Muschelkalk	3728	67	1.29	0.34
G	Burdigal-Sande	268	45	0.22	0.82
	Aquitan-Sande	763	45	1.33	1.82
	Chatt-Sande	3348	53	10.48	3.13
	Baustein-Schichten	304	42	0.14	0.47
	Ampf., Priabon	436	79	0.39	0.89
	Gault/Cenoman	6112	77	4.61	0.75
	Malm	8790	78	17.05	1.94

T_t = mean Temperature at top of aquifer Reg.:
A = areal extent of potential area
A´ = areal extent of probable reserves
P = thermal power (= reserves/30 years)

A = Western North German Basin
B = Eastern North German Basin
C = Lower Rhine Graben
D = Northern Upper Rhine Graben
E = Southern Upper Rhine Graben
F = Western Molasse Basin
G = Eastern Molasse Basin

The positive trend in the use of geothermal energy continued in 2008. In 2008 and 2009 power plants at Landau and at Unterhaching started to convert geothermal energy into electric power, each with a capacity of about 3.0 MW_e (Table 2). At Landau (Fig. 4) an Organic Rankin Cycle is used for the electrical power generation whereas at Unterhaching (Fig. 4) the Kalina technology is used.

The Unterhaching and Landau projects have triggered a boom in deep geothermal energy use in the Munich region and the Upper Rhine Graben.

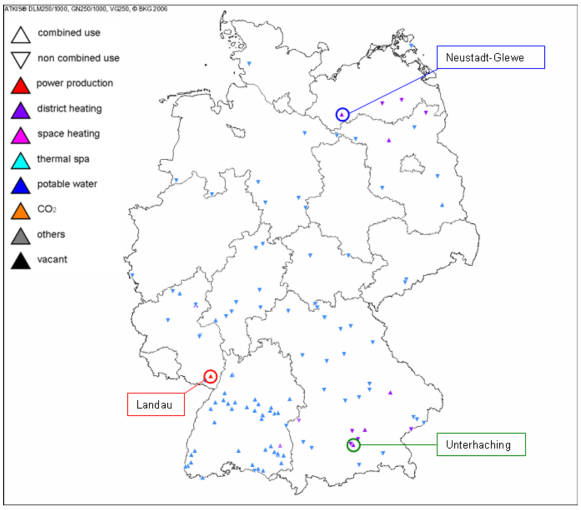

Figure 4: Operating installations for geothermal energy use in Germany (www.geotis.de). Circles indicate plants with combined power and heat supply.

Table 2: Plants for combined power generation (p) and district heating (h) are located in the North German Basin (NG), the Rhine Graben (RG) and the Molasse Basin (M).

power plant	basin	major use	flow rate max. l/s	capacity power MWe	capacity heat MWt
Neustadt-Glewe	NG	h	35	0.23	17.0
Landau	RG	p	70	3.00	---
Unterhaching	M	h	150	3.36	38.0
total 2009			255	6.59	55.0

3.2 Centralised Installations for Direct Use

At present, 162 geothermal installations for direct use of geothermal energy are operating in Germany (Fig. 4 and Table 3). The installations comprise centralised heating units (district heating), space heating in some cases combined with greenhouses, and thermal spas. The total thermal capacity installed is 255.4 MW_t with a geothermal contribution of 144.0 MW_t. The annual utilization amounts to roughly 666 GWh/a (Table 3) or 2398 TJ/a.

Under the prevailing economic and political conditions, multiple uses or cascades can help to improve the economic efficiency of direct use of geothermal heat. For this reason many installations combine district or space heating with greenhouses and thermal spas.

The geothermal units for district heating with an installed capacity of about 210 MW_t (Table 4) are located in the North German Basin and in the Molasse Basin. Ten installations for power production most of them combined with district heating are under construction in the Rhine Graben and the Molasse Basin (Fig. 5). These regions have the most favourable conditions in terms of geothermal potentials, temperature and achievable flow rates in Germany (Haenel and Staroste 1988, Hurter and Haenel 2002). In addition eight installations for district heating are under construction in the Rhine Graben and the Molasse Basin (Fig. 5).

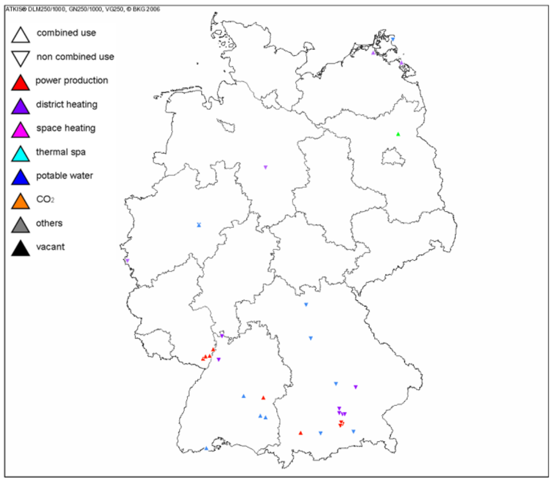

Figure 5: Installations under construction for geothermal energy use in Germany. Red (major use): power plants (www.geotis.de).

Table 3: Installed total and geothermal capacity as well as annual utilization.

major use	number of installations	capacity total MWt	capacity geothermal MWt	annual use GWh/a
district heating	12	209.3	97.9	292.9
space heating	2	1.2	1.2	0.8
thermal spa	148	44.9	44.9	372.0
greenhouse	-	-	-	-
total 2009	162	255.4	144.0	665.7
total 2006	*140*	*177.3*	*92.3*	*523.4*

Table 4: The geothermal units for district heating are located in the North German Basin (NG) and the Molasse Basin (M).

location	basin	capacity total MWt	capacity geothermal MWt	annual use GWh/a
Unterhaching	M	38.0	30.4	66.6
Unterschleißheim	M	12.9	12.9	28.3
München Riem	M	42.0	12.0	43.3
Pullach	M	9.6	9.6	21.0
Erding	M	18.0	8.0	28.0
Simbach-Braunau	M	40.0	7.0	67.0
Neustadt-Glewe	NG	17.0	7.0	11.9
Straubing	M	5.4	4.1	11.8
Neubrandenburg	NG	13.8	3.8	8.3
Waren (Müritz)	NG	10.0	1.3	2.9
Neuruppin	NG	2.1	1.3	2.7
Prenzlau	NG	0.5	0.5	1.1
total		209.3	97.9	292.9

Applications for exploration permits had been submitted for a further 150 sites.

3.3 Small Decentralised Units for Direct Use

Geothermal energy use for space heating in small decentralised units is widespread in Germany and experience in that technology dates back to the 1970s. The market introduction of ground source heat pumps in larger scale began in the mid 1990s, and was backed by support programs from utilities and from the federal government. Depending on local conditions these units consist of ground coupled heat pumps (horizontal heat collectors, vertical heat exchangers), or groundwater heat pumps.

The exact number of units presently installed in Germany is unknown since no national statistics are available. However, based on the number of heat pump sales in Germany, a good estimation can be undertaken. According to sales statistics (BWP 2009) about 34,500 small decentralised unites have been newly installed in 2008, nearly three times of sales compared to 2005 (Fig. 6). The mean installed geothermal power of each of these units typically varies from 10-15 kW_t.

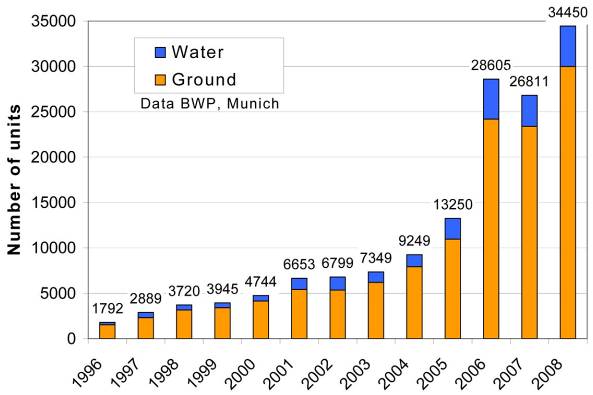

Figure 6: Annual number of new ground source heat pump units since 1996 (data from BWP 2009).

Figure 7 shows the number of all operating ground source heat pump units since 2003. This evaluation considered a replacement of older heat pumps, and abandonment of old plants, with a total of about 10% of the new units. In the year 2008 were about 148,000 units operating. The increase of operating ground source heat pump units amounted in the year 2006, 2007 and 2008 to 37%, 28% and 25% respectively. A conservative estimate for the increase in 2009 can be given with 20%. This results in 178,000 units for 2009.

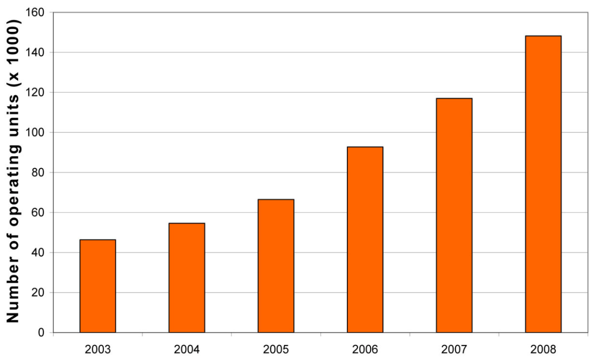

Figure 7: Number of operating ground source heat pump units since 2003 (Sanner 2009).

Figure 8 gives the development of the installed capacity of all operating ground source heat pump units. The geothermal contribution was calculated in consideration of the guidelines in Annex VII of the EU directive "Renewable Energy". Thus it was used a seasonal performance factor (ß) of 3.5 and a coefficient of performance (COP) of 4.0. In 2008 the installed capacity in small size decentralised units is equal to 1860 MW_t and the pure geothermal contribution amounts to 1395 MW_t. A conservative estimate for the increase in 2009 can be given with 20%, which results in 2230 MW_t and the pure geothermal contribution increases to 1670 MW_t. Thus, in decentralised units about 12 times more pure geothermal output is installed than in centralised installations.

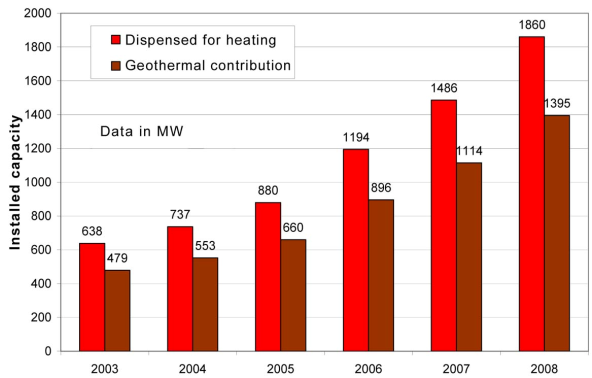

Figure 8: Installed capacity of all earth coupled heat pumps (Sanner, SONG of the GtV-BV, 2009).

The development of the annual heat delivery of ground source heat pumps is given in figure 9. In 2008 the annual use in small size decentralised units is equal to 2.40 TWh/a and the pure geothermal contribution amounts to 1.71 TWh/a. A conservative estimate for the increase in 2009 can be given as above with 20%, which results in 2.88 TWh/a (10,368 TJ/a) with a pure geothermal contribution of 2.05 TWh/a (7380 TJ/a).

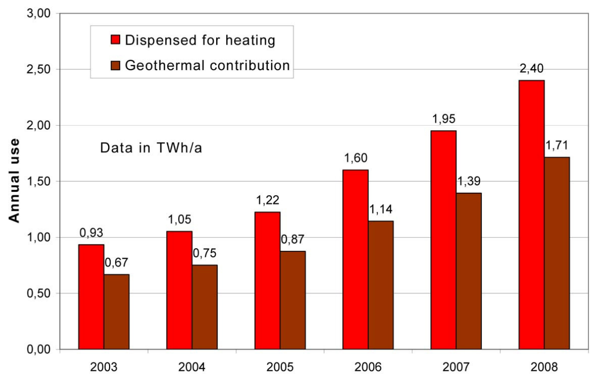

Figure 9: Annual use of all earth coupled heat pumps (Sanner, SONG of the GtV-BV, 2009).

4. PERSPECTIVE OF THE USE OF GEOTHERMAL ENERGY

A new, conservative estimate of the total thermal power currently installed for direct use of geothermal energy in Germany amounts to roughly 2500 MW_t. The pure geothermal part of this sum amounts to 1800 MW_t or 72 %. About 12 times more pure geothermal output is installed in decentralised units than in centralised installations.

4.1 Final Energy Consumption in Germany

The final energy consumption in Germany in 2007 was 8585 PJ (1 PJ = 10^{15} J) (BMWi 2009). A breakdown in Figure 10 shows that 54% of the final energy consumption was required for space-heating, hot water, or process heat (BMWi 2009). Most of this demand is at present supplied by fossil fuel. A significant proportion of this demand could, in principle, be supplied by geothermal heat. This would make a significant contribution to reducing the present CO_2 output of Germany.

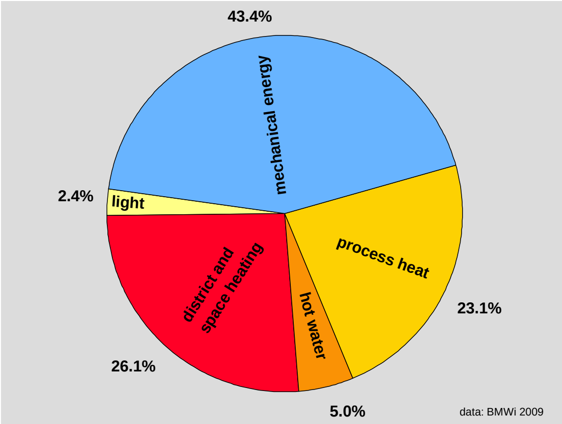

Figure 10: Final energy consumption in Germany according to usage (data BMWi 2009). Distribution shown is for Germany in 2007. Final energy consumption in Germany was 8585 PJ in 2007 (1 PJ = 10^{15} J).

According to Kayser (1999) the potential demand for geothermal heat from centralized geothermal units in Germany amounts to 1165 PJ a^{-1}. This would correspond to an installed thermal capacity of 36,917 MW_t. Kaltschmitt et al. (1995) assessed the potential demand for geothermal energy from ground coupled and groundwater heat pumps to 960 PJ a^{-1}, corresponding to an installed capacity of about 30,420 MW_t. The total potential demand for the direct use of geothermal energy in Germany is therefore 2125 PJ a^{-1} corresponding to 67,337 MW_t. This corresponds to 25 % of the 2007 German final energy consumption of 8585 PJ.

Thus, a fourth of the final energy consumption in Germany could be supplied by the direct use of geothermal energy. However, at present only about 0.7 % of the potential demand is covered by geothermal heat.

4.2 Renewable Energy Source Act and Governmental Support of Geothermal Energy

The Renewable Energy Sources Act (Erneuerbare Energien Gesetz, EEG) guarantees system operators fixed payment rates for electricity fed into the main grid. These are laid down over years, ensuring economical operation. Duration for the fixed payment rates is 20 years (BMU 2008).

A first revised edition of the Renewable Energy Source Act came into force in August 2004. The payment rates for the feed-in allowance increased from 0.089 to 0.15 €/kWh for electricity produced from geothermal energy. With the adoption of the amended Renewable Energy Sources Act on 6th June 2008, the German Bundestag (Lower House of the German Parliament) further significantly improved the conditions for geothermal energy in Germany. Table 5 gives the new provisions valid from January 2009.Download of the EEG:

http://www.bmu.de/files/pdfs/allgemein/application/pdf/eeg_2009_en.pdf

The strong market development for deep geothermal energy in Germany is primarily attributable to the Renewable Energy Sources Act (EEG), which created good economic framework conditions for the operation of geothermal plants thanks to its fee scale. There is now a real chance for planning and installing geothermal power plants on a sound economic basis. The EEG will presumably stimulate the build-up of a geothermal power industry in Germany and will open new opportunities for geosciences and for the drilling and service industry.

Table 5: The new feed-in tariffs for power production by the Renewable Energy Source Act (valid since January 2009). Basic tariff from a plant capacity of 10 MW or more is 10.5 cents per kilowatt.

basic tariff and bonuses from a plant capacity < 10 MW	payment rates €-Ct/kWh
Electrical power basic tariff	16
Plants starting up until 2015	4
Power-heat-coupling	3
Petrothermal techniques (EGS)	4
maximum of feed-in tariff	27

The positive effect of the new Renewable Energy Act has been further enhanced by financial support of pilot and demonstration projects (Market Incentive Programme, Future Investments Programme) by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). As part of the German Government’s integrated energy and climate programme, the BMU has adopted new funding guidelines for the Market Incentive Programme, which offers subsidies for installation of the power or heating plant, deep boreholes and heat extraction. The Market Incentive Programme also supports district heating networks that run on regenerative resources. Under this programme, in 2009 some 400 million Euros will be made available to promote renewable energies in the heat market. Figure 11 shows the annual project funding (research and development) by BMU in the field of geothermal energy from 1974 to 2008 (BMU 2008).

In collaboration with the “KfW Bankengruppe” (group of banks) the BMU has created a new loan programme for the long-term financing of deep geothermal drillings. Münchener Rück (Munich Re Group, insurance provider) is supporting the KfW as a cooperation partner. The loan programme helps to hedge the discovery risk – i.e. the risk of failing to find sufficient temperatures or water volumes when drilling, and should therefore minimize one of the main barriers to the faster market development of deep geothermal projects. For more details see this issue Schulz et al. (2010).

The Heat Act (EEWärmeG) was adopted by the Bundestag (Lower House of Parliament) on 6 June 2008 and entered into force on 1 January 2009. Under this Act, all owners of new buildings are obliged to purchase part of their heat demand from renewable energy sources.

The Installation of ground coupled heat pumps will be supported by the German Government as follows: 20 €/ m² living space, but not more than 3.000 € per house for existing houses and 10 €/ m² lining space, but not more than 2.000 € per house for new houses (http://www.erneuerbare-energien.de/files/pdfs/allgemein/application/pdf/foerderrichtlinie_waerme_09.pdf).

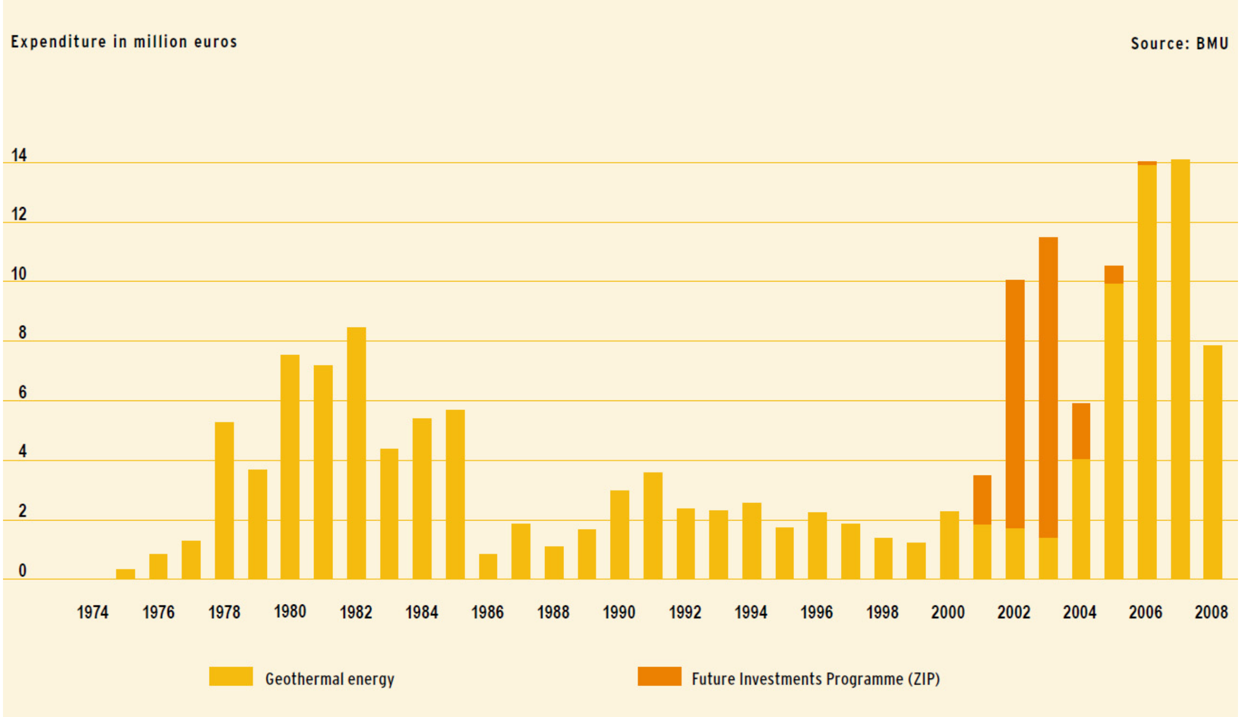

Figure 11: Annual research expenditure by BMU in the in the field of geothermal energy from 1974 to 2008 (BMU 2008).

4.3 Internet Based Information System

In order to improve the project-planning quality of geothermal plants and minimise the finding risk, the Leibniz Institut für Angewandte Geophysik (LIAG, Leibniz Institute for Applied Geophysics) former Institut für Geowissenschaftliche Gemeinschaftsaufgaben (GGA, Institute for Applied Geosciences) in Hanover has developed a unique information system.

The geothermal information system (GeotIS) provides information and data compilations on deep aquifers in Germany relevant for geothermal exploitation. GeotIS is a public internet based information system and satisfies the demand for a comprehensive, largely scale-independent form of a geothermal atlas which can be continuously updated. GeotIS helps users identify geothermal potentials by visualizing temperature, hydraulic properties and depth levels of relevant stratigraphic units. A sophisticated map interface simplifies the navigation to all areas of interest. An additional component contains a catalogue of all geothermal installations in Germany.

The project is funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The Leibniz Institute for Applied Geophysics realises this project in close collaboration with partners. The purpose of the project is to minimise the exploration risk of geothermal wells and to improve the quality in the planning of geothermal plants. The current stage of expansion includes the South German Molasse Basin, the Upper Rhine Graben, and the North German Basin.

GeotIS is designed as a digital information system which will be available to the public through the World Wide Web (www.geotis.de).

For more details see this issue Pester et al. (2010).

5. CONCLUSIONS

Due to the moderate temperature gradients persisting in most parts of Germany geothermal energy use is still on a comparatively low level. The installed capacity for geothermal heat is about 2500 MW_t. 90% of which is attributed to about 178,000 decentralized units using heat from shallow depth. The remaining 10% is attributed to 162 centralized installations exploiting mainly deep-seated aquifers.

Three geothermal plants for power generation are working in Germany at Neustadt-Glewe, Landau and Unterhaching, two of them combined with district heating. The total capacity of these plants is 6.6 MW_e for power generation and additional 55 MW_t for district heating. The Unterhaching and Landau projects have triggered a boom in deep geothermal energy use in the Munich region and the Upper Rhine Graben.

With the adoption of the amended Renewable Energy Sources Act on 6 June 2008, the German Bundestag (Lower House of Parliament) further significantly improved the conditions for geothermal energy in Germany. The positive effect of the new Renewable Energy Act has been further enhanced by financial support of pilot and demonstration projects (Market Incentive Programme, Future Investments Programme) by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU).

The Renewable Energy Sources Act will presumably stimulate the build-up of a geothermal power industry in Germany and will open new opportunities for geosciences and for the drilling and service industry.

In its most recent funding announcement of 20 November 2008, the BMU outlined its priority areas for research funding in the field of geothermal energy. The aim is to continuously reduce the cost of extracting and using heat and electricity from geothermal reservoirs. For more details see BMU report (2008) “Annual Report on Research Funding in the Renewable Energies Sector”.

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Tables 1-8

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (wind, photovoltaics, biomass energy)		Total	
	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr	Capac-ity MWe	Gross Prod. GWh/yr
In operation in December 2008	6.59	50084	78500	372000	10100	27000	21300	148800	27500	77100	137407	674984
Under construction in December 2008												
Funds committed, but not yet under construction in December 2009												
Total projected use by 2015												

(data BMWi 2009)

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2009

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash B = Binary (Rankine Cycle)
2F = Double Flash H = Hybrid (explain)
3F = Triple Flash O = Other (Kalina technology)
D = Dry Steam

3) Data for 2009 if available, otherwise for 2008. Please specify which.

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe*	Total Running Capacity MWe*	Annual Energy Produced 2009[3)] GWh/yr	Total under Constr. or Planned MWe
Neustadt-Glewe	Neustadt-Glewe	2003	1		B	0.23	0.23	1748	
Landau	Landau	2008	1		B	3.00	3.00	22800	
Unter-haching	Unter-haching	2009	1		O	3.36	3.36	25536	
Total						6.59	6.59	50084	

* Installed capacity is maximum gross output of the plant; running capacity is the actual gross being produced.

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT

GeotIS
www.geotis.de/vgs

Übersicht aller ausgewählten geothermischen Anlagen

Name	Zustand	Hauptnutzung	Nebennutzung	Temperatur [max.]	Fließrate [max.]	Teufe [max.]	Leistung gesamt	Leistung geothermisch	Jahresproduktion
Aachen, Kaiserquelle	Betrieb	Thermalbad / Balneologie	kein Eintrag	53 °C	9,7 l/s	kein Eintrag	0,34 MW_t	0,34 MW_t	3,02 GWh/a
Aachen, Landesbadquelle	Betrieb	Thermalbad / Balneologie	kein Eintrag	72 °C	22 l/s	kein Eintrag	3,48 MW_t	3,48 MW_t	30,47 GWh/a
Aachen, Rosenquelle	Betrieb	Thermalbad / Balneologie	kein Eintrag	47 °C	15 l/s	kein Eintrag	1,35 MW_t	1,35 MW_t	11,86 GWh/a
Aachen, Schwertbadquelle	Betrieb	Thermalbad / Balneologie	kein Eintrag	70 °C	1,67 l/s	kein Eintrag	0,12 MW_t	0,12 MW_t	1,03 GWh/a
Aachen-Burtscheid, Rosenquelle	Betrieb	Thermalbad / Balneologie	kein Eintrag	61 °C	10 l/s	kein Eintrag	0,57 MW_t	0,57 MW_t	5,00 GWh/a
Aalen, TB I u. II	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	36,35 °C	4,5 l/s	650,4 m	0,31 MW_t	0,31 MW_t	2,69 GWh/a
Aulendorf	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	54 °C	4,8 l/s	2076 m	0,50 MW_t	0,50 MW_t	4,36 GWh/a
B. Peterstal, Br. 1, Parkpl.	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	20,5 °C	0,2 l/s	438,5 m	< 0,01 MW_t	< 0,01 MW_t	< 0,01 GWh/a
B. Teinach, Otto-Therme II	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	20 °C	0,64 l/s	460 m	kein Wert	kein Wert	kein Wert
Bad Abbach	Betrieb	Thermalbad / Balneologie	kein Eintrag	26,4 °C	6,5 l/s	676,5 m	0,05 MW_t	0,05 MW_t	0,48 GWh/a
Bad Bellingen Markusquelle	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	36,45 °C	5 l/s	650 m	0,34 MW_t	0,34 MW_t	3,01 GWh/a
Bad Bellingen, Leodegar	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	37,9 °C	8 l/s	650 m	0,60 MW_t	0,60 MW_t	5,24 GWh/a
Bad Bellingen, QU III	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	39,8 °C	8 l/s	1194 m	0,66 MW_t	0,66 MW_t	5,80 GWh/a
Bad Bentheim - Fürsten-Quelle (Solequelle)	Betrieb	Thermalbad / Balneologie	kein Eintrag	40 °C	kein Eintrag	1175 m	kein Wert	kein Wert	kein Wert
Bad Bergzabern, Petronella-Quelle I	Betrieb	Thermalbad / Balneologie	kein Eintrag	21,9 °C	kein Eintrag	358 m	kein Wert	kein Wert	kein Wert
Bad Bertrich, Bergquelle	Betrieb	Thermalbad / Balneologie	kein Eintrag	31,7 °C	kein Eintrag	kein Eintrag	kein Wert	kein Wert	kein Wert
Bad Bevensen - Thermal-Jod-Sole-Quelle	Betrieb	Thermalbad / Balneologie	kein Eintrag	24 °C	kein Eintrag	629 m	kein Wert	kein Wert	kein Wert
Bad Birnbach T 3	Betrieb	Thermalbad / Balneologie	kein Eintrag	48 °C	2,5 l/s	1618 m	0,29 MW_t	0,29 MW_t	2,56 GWh/a
Bad Birnbach T 4	Betrieb	Thermalbad / Balneologie	kein Eintrag	62 °C	14 l/s	1362 m	2,46 MW_t	2,46 MW_t	21,53 GWh/a
Bad Breisig, Geiersprudel	Betrieb	Thermalbad / Balneologie	CO_2 -Gewinnung	31,4 °C	kein Eintrag	605 m	kein Wert	kein Wert	kein Wert
Bad Breisig, Ludgerussprudel	Betrieb	CO_2 -Gewinnung	Thermalbad / Balneologie	26 °C	kein Eintrag	608 m	kein Wert	kein Wert	kein Wert
Bad Buchau 1	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	45,7 °C	5 l/s	795 m	1,13 MW_t	1,13 MW_t	2,47 GWh/a
Bad Buchau 2	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	44,4 °C	5 l/s	852,5 m	0,51 MW_t	0,51 MW_t	4,47 GWh/a
Bad Colberg, Thermalsolebohrung 1994	Betrieb	Thermalbad / Balneologie	kein Eintrag	59 °C	4,72 l/s	1400 m	0,03 MW_t	0,03 MW_t	0,30 GWh/a
Bad Ditzenbach, Canisius I	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	45,7 °C	14,03 l/s	560,7 m	1,19 MW_t	1,19 MW_t	10,45 GWh/a

Bad Ems, Bohrung Ia (Robert-Kampe-Sprudel)	Betrieb	Thermalbad / Balneologie	kein Eintrag	57,2 °C	kein Eintrag	72,9 m	kein Wert	kein Wert	kein Wert
Bad Ems, Bohrung IV	Betrieb	Thermalbad / Balneologie	kein Eintrag	39 °C	kein Eintrag	130,45 m	kein Wert	kein Wert	kein Wert
Bad Ems, Bohrung V	Betrieb	Thermalbad / Balneologie	kein Eintrag	55,2 °C	kein Eintrag	368,5 m	kein Wert	kein Wert	kein Wert
Bad Ems, Emser Kränchen	Betrieb	Thermalbad / Balneologie	kein Eintrag	32,1 °C	kein Eintrag	kein Eintrag	kein Wert	kein Wert	kein Wert
Bad Ems, Römerquelle	Betrieb	Trink- / Brauchwasser	Thermalbad / Balneologie	46,2 °C	kein Eintrag	kein Eintrag	kein Wert	kein Wert	kein Wert
Bad Emstal	Betrieb	Thermalbad / Balneologie	kein Eintrag	34 °C	4 l/s	759 m	0,12 MW_t	0,12 MW_t	1,03 GWh/a
Bad Endorf 2	Betrieb	Thermalbad / Balneologie	kein Eintrag	90 °C	kein Eintrag	4263,5 m	kein Wert	kein Wert	kein Wert
Bad Endorf Gt 3	Betrieb	Thermalbad / Balneologie	kein Eintrag	52 °C	2,1 l/s	2450 m	0,21 MW_t	0,21 MW_t	1,82 GWh/a
Bad Füssing 1	Betrieb	Thermalbad / Balneologie	kein Eintrag	58,6 °C	16 l/s	1142,3 m	2,58 MW_t	2,58 MW_t	22,61 GWh/a
Bad Füssing 2	Betrieb	Thermalbad / Balneologie	kein Eintrag	53,8 °C	13,5 l/s	978,8 m	1,91 MW_t	1,91 MW_t	16,71 GWh/a
Bad Füssing 3	Betrieb	Thermalbad / Balneologie	kein Eintrag	49,9 °C	13,4 l/s	1060,6 m	1,67 MW_t	1,67 MW_t	14,67 GWh/a
Bad Gögging Thermalbr. 1	Betrieb	Thermalbad / Balneologie	kein Eintrag	24 °C	6,8 l/s	652,2 m	0,11 MW_t	0,11 MW_t	1,00 GWh/a
Bad Gögging Therme 2	Betrieb	Thermalbad / Balneologie	kein Eintrag	26,4 °C	5 l/s	563 m	0,13 MW_t	0,13 MW_t	1,17 GWh/a
Bad Griesbach 1	Betrieb	Thermalbad / Balneologie	kein Eintrag	34,8 °C	2 l/s	878 m	0,12 MW_t	0,12 MW_t	1,08 GWh/a
Bad Griesbach 2	Betrieb	Thermalbad / Balneologie	kein Eintrag	29 °C	11 l/s	480 m	0,41 MW_t	0,41 MW_t	3,63 GWh/a
Bad Griesbach 3	Betrieb	Thermalbad / Balneologie	kein Eintrag	57 °C	5 l/s	1522,4 m	0,77 MW_t	0,77 MW_t	6,77 GWh/a
Bad Harzburg - Harras-Schneider-Quelle (Neue Solebohrung)	Betrieb	Thermalbad / Balneologie	kein Eintrag	20,6 °C	kein Eintrag	840 m	kein Wert	kein Wert	kein Wert
Bad Herrenalb I	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	28,3 °C	2,5 l/s	599 m	0,09 MW_t	0,09 MW_t	0,76 GWh/a
Bad Herrenalb IV	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	20,6 °C	kein Eintrag	536 m	kein Wert	kein Wert	kein Wert
Bad Homburg: Viktoria Louisenbrunnen	Betrieb	Thermalbad / Balneologie	kein Eintrag	22,4 °C	1,6 l/s	250 m	0,02 MW_t	0,02 MW_t	0,14 GWh/a
Bad Hönningen, Deutschland-Sprudel (MQ 7)	Betrieb	Thermalbad / Balneologie	CO_2 -Gewinnung	27,9 °C	kein Eintrag	372 m	kein Wert	kein Wert	kein Wert
Bad Hönningen, Hönniger Sprudel-Neubohrung	Betrieb	CO_2 -Gewinnung	Thermalbad / Balneologie	31,2 °C	kein Eintrag	580,8 m	kein Wert	kein Wert	kein Wert
Bad Kissingen Schönbornsprudel	Betrieb	Thermalbad / Balneologie	kein Eintrag	kein Eintrag	kein Eintrag	kein Eintrag	kein Wert	kein Wert	kein Wert
Bad Kreuznach, Theodorshaller Brunnen	Betrieb	Thermalbad / Balneologie	kein Eintrag	28,8 °C	kein Eintrag	500,5 m	kein Wert	kein Wert	kein Wert
Bad Krozingen TB 2	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	38,1 °C	0,8 l/s	596 m	0,06 MW_t	0,06 MW_t	0,53 GWh/a
Bad Krozingen TB 3	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	39,4 °C	20 l/s	610 m	0,15 MW_t	0,15 MW_t	1,35 GWh/a
Bad Krozingen TB 4	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	37,6 °C	12 l/s	580 m	0,12 MW_t	0,12 MW_t	1,03 GWh/a
Bad Laer - Neue Martinsquelle	Betrieb	Thermalbad / Balneologie	kein Eintrag	20,6 °C	kein Eintrag	159 m	kein Wert	kein Wert	kein Wert

Bad Langensalza, Thermalsolebohrung 1996	Betrieb	Thermalbad / Balneologie	kein Eintrag	25 °C	0,1 l/s	741 m	kein Wert	kein Wert	kein Wert
Bad Liebenzell (summarisch)	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	23 °C	6 l/s	250 m	0,06 MW_t	0,06 MW_t	0,55 GWh/a
Bad Mingolsheim, St. Rochus I	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	25,8 °C	3,5 l/s	214 m	0,06 MW_t	0,06 MW_t	0,51 GWh/a
Bad Münster am Stein, Rheingrafenquelle	Betrieb	Thermalbad / Balneologie	kein Eintrag	29,6 °C	kein Eintrag	20 m	kein Wert	kein Wert	kein Wert
Bad Nauheim, Sprudel VII	Betrieb	Thermalbad / Balneologie	kein Eintrag	30 °C	4,2 l/s	151 m	0,18 MW_t	0,18 MW_t	1,54 GWh/a
Bad Nauheim, Sprudel XII	Betrieb	Thermalbad / Balneologie	kein Eintrag	33 °C	11 l/s	176 m	0,60 MW_t	0,60 MW_t	5,24 GWh/a
Bad Nauheim, Sprudel XIV	Betrieb	Thermalbad / Balneologie	kein Eintrag	31 °C	4,3 l/s	182 m	0,20 MW_t	0,20 MW_t	1,73 GWh/a
Bad Nenndorf/ Soldorf - Neue Landgrafenquelle	Betrieb	Thermalbad / Balneologie	kein Eintrag	21,7 °C	kein Eintrag	297 m	kein Wert	kein Wert	kein Wert
Bad Neuenahr, Großer Sprudel	Betrieb	Thermalbad / Balneologie	kein Eintrag	28,5 °C	kein Eintrag	88,2 m	kein Wert	kein Wert	kein Wert
Bad Rodach Therme 1	Betrieb	Thermalbad / Balneologie	kein Eintrag	33,4 °C	8,2 l/s	652 m	0,46 MW_t	0,46 MW_t	4,02 GWh/a
Bad Rodach Therme 2	Betrieb	Thermalbad / Balneologie	kein Eintrag	35 °C	5,3 l/s	1015 m	0,33 MW_t	0,33 MW_t	2,91 GWh/a
Bad Saarow-Pieskow	Betrieb	Thermalbad / Balneologie	kein Eintrag	22 °C	kein Eintrag	457 m	kein Wert	kein Wert	kein Wert
Bad Säckingen, Badquelle	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	31 °C	15 l/s	600,3 m	0,06 MW_t	0,06 MW_t	0,56 GWh/a
Bad Säckingen, Fridolinquelle	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	28,3 °C	8 l/s	505 m	0,28 MW_t	0,28 MW_t	2,43 GWh/a
Bad Schönborn, Karl Sigel	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	48,5 °C	6,25 l/s	607 m	0,25 MW_t	0,25 MW_t	2,19 GWh/a
Bad Schönborn, Lambertus,	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	43,5 °C	6,5 l/s	636 m	0,64 MW_t	0,64 MW_t	5,59 GWh/a
Bad Schönborn, St. Vitus	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	28 °C	2 l/s	208 m	0,07 MW_t	0,07 MW_t	0,59 GWh/a
Bad Soden: Alter Sprudel	Betrieb	Thermalbad / Balneologie	kein Eintrag	26,4 °C	kein Eintrag	220 m	kein Wert	kein Wert	kein Wert
Bad Soden: Br. IIIa und IIIb	Betrieb	Thermalbad / Balneologie	kein Eintrag	22,7 °C	0,39 l/s	6 m	< 0,01 MW_t	< 0,01 MW_t	0,04 GWh/a
Bad Soden: Br. IIIa und IIIb	Betrieb	Thermalbad / Balneologie	kein Eintrag	22,7 °C	0,39 l/s	6 m	< 0,01 MW_t	< 0,01 MW_t	0,04 GWh/a
Bad Soden: Milchbrunnen	Betrieb	Thermalbad / Balneologie	kein Eintrag	23 °C	0,25 l/s	7 m	< 0,01 MW_t	< 0,01 MW_t	0,03 GWh/a
Bad Soden: Neuer Sprudel	Betrieb	Thermalbad / Balneologie	kein Eintrag	30,9 °C	kein Eintrag	372 m	kein Wert	kein Wert	kein Wert
Bad Soden: Winklerbrunnen	Betrieb	Thermalbad / Balneologie	kein Eintrag	21,4 °C	0,07 l/s	kein Eintrag	< 0,01 MW_t	< 0,01 MW_t	< 0,01 GWh/a
Bad Soden-Salmünster, Fritz-Hamm-Sprudel	Betrieb	Thermalbad / Balneologie	kein Eintrag	22,5 °C	1 l/s	503 m	0,01 MW_t	0,01 MW_t	0,09 GWh/a
Bad Staffelstein Therme 1	Betrieb	Thermalbad / Balneologie	kein Eintrag	50 °C	3,33 l/s	1050 m	0,42 MW_t	0,42 MW_t	3,66 GWh/a
Bad Staffelstein Therme 2	Betrieb	Thermalbad / Balneologie	kein Eintrag	53,1 °C	5 l/s	1180 m	0,69 MW_t	0,69 MW_t	6,06 GWh/a
Bad Sulza, Bohrung Bad Sulza 1984 (Sole 84)	Betrieb	Thermalbad / Balneologie	kein Eintrag	22,4 °C	1,4 l/s	613 m	< 0,01 MW_t	< 0,01 MW_t	0,02 GWh/a
Bad Überkingen, Ottotherme I	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	40,8 °C	2,27 l/s	1020 m	0,20 MW_t	0,20 MW_t	1,73 GWh/a

Bad Überkingen, Ottotherme II	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	43,2 °C	11,6 l/s	1051 m	0,44 MW_t	0,44 MW_t	3,85 GWh/a
Bad Überkingen, Renato	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	34,4 °C	10 l/s	395 m	0,36 MW_t	0,36 MW_t	3,16 GWh/a
Bad Urach (TB1, TB2)	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	54 °C	10 l/s	770 m	1,0 MW_t	1,0 MW_t	1,5 GWh/a
Bad Waldsee 1	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	31 °C	6,6 l/s	1825 m	0,44 MW_t	0,44 MW_t	0,96 GWh/a
Bad Waldsee 2	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	69 °C	3,4 l/s	1925 m	0,27 MW_t	0,27 MW_t	2,33 GWh/a
Bad Wiessee	Betrieb	Thermalbad / Balneologie	kein Eintrag	22,8 °C	kein Eintrag	kein Eintrag	kein Wert	kein Wert	kein Wert
Bad Wilsnack	Betrieb	Thermalbad / Balneologie	kein Eintrag	48,1 °C	kein Eintrag	1017,5 m	kein Wert	kein Wert	kein Wert
Bad Windsheim TWB 1	Betrieb	Thermalbad / Balneologie	kein Eintrag	20,8 °C	0,22 l/s	680 m	< 0,01 MW_t	< 0,01 MW_t	< 0,01 GWh/a
Bad Windsheim TWB 2 flach	Betrieb	Thermalbad / Balneologie	kein Eintrag	20 °C	1 l/s	296 m	kein Wert	kein Wert	kein Wert
Bad Windsheim TWB 2 tief	Betrieb	Thermalbad / Balneologie	kein Eintrag	25 °C	0,5 l/s	548 m	0,01 MW_t	0,01 MW_t	0,09 GWh/a
Bad Wörishofen Gt 1	Betrieb	Thermalbad / Balneologie	kein Eintrag	39,9 °C	2 l/s	1101 m	0,17 MW_t	0,17 MW_t	1,46 GWh/a
Bad Wörishofen Gt 2	Betrieb	Thermalbad / Balneologie	kein Eintrag	kein Eintrag	kein Eintrag	2600 m	kein Wert	kein Wert	kein Wert
Bad Wurzach	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	33,7 °C	3 l/s	800 m	0,02 MW_t	0,02 MW_t	0,15 GWh/a
Baden-Baden (summarisch)	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	60 °C	9 l/s	552 m	1,49 MW_t	1,49 MW_t	13,04 GWh/a
Badenweiler	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	26,2 °C	11,4 l/s	364 m	0,30 MW_t	0,30 MW_t	2,59 GWh/a
Bayreuth	Betrieb	Thermalbad / Balneologie	kein Eintrag	36 °C	17 l/s	1122 m	1,14 MW_t	1,14 MW_t	9,96 GWh/a
Belzig	Betrieb	Thermalbad / Balneologie	kein Eintrag	34,2 °C	kein Eintrag	786,5 m	kein Wert	kein Wert	kein Wert
Beuren TB I	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	48,7 °C	8 l/s	755 m	0,24 MW_t	0,24 MW_t	2,10 GWh/a
Beuren TB II	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	38 °C	2,5 l/s	398 m	0,15 MW_t	0,15 MW_t	1,32 GWh/a
Binz / Rügen	Betrieb	Thermalbad / Balneologie	kein Eintrag	35 °C	kein Eintrag	1100 m	kein Wert	kein Wert	kein Wert
Böblingen, TB II	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	33,6 °C	3 l/s	775 m	0,17 MW_t	0,17 MW_t	1,49 GWh/a
Bodenwerder - Solebohrung (Kalibohrung Addashall)	Betrieb	Thermalbad / Balneologie	kein Eintrag	21,5 °C	kein Eintrag	489 m	kein Wert	kein Wert	kein Wert
Boll - Bad Boll, TB	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	45,6 °C	11,7 l/s	467 m	1,07 MW_t	1,07 MW_t	9,37 GWh/a
Bonlanden	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	24 °C	0,3 l/s	365 m	< 0,01 MW_t	< 0,01 MW_t	0,04 GWh/a
Breitenbrunn/Bedernau	Betrieb	Thermalbad / Balneologie	kein Eintrag	28 °C	2,5 l/s	760,1 m	0,08 MW_t	0,08 MW_t	0,73 GWh/a
Burg	Betrieb	Thermalbad / Balneologie	Forschung	55 °C	kein Eintrag	1350 m	kein Wert	kein Wert	kein Wert
Erding	Betrieb	Fernwärme	Thermalbad / Balneologie	65 °C	55 l/s	2200 m	18,0 MW_t	8,0 MW_t	28,0 GWh/a
Esslingen, Merkelsches Bad	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	31,3 °C	100 l/s	184 m	0,09 MW_t	0,09 MW_t	0,83 GWh/a

Freiburg Mooswald 1	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	45,3 °C	8,5 l/s	858 m	0,90 MW_t	0,90 MW_t	7,87 GWh/a
Freiburg Mooswald 2	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	30,1 °C	2,2 l/s	545 m	0,09 MW_t	0,09 MW_t	0,81 GWh/a
Friedrichshafen 1	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	30,2 °C	3 l/s	710,3 m	0,13 MW_t	0,13 MW_t	1,12 GWh/a
Gartow - Thermalsole-Brunnen	Betrieb	Thermalbad / Balneologie	kein Eintrag	21,5 °C	kein Eintrag	211 m	kein Wert	kein Wert	kein Wert
Göppingen	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	26 °C	5,5 l/s	512 m	0,05 MW_t	0,05 MW_t	0,44 GWh/a
Günzburg	Betrieb	Gebäudeheizung	kein Eintrag	24 °C	30,5 l/s	510 m	kein Wert	kein Wert	kein Wert
Heide	Betrieb	Thermalbad / Balneologie	kein Eintrag	23 °C	1 l/s	530 m	< 0,01 MW_t	< 0,01 MW_t	0,04 GWh/a
Hersbruck TH 1	Betrieb	Thermalbad / Balneologie	kein Eintrag	29,3 °C	7,5 l/s	717 m	0,29 MW_t	0,29 MW_t	2,55 GWh/a
Hubbad, Ottersweier	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	36 °C	1,2 l/s	23 m	0,08 MW_t	0,08 MW_t	0,70 GWh/a
Ingolstadt	Betrieb	Thermalbad / Balneologie	kein Eintrag	28,4 °C	2,75 l/s	650 m	0,10 MW_t	0,10 MW_t	0,85 GWh/a
Jordanbad, Biberach	Betrieb	Gebäudeheizung	Gewächshaus	46,7 °C	10 l/s	955 m	1,17 MW_t	1,17 MW_t	0,80 GWh/a
Kassel, Bohrung Wilhelmshöhe 3	Betrieb	Thermalbad / Balneologie	kein Eintrag	40 °C	0,8 l/s	672 m	0,01 MW_t	0,01 MW_t	0,11 GWh/a
Kißlegg, Otto, B12	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	31,2 °C	4,9 l/s	944 m	0,23 MW_t	0,23 MW_t	2,01 GWh/a
Kißlegg, Otto, B13	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	33,3 °C	kein Eintrag	944 m	kein Wert	kein Wert	kein Wert
Konstanz	Betrieb	Thermalbad / Balneologie	kein Eintrag	26 °C	7 l/s	625 m	0,62 MW_t	0,62 MW_t	2,0 GWh/a
Landau in der Pfalz	Betrieb	Stromerzeugung	Fernwärme	160 °C	70 l/s	3340 m	3,5 MW_t	3,5 MW_t	kein Wert
Meersburg	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	26 °C	4 l/s	501 m	0,10 MW_t	0,10 MW_t	0,88 GWh/a
München Riem	Betrieb	Fernwärme	kein Eintrag	98,4 °C	75 l/s	2746,7 m	42,0 MW_t	12,0 MW_t	43,30 GWh/a
Neubrandenburg	Betrieb	Fernwärme	kein Eintrag	53 °C	28 l/s	1267 m	13,80 MW_t	3,80 MW_t	8,32 GWh/a
Neuruppin	Betrieb	Fernwärme	Thermalbad / Balneologie	64 °C	13,9 l/s	1929,5 m	2,10 MW_t	1,25 MW_t	2,74 GWh/a
Neustadt-Glewe	Betrieb	Fernwärme	Stromerzeugung	99 °C	35 l/s	2320 m	17,0 MW_t	7,0 MW_t	11,9 GWh/a
Neu-Ulm	Betrieb	Thermalbad / Balneologie	kein Eintrag	56 °C	2 l/s	1036,6 m	0,30 MW_t	0,30 MW_t	2,64 GWh/a
Obernsees	Betrieb	Thermalbad / Balneologie	kein Eintrag	44,5 °C	3,67 l/s	1283 m	0,38 MW_t	0,38 MW_t	3,29 GWh/a
Prenzlau	Betrieb	Fernwärme	kein Eintrag	108 °C	kein Eintrag	2790 m	0,5 MW_t	0,5 MW_t	1,10 GWh/a
Pullach	Betrieb	Fernwärme	kein Eintrag	102 °C	43 l/s	3445 m	9,60 MW_t	9,60 MW_t	21,02 GWh/a
Regensburg	Betrieb	Thermalbad / Balneologie	kein Eintrag	21,2 °C	8 l/s	623 m	0,04 MW_t	0,04 MW_t	0,35 GWh/a
Rheinbrohl, Petronella-Quelle 2	Betrieb	Thermalbad / Balneologie	kein Eintrag	22,8 °C	kein Eintrag	411,5 m	kein Wert	kein Wert	kein Wert
Salzgitter-Bad - Solequelle	Betrieb	Thermalbad / Balneologie	kein Eintrag	20 °C	kein Eintrag	243 m	kein Wert	kein Wert	kein Wert
Saulgau TB I, TB II	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	40,9 °C	12,5 l/s	639 m	1,09 MW_t	1,09 MW_t	9,57 GWh/a
S-Bad Cannstatt, Hofr. Seyffer Qu,	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	21,8 °C	2,9 l/s	477 m	< 0,01 MW_t	< 0,01 MW_t	0,02 GWh/a
Schliengen Schlossquelle	Betrieb	Thermalbad /	Gebäudeheizung	35 °C	3 l/s	739 m	0,19 MW_t	0,19 MW_t	1,65 GWh/a

		Balneologie							
Simbach-Braunau	Betrieb	Fernwärme	kein Eintrag	80 °C	80 l/s	1941,8 m	40,0 MW_t	7,0 MW_t	67,0 GWh/a
Stein b. Nbg. TH 1	Betrieb	Thermalbad / Balneologie	kein Eintrag	20,5 °C	3,5 l/s	470 m	< 0,01 MW_t	< 0,01 MW_t	0,06 GWh/a
Steinenstadt, Georgsquelle	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	28 °C	3,7 l/s	487 m	0,12 MW_t	0,12 MW_t	1,08 GWh/a
Straubing	Betrieb	Fernwärme	Thermalbad / Balneologie	36,5 °C	45 l/s	824,8 m	5,40 MW_t	4,10 MW_t	11,83 GWh/a
Templin	Betrieb	Thermalbad / Balneologie	kein Eintrag	67,4 °C	kein Eintrag	1788,1 m	kein Wert	kein Wert	kein Wert
Thermalwasserbrunnen Herbstein, Vogelsberg	Betrieb	Thermalbad / Balneologie	kein Eintrag	32 °C	2,5 l/s	980 m	0,13 MW_t	0,13 MW_t	1,10 GWh/a
Treuchtlingen T 1 (Schäffbräu)	Betrieb	Thermalbad / Balneologie	kein Eintrag	27,4 °C	10 l/s	615,8 m	0,31 MW_t	0,31 MW_t	2,71 GWh/a
Treuchtlingen T 2	Betrieb	Thermalbad / Balneologie	kein Eintrag	29 °C	6,8 l/s	812 m	0,26 MW_t	0,26 MW_t	2,24 GWh/a
Tuttlingen I	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	45,3 °C	10 l/s	644,3 m	0,32 MW_t	0,32 MW_t	2,78 GWh/a
Überlingen, Bodensee-Therme	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	36,8 °C	4 l/s	1006 m	0,14 MW_t	0,14 MW_t	1,23 GWh/a
Unterhaching	Betrieb	Fernwärme	Stromerzeugung	122,8 °C	150 l/s	3446 m	38,0 MW_t	30,40 MW_t	66,58 GWh/a
Unterschleißheim	Betrieb	Fernwärme	kein Eintrag	81 °C	90 l/s	1960 m	12,9 MW_t	12,9 MW_t	28,25 GWh/a
Waldbronn, 2. R	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	25,3 °C	0,85 l/s	2000 m	0,02 MW_t	0,02 MW_t	0,16 GWh/a
Waren / Müritz	Betrieb	Fernwärme	kein Eintrag	63 °C	17 l/s	1566 m	10,0 MW_t	1,3 MW_t	2,90 GWh/a
Warmbad Wolkenstein	Betrieb	Thermalbad / Balneologie	kein Eintrag	26,3 °C	2,5 l/s	kein Eintrag	0,07 MW_t	0,07 MW_t	0,58 GWh/a
Weiden Therme	Betrieb	Thermalbad / Balneologie	kein Eintrag	23,3 °C	1,8 l/s	1459,7 m	0,02 MW_t	0,02 MW_t	0,22 GWh/a
Wiesbaden: Gr. Adlerquelle	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	65,1 °C	6 l/s	60 m	0,90 MW_t	0,90 MW_t	7,86 GWh/a
Wiesbaden: Kl. Adlerquelle	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	62 °C	6 l/s	55 m	0,28 MW_t	0,28 MW_t	2,45 GWh/a
Wiesbaden: Kochbrunnen	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	67,5 °C	10 l/s	40 m	1,57 MW_t	1,57 MW_t	13,79 GWh/a
Wiesbaden: Salmquelle	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	64,2 °C	6 l/s	47 m	0,59 MW_t	0,59 MW_t	5,13 GWh/a
Wiesbaden: Schützenhofquelle	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	49,3 °C	6 l/s	65 m	0,19 MW_t	0,19 MW_t	1,71 GWh/a
Wiesenbad Georgsquelle	Betrieb	Thermalbad / Balneologie	kein Eintrag	26 °C	kein Eintrag	kein Eintrag	kein Wert	kein Wert	kein Wert
Wildbad I-VI	Betrieb	Thermalbad / Balneologie	Gebäudeheizung	37,7 °C	13 l/s	200,7 m	0,96 MW_t	0,96 MW_t	8,43 GWh/a

Die Tabelle wurde nicht sortiert. Stand 27.10.2009

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2009

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate
SFP = seasonal performance factor

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

Note: please report all numbers to three significant figures

Locality	Ground or water temp. (°C)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2)]	COP[3)] (SPF)	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Germany	8 - 12	2,230,000	178,000	V,H,W	4 (3.5)		10,368	

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2009

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

Note: please report all numbers to three significant figures.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]	1.2	2.9	0.076633
District Heating [4]	209.3	1054.4	0.159747
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	44.9	1339.2	0.945791
Other Uses (specify)			
Subtotal	255.4	2396.5	
Geothermal Heat Pumps	2230	10368.0	0.14743
TOTAL	2485.4	12764.5	

[4] Other than heat pumps
[5] Includes drying or dehydration of grains, fruits and vegetables
[6] Excludes agricultural drying and dehydration
[7] Includes balneology

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2005 TO DECEMBER 31, 2009 (excluding heat pump wells)

[1] Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1]	(all)	3	8	6	19 spa	4 wells no information 57.0
Production	>150° C			1		3.3
	150-100° C		2	1		9.7
	<100° C		8			14.5
Injection	(all)		9	3		27.0
Total		3	27	11	19	111.5

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Program
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2005						
2006						
2007						
2008						
2009						
Total						

ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES

Year	number of employees
2004	1,800
2005	n. o.
2006	4,200
2007	4,500
2008	9,100

Activities **not** restricted to personnel with University degrees

n. o. = not available

(data BMU 2009)

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2009) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	see Figure 11					
2000-2004	see Figure 11					
2005-2009	see Figure 11					