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Geothermal Energy Use in Germany

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ABSTRACT

With the commissioning of a 5 MW_e ORC plant in Insheim, geothermal power generation in Germany has now reached an installed capacity of 12.1 MW_e. Further units for power generation are located in Bruchsal, Landau, and Unterhaching. Several new plants are expected to be put into operation within a few years.

Geothermal heat uses in Germany reached a total installed capacity of 3,500 MW_t at the end of 2011, with a pure geothermal contribution of about 2,400 MW_t. The renewable heat produced amounted to nearly 4,600 GWh in 2011 and is estimated with 5,000 GWh in 2012. The largest portion of geothermal heat is provided by heat pumps. Their number reached about 244,000 at the end of 2011, with a heating capacity of about 3,000 MW_t and a geothermal contribution of 2,250 MW_t. The renewable heat produced by geothermal heat pumps in 2011 amounted to 3,870 GWh. Furthermore, about 170 centralised installations for geothermal direct use were in operation in Germany. In 2011, deep geothermal heat utilizations provided an installed capacity (geothermal) of 211 MW_t. Common uses are district or space heating and thermal spas. Deep geothermal heat use reached nearly 730 GWh in 2011.

The development of geothermal projects is supported by the German Government by project funding and subsidies for drilling costs. A loan program in collaboration with the KfW Banking Group helps to cover exploration risks. The feed-in tariff for geothermal electricity guaranteed in the Renewable Energy Sources Act (EEG) has been increased to 25 cents/ kWh, with additional 5 cents/ kWh for EGS systems. Furthermore, a market incentive program (MAP) offers financial support for geothermal developments.

1. INTRODUCTION

As Germany lacks natural steam reservoirs, which can be used for a direct drive of turbines, geothermal electricity generation is based on the use of binary systems, which use a working fluid in a secondary cycle (Kalina cycle or ORC). Aquifers with temperatures and hydraulic conductivities suitable for power generation can be expected particularly in the Upper Rhine Graben and in the south-eastern part of the Molasse Basin (Schellschmidt et al. 2010). A successful development of hydraulic stimulation techniques in sediments and crystalline rocks (EGS) would change the situation in Germany fundamentally and make geothermal energy an option in regions without hydrogeothermal potential.

At present, 19 plants for district heating or power generation are in operation in Germany and several new plants are under construction. The occurrence of deep hot aquifers has lead to a vivid project development especially in southern Germany. Current project development concentrates in the Bavarian part of the South German Molasse Basin, where karstified Upper Jurassic limestones provide a suitable aquifer of several hundred meters thickness. Due to the southward inclination of the water-bearing horizon, fluid temperatures increase towards the Alps, reaching temperatures usable for power generation in the area of Munich. Several projects are also under development in the Upper Rhine Graben, which is another region of hydrogeothermal potential. Over-average geothermal gradients make this region interesting for the development of electricity projects.

This paper describes existing geothermal resources and potentials followed by the status of geothermal energy use in Germany. Different use categories such as district and space heating, thermal spas, as well as heat pumps and their contribution to geothermal heat supply are listed. Furthermore, we give an overview of governmental support for geothermal projects and developments and discuss the future perspectives of geothermal energy use in Germany.

2. 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 Generation

Organic Rankine and Kalina cycle techniques allow efficient electricity production at temperatures down to 100 °C and make 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 7,000 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 for Germany in 2011 was 1.9 EJ (BMWi 2013). 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: Areas with potential for hydrogeothermal exploitation in Germany (Pester et al. 2010). From North to South: Upper Rotliegend (Upper Permian) sandstone 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.

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. The most important regions for hydrogeothermal exploitation in Germany are the North German Basin, the Upper Rhine Graben, and the South German Molasse Basin (Fig. 1).

The North German Basin is the central part of the Central European Basin. The present-day sediment thickness ranges from 2-10 km. Halokinetic movements of the Zechstein layers are responsible for the intense and complex deformation of Mesozoic and Cenozoic formations (Franke et al. 1996, Kockel 2002). 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, temperature and energy content of the geothermal resources vary strongly on a regional scale. Table 1 shows the resources of these aquifers.

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

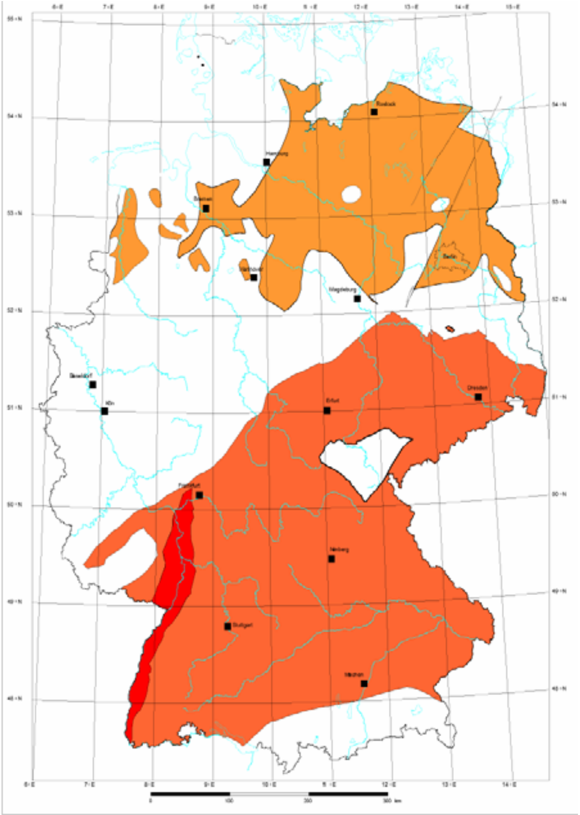

Figure 3: Crystalline rocks for geothermal power production in Germany. Red area: crystalline rock at 3 km depth and with a mean temperature of 100 °C; dark red area: crystalline rock in the Upper Rhine Graben at 3 km depth and with a temperature of 130 °C; orange area: Rotliegend (Permian) volcanic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

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, Haupt-rogenstein, Upper Muschelkalk, Buntsandstein and Rotliegend. The resources of these aquifers are listed in Table 1.

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

2.3 Internet Based Information System

The quantification of exploration risks for geothermal wells, respectively the estimation of probability of success is one of the most important factors for investors and decision makers (Schulz et al. 2010). In order to minimise the exploration risk of geothermal wells and to improve the quality in the planning of geothermal plants, the Leibniz Institute for Applied Geophysics (LIAG) at Hannover, has developed a geothermal information system (GeotIS). The project was funded by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. LIAG realised this project in close collaboration with partners.

GeotIS provides information and data compilations on deep aquifers in Germany relevant for geothermal exploitation. GeotIS includes data of the South German Molasse Basin, the Upper Rhine Graben, and the North German Basin. 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 to 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 (Pester et al. 2010).

GeotIS is designed as a digital information system which is available free of charge to the public through the World Wide Web (www.geotis.de). For more details see Pester et al. (2010).

3. GEOTHERMAL ENERGY USE UPDATE

The German Government supports the development of geothermal energy by project funding, market incentives, credit offers as well as offering a feed-in tariff for geothermal electricity. However, as Germany lacks high enthalpy reservoirs, progress in the development of geothermal energy lags behind the development of other renewables. On the other hand, some regions provide good conditions for heating plants and regionally also for power production (Fig. 1). Thus, especially in the South of Germany a number of new projects has been realized and further developments are being planned.

Geothermal power only plays a marginal role in the German electricity market (BMU 2012 a). Though the development of geothermal electricity in Germany is rather slow, the new plant in Insheim and several power plants presently under construction will lead to a further increase of geothermal power generation in the next years.

Geothermal heat is produced in 170 larger installations using thermal waters and numerous geothermal heat pumps for heating and cooling of office buildings and private houses. The most widespread utilisations of deep geothermal heat are thermal spas. However, the number of larger district heating plants is growing continuously. They presently account for about half of the deep geothermal heat production, with an upward tendency.

Geothermal heat pumps contribute the major portion to geothermal heat use in Germany. Though the strong positive trend of former years did recently not continue, the number of geothermal heat pumps still increases and reached about 265,000 at the end of 2012 (BMU according to AGEE-stat 2013).

3.1 Geothermal Power Generation

With the commissioning of the 5 MW_e plant in Insheim at the end of 2012, geothermal power in Germany had reached an installed capacity of 12.1 MW_e. The electricity produced amounted to 25.4 GWh in 2012, a slight increase compared to 18.7 GWh produced in 2011, but still below the 27.5 GWh produced in 2010 (www.geotis.de). Part of the decrease was caused by reduced electricity generation in the Landau plant, which is presently operated at lower capacity. A considerable increase in power generation can be expected in 2013 with a year-round production in Insheim and several new projects to be commissioned.

At the end of 2012, five plants with facilities for geothermal power production were in operation (Fig. 4, Table A); however, not all of them actually contributed to geothermal electricity production:

- The new 5 MW_e ORC plant of Insheim in the Upper Rhine Graben started producing geothermal electricity in November 2012. A heat extraction is planned in the further development of the project.
- As injection pressures had to be reduced, the 3 MW_e ORC plant in Landau, Upper Rhine Graben, is presently not running at full capacity. A second injection well is planned. Heat extraction is newly in operation in the plant. The heating capacity is about 5 MW_t, with about 3 GWh produced in 2012.
- The heat-lead plant in Unterhaching, Bavaria, operates a 3.3 MW_e Kalina unit. With 8.4 GWh electric power produced in 2012, this plant also contributes significantly to geothermal power generation in Germany.
- After extensive reconstruction works, the 0.55 MW_e Kalina unit in Bruchsal, Upper Rhine Graben, was being in operation mainly for tests and optimization in 2012, feeding 0.5 GWh power into the grid.
- The 0.2 MW_e ORC unit in the Austrian-German district heating project Simbach-Braunau (Bavaria, South German Molasse Basin) did not produce power in 2012. The installed geothermal capacity of the heating plant is 7 MW_t. The power unit is about to be dismantled due to economic considerations.
- The heat-operated plant in Neustadt-Glewe (North German Basin), which had installed a 0.2 MW_e ORC unit for seasonal power production, has quit electricity generation. While heat production continues, facilities for power generation have been dismantled in 2012.

Figure 4: Geothermal power plants or combined heat and power plants (CHP) in operation or under construction in Germany (data: www.geotis.de).

Outlook: Several geothermal power projects are expected to be commissioned in the next years:

- Most of the present project development concentrates in Bavaria. With Sauerlach, Dürrnhaar and Kirchstockach, three plants with around 5 MW_e each are about to start operation in 2013. Furthermore, new plants in Kirchweidach (6.7 MW_e), Taufkirchen (4.3 MW_e) and Traunreut (3.2 MW_e) will contribute to geothermal power generation in the short term, and in the heating plant in Oberhaching it is planned to install a 3.2 MW_e ORC unit.
- In Brühl in the Upper Rhine Graben Region, a 5 MW_e plant is under construction.
- In the research plant Groß Schönebeck, north of Berlin, a 1 MW_e ORC unit has been installed.
- Drilling operations for several other power projects are planned for 2013 (Bernried in Bavaria, Neuried and Rülzheim in Baden-Wuerttemberg).

In total, geothermal power development in Germany can be estimated to reach about 60 to 70 MW_e installed capacity by the end of 2015.

3.2 Geothermal Direct Use in Centralised Units

Common deep geothermal utilizations using thermal waters with temperatures over 20 °C from wells over 400 m depth are district heating plants or combined heat and power plants (CHP), thermal spas, and space heating. Presently, about 170 geothermal installations are in operation in Germany (Fig. 5, Table C).

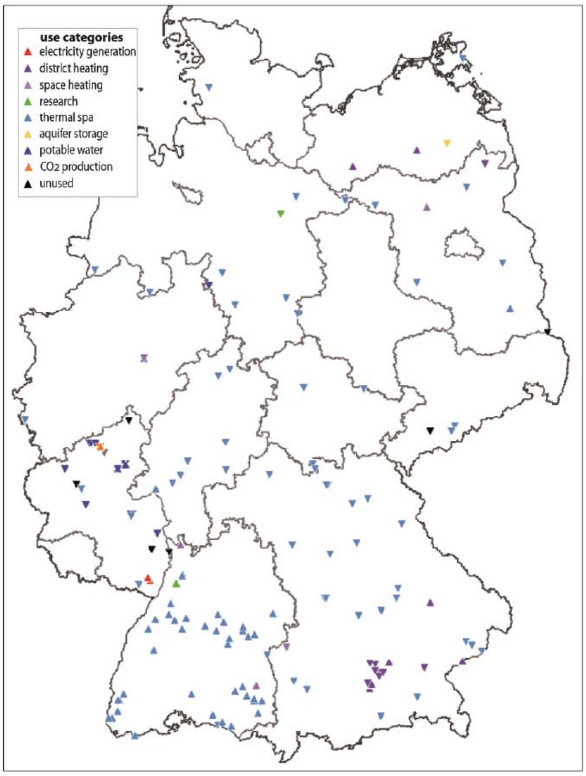

Figure 5: Installations for geothermal energy use in operation in Germany (from www.geotis.de).

Common systems for district heating are geothermal doublets with production and injection well, while spas usually use single wells. Furthermore, three close-loop systems (deep borehole heat exchangers) for space heating are in operation in Germany, the deepest one being used to heat a spa in Arnsberg, North Rhine-Westphalia by a 2,800 m deep well (www.geotis.de).

In 2011, the total installed capacity - which includes auxiliary heat sources such as peak load boilers in addition to the geothermal source - reached about 515 MW_t. The geothermal share of the installed capacity amounted to 211 MW_t. The 19 district heating and combined plants accounted for the largest portion of the total geothermal capacity with about 162 MW_t. Altogether, the installed capacity of deep geothermal heat uses in Germany shows a considerable increase from 144 MW_t in 2009 (Schellschmidt et al. 2010) to the present 211 MW_t (Table 2).

Table 2: Direct use of geothermal energy in Germany: installed capacities (geothermal). Data 2010 to 2012 from www.geotis.de, data 2009 from Schellschmidt et al. (2010). Deviation due to rounding.

primary use	2009 capacity [MW_t]	2010 capacity [MW_t]	2011 capacity [MW_t]	2012 capacity [MW_t]
district heating	98	113	136	163
space heating	1	4	4	4
thermal spas	45	44	44	44
total	**144**	**161**	**183**	**211**

Heat produced by deep geothermal utilisations amounted to 730 GWh in 2011, which was only a slight increase compared to 2010 (Table 3). However, heat use data for 2012 and 2013 can be expected to show a more significant increase due to the commissioning of new heating and combined plants.

Table 3: Direct use of geothermal energy in Germany: annual heat use (geothermal contribution only). Data 2010 and 2011 from GeotIS (www.geotis.de), data 2009 from Schellschmidt et al. (2010). Deviation due to rounding.

	2009	2010	2011
primary use	*annual use [GWh/a]*	*annual use [GWh/a]*	*annual use [GWh/a]*
district heating	*293*	*331*	*349*
space heating	*1*	*7*	*7*
thermal spas	*372*	*374*	*374*
total	***666***	***711***	***729***

Outlook: In 2013, the installed capacity of installations using deep geothermal heat will presumably exceed 250 MW_t. With the supposed commissioning of several new district heating and combined heat and power plants in the next years, the heating capacity can be expected to reach about 320 MW_t by the end of 2015.

3.3 Geothermal Heat Pumps

Heat pump systems for heating and cooling of residential houses and office buildings are widespread in Germany. Geothermal heat pumps use the heat within the subsurface as the renewable heat source or they extract heat directly from the groundwater. Common systems are horizontal heat collectors or borehole heat exchangers (brine/water systems), and groundwater systems with extraction and injection well(s) (water/water systems).

Typical installed capacities of heat pumps used in residential houses are about 10 kW for brine/water and ca 14 kW for water/water systems (GZB 2010). Heat pump systems in office buildings reach capacities of several 100 kW. The largest heat pump installation known in Germany is running in an office building in Duisburg and has a heating capacity of over 1 MW_t (BWP 2012); for large systems, see Table 4.

The total number of all heat pumps including non-geothermal systems reached about 460,000 in 2012, producing 7.2 TWh of renewable heat (BMU according to AGEE-stat 2013). Geothermal heat pumps constitute the major portion of the total number of heat pumps used for space heating and cooling. The number of geothermal systems reached 265,000 at the end of 2012, a considerable increase compared to 244,000 geothermal heat pumps in 2011 (Fig. 6). Brine/water systems are the most common installations with a share of about 85 % of the geothermal heat pumps (GZB 2010).

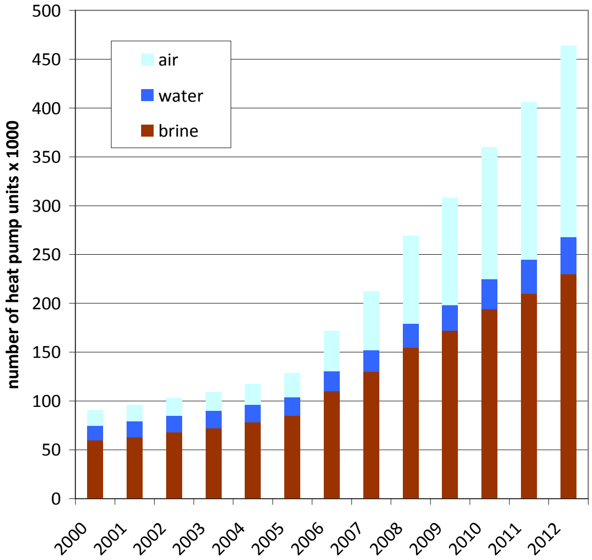

Figure 6: Development of the heat pump market in Germany since 2000 (BMU according to AGEE-stat 2013).

The long-term development of ground source heat pumps sales can be seen in Figure 8. Geothermal heat pumps still constitute the major portion of the total number of heat pump systems used for space heating and cooling, however, sales figures of ground source heat pumps have decreased in the last five years (Fig. 7).

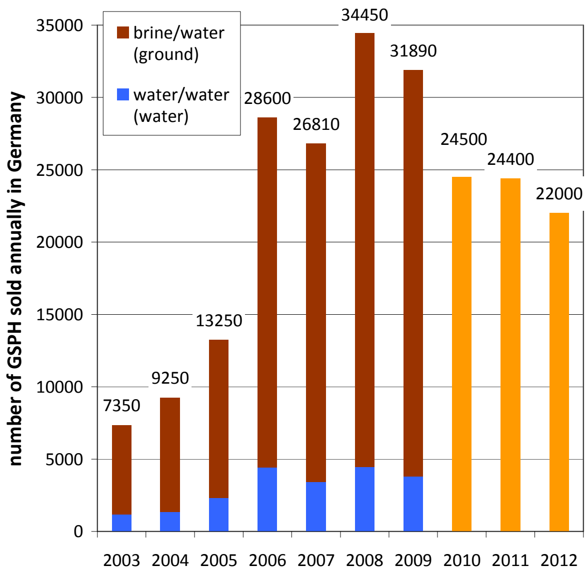

Figure 7: Annual number of new ground source heat pumps (after data from BWP 2013; from 2010 on, the distinction between water and brine heat pumps was no longer made by BWP).

Market figures of the German Heat Pump Association (BWP 2013) show that the share of air coupled systems in total heat pump sales increases continuously, while that of geothermal systems goes down. From a peak of about 85 % of geothermal heat pumps in 1998 the decrease is accelerating steadily, reaching a low of only 37 % in 2012 (Fig. 9)!

According to BWP, the reasons for the decreasing interest in ground source heat pumps are various:

- high cost for drilling, partly arising from imposed official requirements for geothermal boreholes
- lower cost for installation for air source units and low prices of imported air-source heat pumps
- lack of appropriate support measures and incentives (cf. chapter 4.2),
- complicated approval practices.

According to the Working Group on Renewable Energy-Statistics (AGEE-stat), the heating capacity of the stock number of 244,000 geothermal heat pumps amounted to about 3,000 MW_t in 2011 and reached 3,200 MWt in 2012 by 265,000 units (AGEE-stat c/o ZSW, pers. comm.). Assuming an average COP of 4 to 4.5 (GZB 2010, Miara et al. 2011), the geothermal contribution of the heating capacity can be estimated with about 2,250 MW_t in 2011 and 2,400 MW_t in 2012.

Using an average runtime of 1950 full load hours (GZB 2010), the total heat produced by geothermal heat pumps can be estimated with 5 TWh in 2011 and 5.5 TWh in 2012. The renewable share of the produced heat amounted to 3,870 GWh in 2011 and 4,170 GWh in 2012 (AGEE-stat c/o ZSW, pers. comm.).

For EU statistical purposes, the renewable (geothermal) contribution to the heating capacity from now on should be calculated according to the EU Directive 2009/28/EC "Renewable Energy", Annex VII, by the equation:

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

E_{RES}	*renewable energy (in GWh)*
Q_{usable}	*estimated total usable heat (in GWh)*
SPF	*seasonal performance factor*

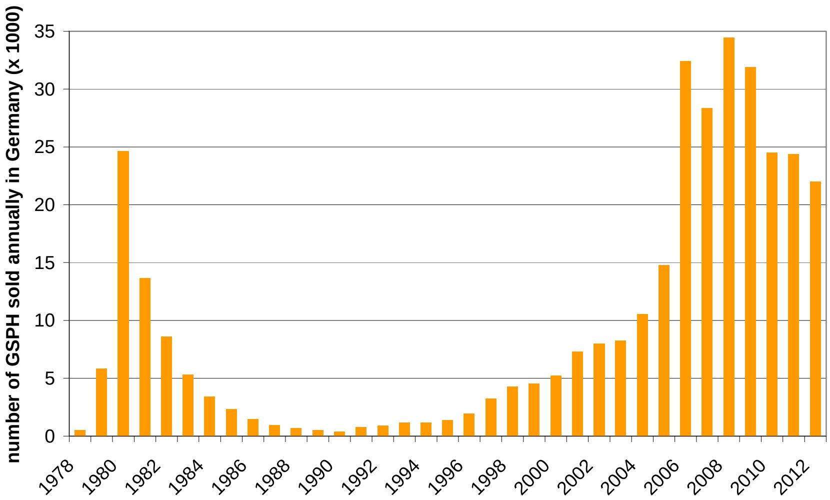

Figure 8: Long-term development of ground source heat pump sales in Germany (both brine and water, 1978-2012) (after annual data from BWP, latest BWP 2013)

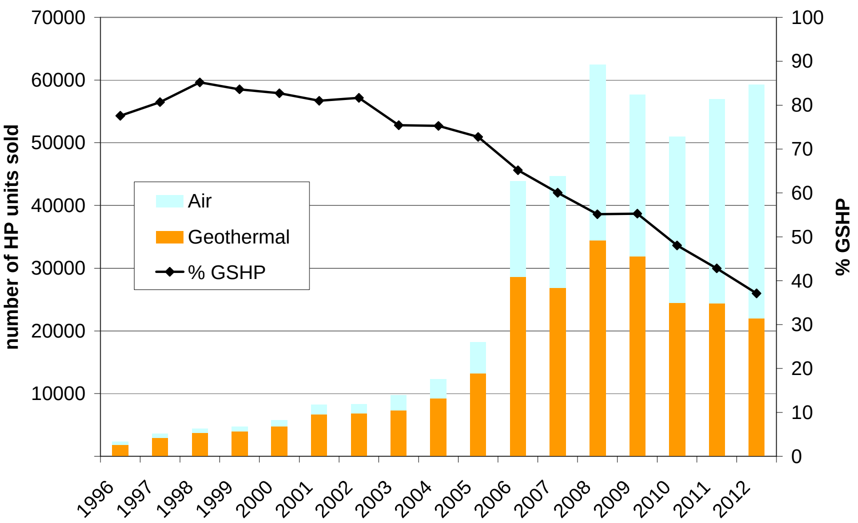

Figure 9: Development of sales for ground source (geothermal) and air source heat pumps in Germany (after annual data from BWP, latest BWP 2013)

Table 4: Large GSHP systems in Germany, status August 2012 (from EGEC 2012)

City, Name	Year	Inst. capacity [kW_{th}]	Type
Duisburg, ZBBW	2011	1480 (H) / 1030 (C)	180 BHE each 130 m deep, 3 HP
Bonn, Bonner Bogen	2009	920 (H) / 620 (C)	3 + 3 groundwater wells 28 m deep, HP
Munich, Dywidag	2001	840 (H) / 500 (C)	Several groundwater wells for 500 m^3/h, HP
Schwabach, MF Niehoff	2009	600 (H) / 900 (C)	103 BHE each 85 m deep, 2 HP
Frankfurt/M, Ordnungsamt	2009	600 (H/C)	112 BHE each 85 m deep, HP
Bonn, „Bonnvisio“	2004	600 (H) / 550 (C)	2 + 2 groundwater wells 11 m deep, HP
Golm near Potsdam, MPI	1999	560 (H) / 360 (C)	160 BHE each 100 m deep, HP
Nuremberg, Panalpina	2008	560 (H) / 270 (C)	81 BHE each 75 m deep, 2 HP
Frankfurt/M, WestendDuo	2005	ca. 400 (H/C)	2 + 3 groundwater wells 140 m deep, HP
Münster, LVM 7	2008	550 (H/C)	91 BHE each 100 m deep, HP
Freiburg i.Br., Qu. Unterlinden	2011	ca. 500 (H/C)	108 BHE each 125 m deep, HP
Frankfurt/M, Maintower	1999	ca. 500 (C)	ca. 210 energy piles each about 30 m tief, cold storage
Gelnhausen, MK-Forum	2005	400 (H) / 440 (C)	96 BHE each 99 m deep, HP
Frankfurt/M, Cargo City Süd 577	2010	380 (H) / 480 (C)	38 BHE each 130 m tief, HP
Leinfelden-Echertdingen, HC	2010	340 (H) / 355 (C)	80 BHE each 140 m tief, HP
Langen, DFS	2001	330 (H) / 340 (C)	154 BHE each 70 m deep, HP
Frankfurt/M, Baseler Platz	2003	300 (H) / 180 (C)	2 groundwater wells 80 m deep, HP

H: Heating, C: Cooling, BHE: Borehole Heat Exchanger

In March 2013, the EC has issued the necessary rules for applying this formula, prepared by Eurostat (Decision 2013/114/EU). As a default (i.e. if no better data from actual measurements are available), Q_{usable} shall be calculated as:

$$Q_{usable} = H_{HP} * P_{rated}$$

Q_{usable} *estimated total usable heat (in GWh)*
H_{HP} *full-load hours of operation*
P_{rated}: *capacity of heat pumps installed*

Also default values for H_{HP} and SPF are given in 2013/114/EU. For Germany, located in the "average climate" zone, H_{HP} is considered as 2070 h/year (a rather high value), and SPF for Ground-Water and Water-Water heat pumps as 3.5 (this value is more on the low side for Germany). Then the full calculation is:

Q_{usable} = 3200 MW * 2070 h/yr = 6'624 GWh/yr

(so following this rule, Q_{usable} will be estimated considerably higher than the value of 5'500 GWh/yr calculated by AGEE-stat).

E_{RES} = 6'624 GWh/yr * (1 – 1 / 3.5) = 4731 GWh/yr

(this is equivalent to 580 Ktoe)

The pure geothermal contribution from ground source heat pump systems in Germany thus can be estimated to be 4.73 TWh_{th} in 2012, according to the new EU calculation rule.

It is also possible to calculate the amount of CO_2-emmissions saved by using ground source heat pumps instead of natural gas burners, still the most popular heat source in Germany (Fig. 10). Using the emission factors of 0.25 g/kWh for natural gas and 0.6 g/kWh for the electricity in Germany, and assuming the (low) average SPF of 3.5 as given by Eurostat, the total emission reductions would amount to about 590 Kt in 2012, or ca 38 % compared to the same heat provided by natural gas.

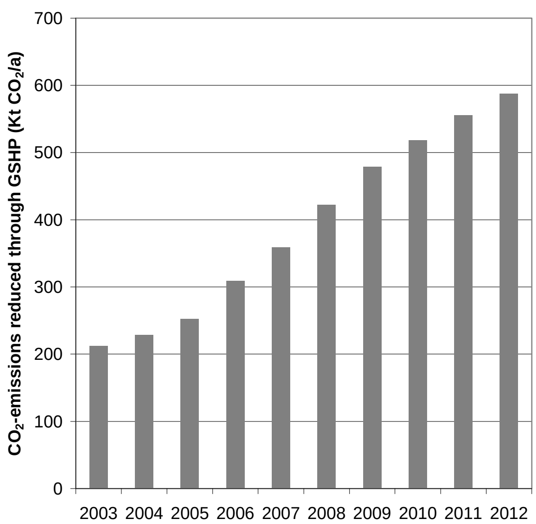

Figure 10: Annual reduction of CO_2-emissions due to GSHP in Germany (calculated after data from BWP 2013, see text)

4. GOVERNMENTAL SUPPORT AND FUTURE PERSPECTIVE

4.1 Energy Market and the Role of Geothermal

A new, conservative estimate of the total thermal capacity currently installed for direct use of geothermal energy in Germany amounts to roughly 3,500 MW_t with a geothermal contribution of about 2,400 MW_t and 4,600 GWh renewable heat produced. About 85 % of the renewable heat by geothermal applications is attributed to small decentralised units.

According to BMWi (2013), the final energy consumption in Germany in 2011 was 8744 PJ (1 PJ = 10^{15} J). A breakdown in Figure 11 shows that about 54 % of the final energy consumption was required for district and space-heating, hot water, or process heat.

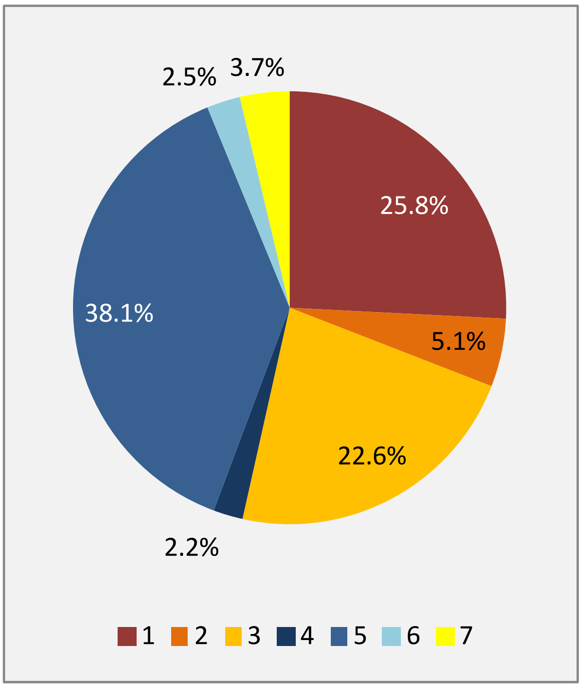

Figure 11: The final energy consumption for Germany in 2011 was 8744 PJ (data BMWi 2013). Distribution shown according to usage: (1) district and space heating, (2) hot water, (3) process heat, (4) air condition, (5) mechanical energy, (6) information and communications technology, (7) electric lighting.

Most of this demand at present is supplied by fossil fuels. 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.

4.2 Governmental Support

Germany has set itself ambitious climate protection targets and resolved to phase out of nuclear energy by 2022. The German Government aims for an energy supply based predominantly on renewables, meeting 80 % of the electricity demand and 60 % of the final energy consumption by 2050 (BMU 2012b).

To support the development of renewable energy, the German Government has set aside some 3.5 billion Euros for the research and development (R&D) of future energy technologies from 2011 to 2014 under the 6th Energy Research Programme. From 1.3 billion Euros budgeted for research funding, 1.1 billion is designated for project funding (BMU 2012b).

In the field of geothermal R&D, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) has granted funding for 42 new projects with a total volume of 24.1 million Euros (2010: 30 projects and 15.1 million €, Fig. 12). Furthermore, the financing of running projects amounted to 11.6 million € in 2011 (2010: 9.9 million €) (BMU 2012b).

Apart from funding R&D projects, the Federal Government is also creating incentives for new projects by offering a feed-in tariff for geothermal electricity under the Renewable Energy Sources Act (EEG). The amendment of the EEG with improved conditions for geothermal energy has come into effect on 1st January 2012. The subsidy for geothermal electricity has been increased to 25 cents/ kWh with additional 5 cents/ kWh for the use of petrothermal (EGS) techniques.

The Renewable Heat Act (EEWärmeG) of 2009, which has come into force in an amended version in 2011, mainly aims at the installation of renewable heat sources in buildings. An obligation for use of renewable energy in new buildings is given in EEWärmeG; geothermal heat pumps are eligible if they meet the criteria, for example certain quality

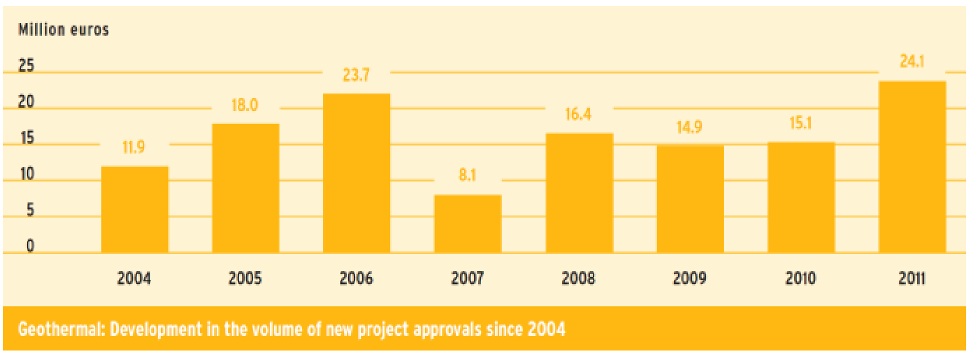

Figure 12: Funding for new geothermal R&D projects by BMU from 2004 to 2011 (BMU 2012b).

labels, a minimum coverage of 50 % of the annual heat load by the heat pump, and a minimum seasonal performance factor (SPF) as to Figure 13.

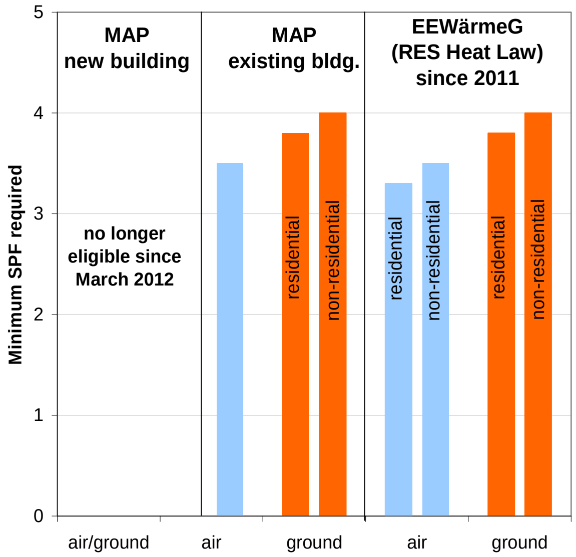

Figure 13: Required minimum SPF for heat pumps being considered eligible for support under MAP or accepted for fulfilling the renewable energy obligation after EEWärmeG.

The lower SPF values for air-source heat pumps and that fact that only 50 % of the annual heat load must be covered (i.e. bivalent/monoenergetic heat pumps are possible) are a clear benefit for air source heat pumps. As a result, the EEWärmeG politically sets the signal to continued decrease of the share of ground source heat pumps as discussed in chapter 3.3 – in spite of the fact that they could render a higher contribution to CO_2 emission reductions!

The market incentive programme (MAP) of the German Government promotes renewable energy systems that provide space heating, hot water, cooling and process heat. It has a section for smaller buildings and one for larger investments. The MAP supports the installation of heat efficient heat pump systems. The section for smaller buildings is in the competency of the Federal Office of Economics and Export Control (BAFA). Investments in larger heat pump systems in commercial buildings as well as in deep geothermal projects are supported within the KfW Banking Group renewable energies program, which offers low-interest loans and repayment bonuses for larger investments.

For deep geothermal heat and power plants, a repayment bonus up to a maximum of 2 million Euros/ plant and for drill costs of wells over 400 m depth is offered. By order of BMU, a loan program of KfW in cooperation with Munich Re (insurance provider) helps furthermore to hedge exploration risks. The program includes financing of up to 80 % of the drill costs and full risk coverage in case of unsuccessful exploration.

For geothermal heat pumps, the financial support from the MAP is only granted for existing buildings since March 2012. Before this it was limited in new buildings to very efficient systems only, since late 2010. The rules in the refurbishment sector now are disadvantageous to geothermal heat pumps; the same high values for SPF (up to 4.0) are stipulated for financial support of systems in existing buildings than those required in EEWärmeG for new buildings (Fig. 13)! To achieve this high values, refurbishment at high extra cost in existing buildings is required, which cannot be offset by the support granted. As a result, the number of plants supported within MAP dropped drastically from 2011 on, and is almost negligible today (Fig. 14) – in 2012 the share of supported plants was <9 % of all heat pumps installed in that year.

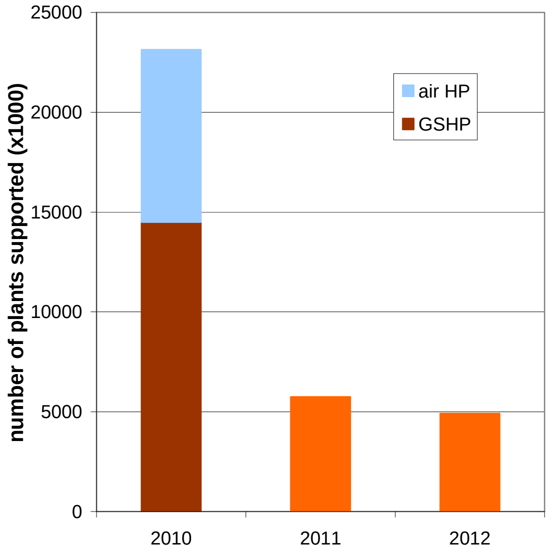

Figure 14: Number of heat pump plants supported within MAP (after data from BAFA; in 2011 and 2012 all heat pumps, no distinction ground/air).

4.3 Outlook

Based on information on projects currently under construction, the development of geothermal power generation can be expected to exceed 50 MW_e in 2015. 70 MW_e are possible, if project development goes fast without larger technical problems or other reasons like legal aspects.

Evaluating data from projects for deep geothermal heat use, the installed capacity is estimated to increase from 211 MW_t at the end of 2011 to about 350 MW_t in 2015 with an annual heat production of 1,000 GWh. Given a continuing trend, the number of geothermal heat pumps can reach 350,000 units in 2015 with an installed capacity of over 4,300 MW_t producing 5.500 GWh renewable heat. The total geothermal heating capacity can thus be estimated to reach about 3,500 MW_t in 2015 with a renewable heat production of over 6,000 GWh (21 PJ).

The pilot study 2010 for long-term scenarios and strategies for the development of renewables in Germany (BMU 2010) projects for the development of geothermal power installed capacities of nearly 300 MW_e by 2020 and 1 GW_e in 2030 in one scenario. Geothermal heat use is estimated to reach 8,000 GWh (29 PJ) in 2020 and nearly 25,000 GWh (89 PJ) by 2030.

5. CONCLUSIONS

Due to moderate temperature gradients in most parts of Germany and a general lack of high enthalpy reservoirs, geothermal energy use in Germany is still on a comparably low level. Current project development concentrates in the southern part of Germany, where regional geologic settings provide good conditions for heat use and in part also for power generation.

The installed capacity of geothermal heat uses in Germany amounted to 3,500 MW_t in 2011, with a pure geothermal contribution of about 2,400 MW_t. 90 % of the installed capacity is attributed to geothermal heat pumps. The remaining 10 % is contributed by centralised installations using thermal waters from depths over 400 m, such as heating plants and thermal spas. The geothermal heat production in Germany amounted to 4.6 TWh in 2011 with 15 % attributed to deep geothermal utilizations. In 2012, geothermal heat production is estimated with about 5 TWh.

In 2012, four geothermal power plants or combined heat and power plants were in operation in Germany, the power-led plants of Insheim, Landau and Bruchsal in the Upper Rhine Graben, and the combined plant of Unterhaching in Bavaria. Due to the commissioning of the Insheim plant, the installed electric capacity increased to 12.1 MW_e at the end of 2012. A continuation of this positive trend can be expected in the next years. Considering projects presently under construction, 60 to 70 MW_e installed capacity seem feasible until the end of 2015 by a conservative estimate.

With the resolution of the amended Renewable Energy Sources Act (EEG) on 30 June 2011, the German Government further improved the conditions for the development of geothermal energy in Germany. The positive effect of the EEG on geothermal power development is backed up by financial support of pilot and demonstration projects by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). In addition, a market incentive programme grants support for the installation of efficient heat pump systems in private houses and office buildings. Furthermore, repayment bonuses for geothermal heat and power plants and drill costs are granted and part of the exploration risk can be covered within a program.

Altogether, the use of geothermal energy in Germany shows a slow but continuous positive trend in the last years. In regions with favourable conditions, a vivid project development takes place, which will further increase the geothermal heat and power capacity in the next years. Governmental support provides interesting incentives for further investments in the geothermal market.

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Tables A-G

Table A: Present and planned geothermal power plants, total numbers

	Geothermal Power Plants		Total Electric Power in the country (2011)		Share of geothermal in total	
	Capacity (MW_e)	Production (GWh/yr)	Capacity (MW_e)	Production (GWh/yr)	Capacity (%)	Production (%)
In operation end of 2012	12.1	18.83	174,000	609,000	< 0.1 %	< 0.1 %
Under construction end of 2012	35					
Total projected by 2015	60 to 70					

Data total capacity and power production: BMWi (2013)

Table B: Existing geothermal power plants, individual sites

Locality	Plant Name *	Region **	Year commiss.	No of units	Status	Type	Total inst. Capacity (MW_e)	Total running cap. (MW_e)	**2012** product. (GWh_e/y)
Bruchsal		URG	2009	1	O	B-Kal	0.55	0.55	0.46
Insheim		URG	2012	1	O	B-ORC	5	5	3.32
Landau		MB	2007	1	O	B-ORC	3	2	13.2
Simbach-Braunau		MB	2001	1	N	B-ORC	0.2	0	0.0
Unter-haching		MB	2007	1	O	B-Kal	3.36	3.36	8.4
Neustadt-Glewe		NGB	1994	1	R Turbine dismantled in 2012	B-ORC	-	-	-
total				**5**			**12.1**	**10.36**	**25.4**

Key for status:		Key for type:			
O	Operating	D	Dry Steam	B-ORC	Binary (ORC)
N	Not operating (temporarily)	1F	Single Flash	B-Kal	Binary (Kalina)
R	Retired	2F	Double Flash	O	Other

* Plants are named after the localities

** Regions with hydrogeothermal potential:

URG Upper Rhine Graben
MB (South German) Molasse Basin
NGB North German Basin

Table C: Present and planned geothermal district heating (DH) plants and other direct uses, total numbers

	Geothermal DH Plants		Geothermal heat in agriculture and industry		Geothermal heat in balneology and other	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2012	163	349	0	0	48	380
Under construction end of 2012	100		0	0	na	na
Total projected by 2015	260	500 - 600	0	0	na	na

Table D: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name *	Region **	Year commiss.	Is the heat from geo-thermal CHP?	Is cooling provided from geo-thermal?	Installed geotherm. capacity (MW_{th})	Total installed capacity (MW_{th})	Geother. heat prod. (GWh_{th}/y) (2011)	Geother. share in total prod. (%)
Bruchsal		BW	2009	Yes	No	5.5	5.5	0	
Landau		BW	2007	Yes	No	5	33	0.40	
Neustadt-Glewe		MWP	1994	Yes	No	4	14	10.20	
Simbach-Braunau		BA	2001	Yes	No	7	40	45.55	
Unterhaching		BA	2007	Yes	No	37	47	73.26	
Oberhaching / Grünwald		BA	2011	Not yet (ORC turbine planned)	No	11	18	2.26	
Ascheim		BA	2009	No	No	9	29	37.02	
Erding		BA	1998	No	No	10.2	48.6	26.44	
Garching		BA	2011	No	No	7.95	27.95	2.50	
München-Riem		BA	2004	No	No	12	45	48	
Poing		BA		No	No	8	37	0	
Prenzlau (borehole heat exchanger)		BB		No	No	0.15	0.65	0.53	
Pullach		BA	2005	No	No	15	32	31	

Table D: Existing geothermal district heating (DH) plants, individual sites (continued)

Locality	Plant Name *	Region **	Year commiss.	Is the heat from geo-thermal CHP?	Is cooling provided from geo-thermal?	Installed geotherm. capacity (MW_{th})	Total installed capacity (MW_{th})	Geother. heat prod. (GWh_t/y) (2011)	Geother. share in total prod. (%)
Straubing		BA	1999	No	No	2.1	7.33	2.9	
Unterföhring		BA	2009	No	No	9.5	29.5	29	
Unterschleiß-heim		BA	2003	No	No	8	28.5	36.6	
Waldkraiburg		BA	2012	No	No	10	20	0	
Waren/Müritz		MWP	1984	No	No	1.30	10	3	
total						162.7	473	348.7	

* Plants are named after the localities

** Regions:
- BA Bavaria
- BB Brandenburg
- BW Baden-Wuerttemberg
- MWP Mecklenburg-West Pomerania

Table E: Shallow geothermal energy, ground source heat pumps (GSHP)

	Geothermal Heat Pumps (GSHP), total			New GSHP in 2012		
	Number	Capacity (MW_t) [1]	Production (GWh_t/yr) [2]	Number	Capacity (MW_t)	Share in new constr. (%)
In operation end of 2012	265,000	3,200	4,200	22,300	280	
Projected by 2015	350,000	4,500	6,000			

[1] heating capacity [2] geothermal share only

Table F: Investment and Employment in geothermal energy

	in 2012		Expected in 2015	
	Investment (million €)	Personnel (number)	Investment (million €)	Personnel (number)
Geothermal electric power	na	na	na	na
Geothermal direct uses	na	na	na	na
Shallow geothermal	na	na	na	na
total	**960 M €**	**14,200**	**na**	**na**

Data: BMU (2012a)

Table G: Incentives, Information, Education

	Geothermal el. power	Geothermal direct uses	Shallow geothermal
Financial Incentives – R&D	35 M € funding for geothermal R&D in general by government in 2011		A few R&D-projects funded by the government
Financial Incentives – Investment	Market Incentive Program: Repayment bonus for drill costs RC: Part of exploration risk can be covered within a program of KfW Banking Group together with Munich Re		Market incentive program: financial support of energy efficient heat pump installations (only for refurbishment in existing buildings)
Financial Incentives – Operation/Production	FIT 25 ct/ kWh + 5 ct./ kWh for EGS		
Information activities – promotion for the public	Geothermal Information System www.geotis.de Information Material of the Federal Environmental Ministry (BMU)		
Information activities – geological information	Geothermal Information System www.geotis.de		Most federal states operate information systems for shallow geothermal uses
Education/Training – Academic	Several universities have meanwhile geothermal energy as part of their curricula; also some summer courses are offered (e.g. Univ. of Bremen)		
Education/Training – Vocational			3-week-training program by DGGT/DGG, some other individual courses; activities to use the Geotrainet-umbrella

Key for financial incentives:					
DIS	Direct investment support	RC	Risk coverage	FIP	Feed-in premium
LIL	Low-interest loans	FIT	Feed-in tariff	REQ	Renewable Energy Quota