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Geothermal Energy Use in Germany

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ABSTRACT

At present, 30 geothermal installations for direct use of geothermal energy each with an installed thermal capacity in excess of 100 kW_t are operating in Germany. The installed capacity of these plants amounts to roughly 105 MW_t. The installations comprise centralised heating units, thermal spas combined with space heating and, in some cases, greenhouses and clusters of ground heat exchangers used for space heating or cooling. Most of the centralised 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 decentralised geothermal heat pump units (ground coupled heat pumps and groundwater heat pumps). Their installed capacity exceeds 400 MW_t. By the end of 2004 direct thermal use of geothermal energy in Germany amounted to a total installed thermal capacity of 505 MW_t.

The first geothermal plant for electrical power generation in Germany is on-line since November 2003 with an installed capacity of about 230 kW_e. The economic situation in the electric power market is determined by the Renewable Energy Act (EEG), which sets a fixed rate for geothermal power sold to the utilities. Ratification of this law in 2000 has created a sound economic basis for the development of geothermal projects, and several have indeed been launched since then, mainly in the Upper Rhine Graben, the Munich area and Northern Germany. An increase of the rate for geothermal power from 0.089 €/kWh to 0.15 €/kWh is scheduled for summer 2004. Currently 6 new installations for power generation are being planned: Groß Schönebeck, Bad Urach, Offenbach, Speyer, Bruchsal and Unterhaching.

A successful development of the Enhanced Geothermal Systems (such as Hot Dry Rock technology) will make an additional contribution. The "Geothermische Vereinigung (GtV)" is promoting the ‘‘1-GW_e Programme’’, which is targeted to achieve the installation of 1 GW_e of geothermal power from Enhanced Geothermal Systems and deep hydrothermal resources within the foreseeable future.

A study of the "Office of Technology Assessment at the German Parliament (TAB)" investigated the potential for geothermal power production in Germany. This study shows that the resources for geothermal power production in Germany amount to about 10^{21} J.

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 binary 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.

A successful development of the Hot Dry Rock (HDR) technology and the hydraulic stimulation technique in sediments would change this situation fundamentally. Two HDR geothermal power plants are in realisation at Groß Schönebeck and Bad Urach. New innovative technologies are currently being developed for converting the heat of deep seated hot aquifers to power at Offenbach, Speyer, Bruchsal and Unterhaching. These projects are supported by the ZIP-programme for investment in the future (Zukunfts-Investitions-Programm), launched by the German federal government.

This paper describes the existing geothermal resources and potentials followed by the status of geothermal utilisation in Germany by the end of 2004, 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 e.g. the Renewable Energy Act, the ZIP-programme and the 1-GW_e Programme.

2. GEOLOGICAL BACKGROUND, 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.

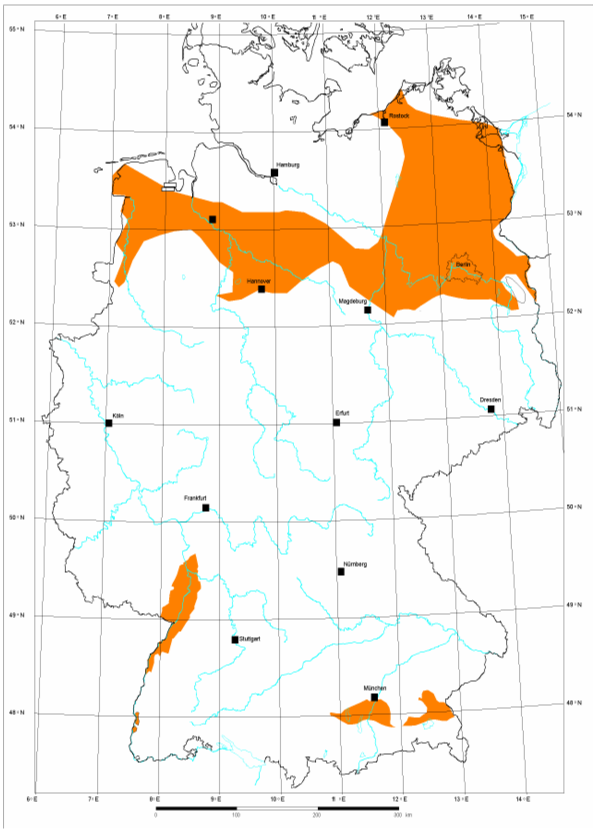

Figure 1: Hot water aquifers for geothermal power production in Germany from North to South: Upper Rotliegend (Upper Permian) sand stone aquifer in the North German Basin; Upper Muschelkalk and Buntsandstein (Middle and Early Triassic) aquifers of the Upper Rhine Graben; Malmkarst (Upper Jurassic) aquifer in the South German Molasse Basin.

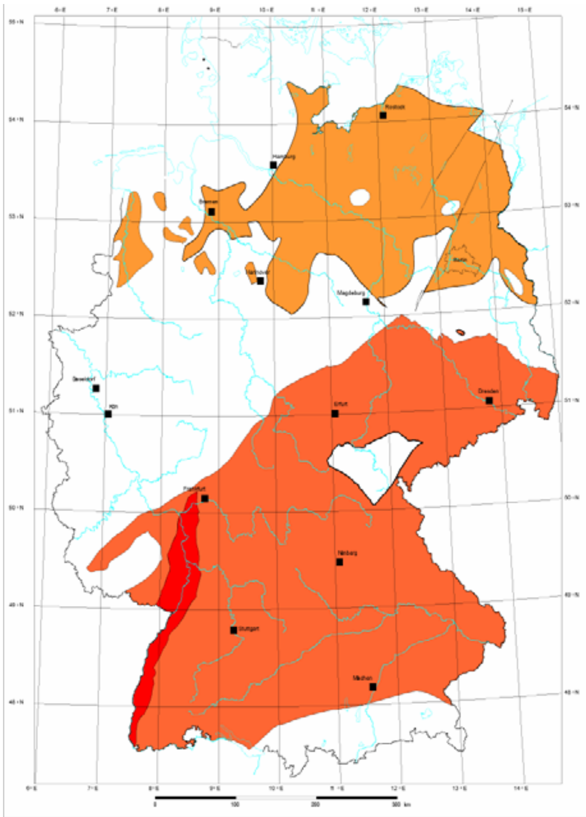

Figure 3: Crystalline rocks for geothermal power production in Germany. Red area: crystalline rock at 3 km depth and with a mean temperature of 100 °C; dark red area: crystalline rock in the Upper Rhine Graben at 3 km depth and with a temperature of 130 °C; orange area: Rotliegend (Permian) volcanic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

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 1100 EJ for crystalline rock. In comparison to these potentials the annual power consumption in 2001 for Germany was 1.741 EJ (BMWA 2003). To recover at least part of this huge resources further research and developments are necessary especially in accessing heat from faults and crystalline rocks.

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 (Fig. 4).

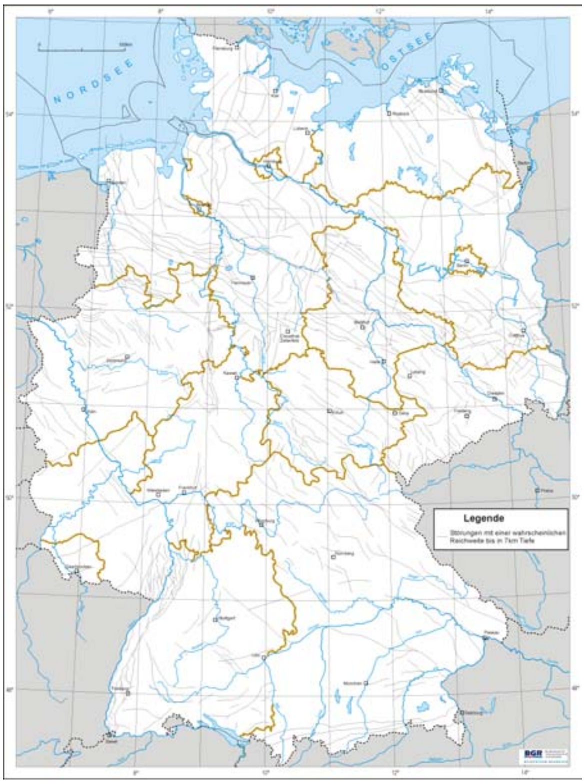

Figure 2 (left): Deep-seated fault systems with a possible extension up to 7 km depth.

Figure 4: Regions of interest for direct use of geothermal energy are indicated in yellow: the North German Basin with salt dome tectonics (blue), the Molasse Basin in southern Germany, and the Upper Rhine Graben, having the highest temperature anomalies. The crystalline basement is shown in red.

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). 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 stones and carbonates, with evaporite intercalations. Six Cretaceous, Jurassic and Triassic sandstone aquifers are of interest for direct use of geothermal energy: (1) Valendis-Sandstein, (2) Bentheimer Sandstein (3) Aalen, (4) Lias and Rhät, (5) Schilfsandstein, and (6) 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 and probable reserves 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: (1) Burdigal-Sande, (2) Aquitan-Sande, (3) Chatt-Sande, (4) Baustein-Schichten, (5) Ampfinger Schichten, (6) Gault/Cenoman-Sandsteine, (7) Malm and (8) 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 and probable reserves 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: (1) Hydrobien-Schichten, (2) Grafenberg-Schicht (3) Hauptrogenstein, (4) Upper Muschelkalk, (5) Buntsandstein and (6) Rotliegend. The resources and probable reserves of these aquifers are listed in Table 1.

3. GEOTHERMAL UTILIZATION

Geothermal energy (Huttrer 2000, Lund and Freestone 2000) 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.

3.1 Geothermal Power Production

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. 5). The installed capacity is about 230 kWe to generate power. In addition 10.7 MW_t are used for district and space heating (Table 2). The projected power production of 1400-1600 MWh/a will provide 500 households with electric power (Broßmann et al. 2003). An Organic Rankin Cycle (ORC) is used for the electrical power generation. The thermal water (maximal flow rate 100 m³/h) 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 (C_5F_{12}) is used, which starts boiling at 31 °C at normal pressure (Kranz 2003).

3.2 Centralised Installations for Direct Use

At present 30 installations for direct use of geothermal heat are operating in Germany (Fig. 5), each with an installed capacity in excess of 100 kW_t (Table 2). These plants comprise centralised heating units, thermal spas sometimes combined with space heating and, in some cases, greenhouses and clusters of ground heat exchangers used for space heating or cooling. The total thermal capacity installed is 104.6 MW_t and the annual utilization amounts to roughly 710 TJ/a or 200 GWh/a (Table 2). Fluid temperature in all of them is below 110 °C (Table 2).

Not all of this thermal capacity is of geothermal origin. In some of the installations heat pumps are used (Table 2) and most of the electrical input is also converted into heat. The ratio of energy produced to energy spent (calculated as power output to input integrated over one year) is termed seasonal performance factor (ß). The factor ß typically varies between 5 and 7 in large centralised hydrothermal heating units. Most of these heating units use auxiliary oil and gas burners to cover peak demand. The pure geothermal part of installed capacity for direct use in 30 major central units in Germany is estimated to be 46.8 MW_t. The pure geothermal contribution of the six major heating plants amounts to 32.9 MW_t which is 70% of the pure geothermal contribution of all installations (Table 2).

In the remaining 24 installations no additional heating (except Staffelstein) is applied to cover peak demand. Therefore the geothermal contribution of these units of 13.9 MW_t is almost identical with their installed capacity.

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 18 of 30 installations listed in Table 2 combine power production, thermal spas and space or greenhouse heating as well as the use of the cooled water for drinking water.

Most of the centralised plants are located in the North German Basin, the Molasse Basin in southern Germany, or along the Rhine Graben (Fig. 4). The six biggest geothermal units (Table 2) with an installed capacity of about 90 MW_t are located in the North German and in the Molasse Basin. As these regions including the Rhine Graben have the largest geothermal resources in Germany (Haenel and Staroste 1988, Hurter and Haenel 2002), most of the new installations are also being developed here (Fig. 5).

3.3 Small Decentralised Units for Direct Use

Geothermal energy use for space heating in small decentralised units is widespread in Germany. 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 statistics are available.

A conservative estimate (Sanner and Bußmann 2003) yields a total geothermal power of 400 MW_t presently installed in Germany in small and medium size decentralised units. The mean installed geothermal power of each of these installations typically varies from 10-15 kW_{th}, with an average of 13 kW_{th}. Thus roughly 30,000 small decentralised units are operating at present in Germany. With an average seasonal performance factor (ß) of 3 to 4 the pure geothermal contribution is equal to 285 MW_t. Thus, decentralised units provide six times the installed pure thermal power of the centralised installations.

4. FUTURE 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 505 MW_t. The pure geothermal part of this sum amounts to 332 MW_t or 66%. Only about 26% of this is provided by large centralised installations. The prevailing part comes from about 30,000 small decentralised units.

The final energy consumption in Germany in 2001 was 9456 PJ (1 PJ = 10^{15} J) (BMWA 2003). A breakdown in Fig. 6 shows that 58% of the final energy consumption was required as heat, be it for space-heating, hot water, or process heat (VDEW, 2003). 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.

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 22% of the 2001 German final energy consumption of 9456 PJ. Thus, a good fifth of the final energy consumption in Germany could be supplied by the direct use of geothermal energy. However, at present only about 7‰ of the potential demand is covered by geothermal heat.

Fifteen projects are scheduled for completion by the years 2005-2010 (Table 3), yielding an additional installed thermal capacity of 126 MW_t and an electric power of 18 MW_e. Fig. 7 shows the increase of the installed geothermal power since 1955 and the planned installed power for direct use of geothermal heat. An increase in total installed power to about 231 MW_t (220% compared to 2004) is expected by the year 2010 (Fig. 7).

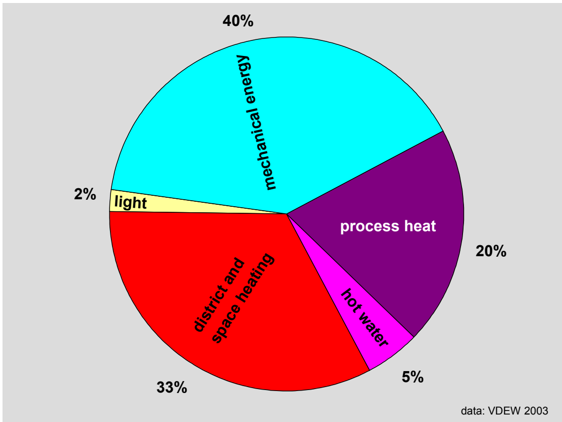

Figure 6: Final energy consumption in Germany according to usage (data: VDEW 2003). Distribution shown is for Germany in 2002. Final energy consumption in Germany was 9456 PJ in 2001.

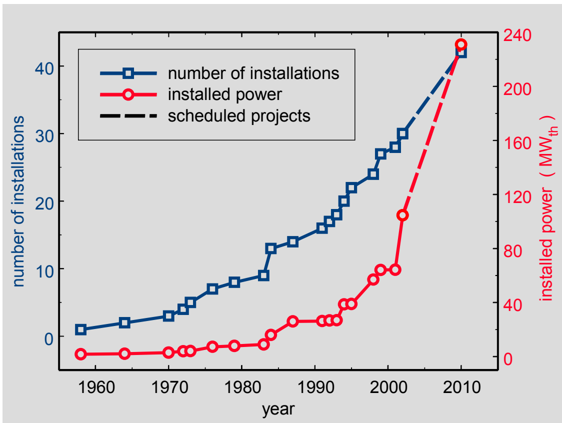

Figure 7: Number of geothermal centralized installations, installed power in Germany and projections to 2010.

A revised edition of the Renewable Energy Act (Erneuerbare Energien Gesetz, EEG) came into force in August 2004. There is now a real chance for planning and installing geothermal power plants on a sound economic basis. The increase of remuneration for the feed-in allowance from 0.089 to 0.15 €/kWh (Table 4) for electricity produced from geothermal energy since August 2004 will presumably stimulate the build-up of a geothermal power industry in Germany and will open up new opportunities for geosciences and for the drilling and service industry.

The positive effect of the new Renewable Energy Act has been further enhanced by the ZIP-Programme (Zukunfts-Investitions-Programm) launched by the German federal government. This led to a series of new projects and innovative technologies offering new perspectives for geothermal power generation.

The German Geothermal Association (GtV) is promoting the ''1-GW$_e$ Programme'', which is targeted at achieving the installation of 1 GWe of geothermal power from Enhanced Geothermal Systems (such as Hot Dry Rock) and deep hydrothermal resources within the foreseeable future.

6. 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 500 MW$_t$. 80% of which is attributed to about 30,000 decentralized units using heat from shallow depth. The remaining 20% is attributed to 30 centralized installations exploiting mainly deep-seated aquifers. The first German geothermal power plant has just started operation with an installed capacity of 230 kW$_e$.

It is expected that the only moderate increase of the installed capacity will be accelerated during the next years by the implementation of the Renewable Energy Act and by other programs giving direct financial support. A 1-GW$_e$ Programme is envisioned for the next decade.

REFERENCES

Broßmann, E., Eckbert, F. and Möllmann, G.: Technisches Konzept des geothermischen Kraftwerkes Neustadt-Glewe, *Geothermische Energie 43*, 31-36, Geeste, 2003.

Bundesministerium für Wirtschaft und Arbeit (BMWA): Energiedaten 2003 – Nationale und internationale Entwicklung, Bundesministerium für Wirtschaft und Arbeit (Federal Ministry of Economics and Labour), Referat LP4 Kommunikation und Internet, Berlin, 2003.

Franke, D., Hoffmann, N. and Lindert, W.: The Variscan deformation front in East Germany, Part 2: tectonic interpretation, *Zeitschrift für angewandte Geologie 42*, 44-56, Hannover.

Haenel, R., and Staroste, E. (Eds.): Atlas of Geothermal Resources in the European Community, Austria and Switzerland, *Publishing company Th. Schaefer*, Hannover, Germany, 1988.

Hurter, S., and Haenel, R. (Eds.): Atlas of Geothermal Resources in Europe, *Office for Official Publications of the European Communities*, Luxemburg, 2002.

Huttrer, G. H.: The Status of World Geothermal Power Generation 1995-2000, in: Iglesias, E., Blackwell, D., Hunt, T., Lund, J. and Tamanyu, S. (Eds.), *Proceedings of the World Geothermal Congress 2000*, Kyushu – Tohoku, Japan, 23-37 (2000).

Jung, R., Röhling, S., Ochmann, N., Rogge, S., Schellschmidt, R., Schulz, R. and Thielemann, T.: Abschätzung des technischen Potenzials der geothermischen Stromerzeugung und der geothermischen Kraft-Wärmekopplung (KWK) in Deutschland, Bericht für das Büro für Technikfolgenabschätzung beim Deutschen Bundestag, *BGR/GGA, Archiv-Nr. 122 458*, Hannover, 2002.

Kaltschmitt, M., Lux, R. and Sanner, B.: Oberflächennahe Erdwärmenutzung, in: Erneuerbare Energien, M. Kaltschmitt und A. Wiese (Eds.), pp.345-366, *Springer Verlag* , Berlin, 1995.

Kayser, M.: Energetische Nutzung hydrothermaler Erdwärmevorkommen in Deutschland – eine energiewirtschaftliche Analyse, *Doctoral dissertation, Faculty for Civil Engineering and Applied Geosciences*, Tech. Univ. Berlin (Germany), 1999.

Kranz, S.: Geothermisches Kraftwerk Neustadt-Glewe, *Geothermische Energie 43*, 39-41, Geeste, 2003.

Lund, J. W. and Freeston, D. H.: World-Wide Direct Uses of Geothermal Energy 2000, in: Iglesias, E., Blackwell, D., Hunt, T., Lund, J. and Tamanyu, S. (eds.), *Proceedings of the World Geothermal Congress 2000*, Kyushu – Tohoku, Japan, 1-21 (2000).

Paschen, H., Oertel, D. and Grünwald, R.: Möglichkeiten geothermischer Stromerzeugung in Deutschland, TAB-Arbeitsbericht Nr. 84, *Büro für Technikfolgenab-schätzung beim Deutschen Bundestag (TAB)*, Berlin, 2003.

Sanner, B. and Bußmann, W.: Current status, prospects and economic framework of geothermal power production in Germany, *Geothermics 32*, 429-438, 2003.

Schellschmidt, R., Hurter, S., Förster, A., and Huenges, E.: Germany, in: Hurter, S., and Haenel, R. (Eds.), Atlas of Geothermal Resources in Europe, pp 32-35, plate 20-24, *Office for Official Publications of the European Communities*, Luxemburg, 2002.

VDEW: Endenergieverbrauch in Deutschland 2002, *VDEW Materialien M-19/2003*, Vereinigung Deutscher Elektrizitätswerke e.V. (VDEW), „Nutzenergie-bilanzen“, Frankfurt am Main, 2003.

Villemin, T., Alvarez, F. and Angelier, J.: The Rhine-Graben: extension, subsidence and shoulder uplift, *Tectonophysics 128*, 47-59, 1986.

Reg.	Aquifer	A km²	T_t °C	Resources 10^{18} J	Resources GJ/m²	A´ km²	Probable reserves 10^{18} J	Probable reserves GJ/m²	P MW_t
A	Valendis Sst.	143	50	0.11	0.79	96	0.023	0.24	24
	Bentheimer Sst.	361	54	0.28	0.78	158	0.078	0.49	82
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	1880	0.210	0.11	222
	Buntsandstein	2746	137	45.72	16.65	2574	1.830	0.71	1937
	Rotliegendes	2117	110	89.79	42.41				
E	Hauptrogenstein	332	79	0.49	1.47	236	0.019	0.08	20
	Ob. Muschelkalk	1616	75	1.11	0.69	764	0.033	0.04	35
	Buntsandstein	1688	85	9.78	5.80	628	0.220	0.35	233
F	Aquitan-Sande	3776	48	6.79	1.80				
	Chatt-Sande	2564	72	9.05	3.53	944	1.050	1.11	1111
	Baustein-Schichten	880	45	0.36	0.41				
	Malm	7740	69	11.79	1.52	6568	0.570	0.09	603
	Ob. Muschelkalk	3728	67	1.29	0.34	140	0.001	0.01	1
G	Burdigal-Sande	268	45	0.22	0.82				
	Aquitan-Sande	763	45	1.33	1.82	124	0.100	0.80	106
	Chatt-Sande	3348	53	10.48	3.13	2044	1.850	0.90	1958
	Baustein-Schichten	304	42	0.14	0.47				
	Ampf., Priabon	436	79	0.39	0.89	156	0.040	0.25	42
	Gault/Cenoman	6112	77	4.61	0.75	1040	0.230	0.27	243
	Malm	8790	78	17.05	1.94	6444	0.630	0.10	667

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

Reg.:
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

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

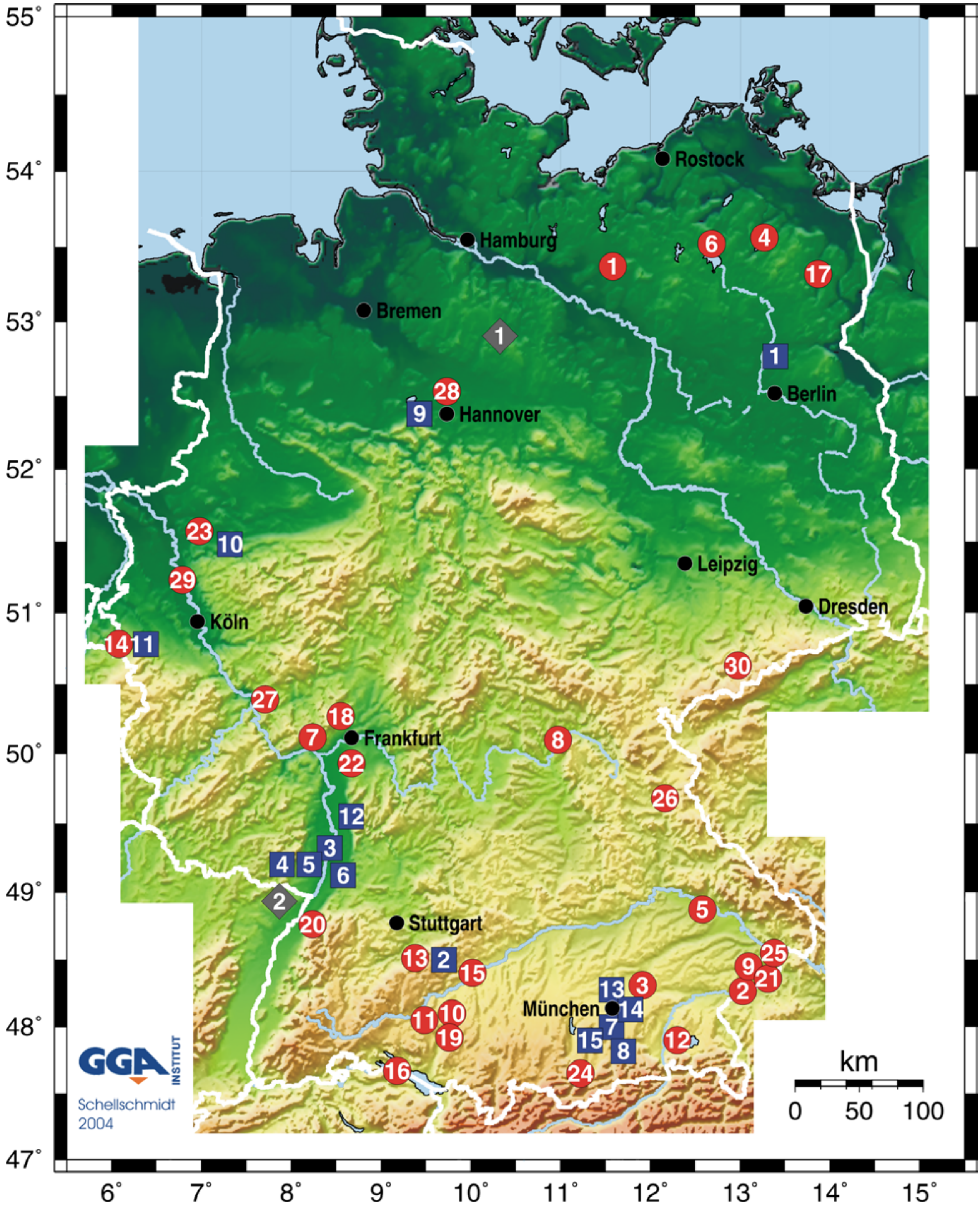

Figure 5: Installations for geothermal energy use in Germany (red circle: operating, see Table 2; blue square: planned, see Table 3; grey diamonds: (1) test site at Horstberg to carry out companion experiment for the GeneSys project at Hannover (see planned project # 9) and (2) European HDR project at Soultz-sous-Forêts in France with German contributions).

No.	location	direct use of geothermal energy: capacity total MWt	capacity geothermal MWt	annual use GWh/a	use	temperature °C	maximal flow rate l/s	miscellaneous
1	Neustadt-Glewe	10.70	6.50	17.95	P, D	97	35.0	doublet, ORC plant
2	Simbach-Braunau	40.00	7.00	67.00	D, S	80	73.9	doublet
3	Erding	18.00	8.00	28.00	D, S, W	65	24.0	direct heat exchanger and heat pump in parallel; cooled thermal water supplied as drinking water (40% of municipal demand)
4	Neubrandenburg	10.00	5.80	26.60	D	54	42.0	2 doublets, heat pump
5	Straubing	5.40	4.10	*11.83*	D, S, W	36	40.0	doublet, production of potable water
6	Waren (Müritz)	5.20	1.50	11.20	D	60	17.0	doublet, no heat pump
7	Wiesbaden	1.76	1.76	4.54	H, S	69	13.0	springs
8	Staffelstein	1.70	0.30	*3.72*	H, S	54	4.0	
9	Birnbach	1.40	1.40	*3.07*	H, S	70	16.0	doublet, 2 heat pumps
10	Biberach	1.17	1.17	0.80	H, G	49	40.0	
11	Bad Buchau	1.13	1.13	*2.47*	H, S	48	30.0	
12	Bad Endorf	1.00	1.00	*2.19*	H, S	60-65	4.0	singlet, use of high caloric in water solued natural rock gas is planed
13	Bad Urach	1.00	1.00	1.50	H, S	58	10.0	
14	Aachen	0.82	0.82	3.38	H, S	68		
15	Neu-Ulm	0.70	0.70	*1.53*	S	45-50	2.5	singlet
16	Konstanz	0.62	0.62	2.00	S	29	9.0	
17	Prenzlau	0.50	0.50	*1.10*	D	108		deep VHE of 2800 m depth
18	Frankfurt-Höchst	0.45	0.45	*0.99*	H			32 VHEs of 50 m depth each
19	Bad Waldsee	0.44	0.44	*0.96*	H, S	30	7.0	
20	Baden-Baden	0.44	0.44	1.43	H, S	70	3.0	
21	Bad Füssing	0.41	0.41	*0.90*	H, S	56	60.0	
22	Langen	0.33	0.33	*0.72*	H			154 VHEs of 70 m depth each provide heating and cooling the German Air Traffic Control (DFS) Headquarter Langen
23	Gladbeck	0.28	0.28	*0.61*	H			32 VHEs of 60 m depth each and 1 HHC provide heating and cooling to an office complex
24	Kochel am See	0.21	0.21	*0.46*	H			21 VHEs of 98 m depth each provide space heating to 35 apartments
25	Griesbach	0.20	0.20	*0.44*	H, S, G	60	5.0	
26	Weiden	0.20	0.20	*0.44*	H, S	26	2.0	
27	Bad Ems	0.16	0.16	0.72	H, S	43	1.0	
28	Hannover	0.15	0.15	0.08	H			122 piles of 20 m depth each with a total pipe lenth of 37 km provide space heating and cooling to a bank office complex
29	Düsseldorf	0.12	0.12	*0.26*	H			73 VHEs of 35 m depth each provide space heating and cooling to an office complex
30	Ehrenfriedersdorf	0.12	0.12	*0.26*	H	7 - 9	6	thermal use of mine water (depth: 100-250 m)

Table 2: Major central installations (installed power >100 kW_t) for direct use of geothermal heat and power generation in Germany (D: district heating; G: greenhouse; H: space heating; P: geothermal power generation; S: thermal spa; W: potable water; HHC: horizontal heat collector; VHE: vertical heat exchanger). The italic written values in row "annual use" are calculated with a load factor of 0.25 for lack of missing information. See also red circles in Fig. 5.

No.	location	direct use of geothermal energy capacity MWt	power generation capacity MWe	use	T °C	maximal flow rate l/s	miscellaneous
1	Groß Schönebeck			P	150	21	HDR-system
2	Bad Urach		*1.00*	P	175		HDR-system
3	Speyer	*24.00*	*5.40*	P, D	*140*	*25*	3 injection and 6 production boreholes
4	Landau in der Pfalz	*7.00*	*2.50*	P, D	*150*	*50 - 70*	doublet
5	Offenbach an der Queich		*3.50*	P	*150*	*100*	aquifer system with ORC-plant 2 production and 1 injection borehole
6	Bruchsal			P	120		doublet, ORC-plant
7	Isar-Süd (München)	*30.00*	*2.00*	P, D			doublet, KALINA cycle,
8	Unterhaching	*16.00*	*3.70*	P, D	*107*	*100*	doublet, KALINA cycle, max capacity 41 MW(th)
9	Hannover (GeneSys)	*4.00*		H	*135*	*14*	singlet, use of fault zones
10	Bochum (Prometheus)	*10.00*		H	*115*		HDR-technology
11	Aachen (SuperC)	*0.48*		H	*85*		deep vertical heat exchanger
12	Weinheim (Miramar)	*2.30*		S	*65*		doublet
13	Unterschleißheim	*20.60*		D, S	79	90	doublet
14	München-Riem	*12.00*		D	*90*	*50*	doublet
15	Pullach i. Isartal			D			

Table 3: Projects (installed power >100 kW_t) for direct use of geothermal heat and power generation currently being developed (D: district heating; H: space heating; P: geothermal power generation; S: thermal spa). Italic written values are planed capacities or estimated temperatures and flow rates. Non italic written values are measured. See also blue squares in Fig. 5.

renewable energy plant capacity (MWe)	**remuneration in Euro-Cent / kWh**			
	≤ 5	**5 - 10**	**10 - 20**	**> 20**
geothermal	15.00	14.00	8.95	7.16
hydro	6.65 - 9.67	6.65	6.10	3.70 - 4.56
biomass	8.90 - 11.50	8.40	8.40	8.40
wind (onshore)	independent of plant capacity 5.50 - 8.70			
wind (offshore)	independent of plant capacity 6.19			
solar	54.00 - 57.40	---	---	---

Table 4: The new remunerations for power production by renewable energy sources are valid since August 2004.

APPENDIX FOR COUNTRY UPDATE PAPER: TABLE 1 - 6

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY (Installed capacity)

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables wind 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 2004	0.23	1.5	83200	373400	8900	26000	23600	164800	14600	18500	130300	582702
Under construction in December 2004												
Funds committed, but not yet under construction in December 2004												
Total projected use by 2010												

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2004

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 (please specify)
D = Dry Steam

Locality	Power Plar Name	Year Com-missioned	No. of Units	Status[1]	Type of Unit[2]	Total Installed Capacity MWe	Annual Energy Produced 2004 GWh/yr	Total under Constr. or Planned MWe
Neustadt-Glewe	Neustadt-Glewe	2003	1		B	0.23	1.5	
Unter-haching	Unter-haching	2006	1		B			3
Total		2003	1		B	0.23	1.5	3

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2004 (other than heat pumps)

I = Industrial process heat	H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling)	D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables)	B = Bathing and swimming (including balneology)
F = Fish farming	G = Greenhouse and soil heating
K = Animal farming	O = Potable water
S = Snow melting	

Locality	Type	Maximum Utilization					Capacity	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy (kJ/kg)			Ave. Flow	Energy	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[b)]
Simbach-Braunau	D, B	73.9	80				40.00		241.2	0.19
Erding	D, B, O	24.0	65				18.00		100.8	0.18
Neustadt-Glewe	D	35.0	97				10.70		64.6	0.19
Neubrandenburg	D	42.0	54				10.00		95.8	0.30
Straubing	D, B, O	40.0	36				5.40		42.6	0.25
Waren (Müritz)	D	17.0	60				5.20		40.3	0.25
Wiesbaden	H, B	13.0	69				1.76		16.3	0.29
Staffelstein	H, B	4.0	54				1.70		13.4	0.25
Birnbach	H, B	16.0	70				1.40		11.0	0.25
Biberach	H, G	40.0	49				1.17		2.9	0.08
Bad Buchau	H, B	30.0	48				1.13		8.9	0.25
Bad Endorf	H, B	4.0	60-65				1.00		7.9	0.25
Bad Urach	H, B	10.0	58				1.00		5.4	0.17
Aachen	H, B		68				0.82		12.2	0.47
Neu-Ulm	B	2.5	45-50				0.70		5.5	0.25
Konstanz	B	9.0	29				0.62		7.2	0.37
Prenzlau	D		108				0.50		3.9	0.25
Frankfurt-Höchst	H						0.45		3.5	0.25
Bad Waldsee	H, B	7.0	30				0.44		3.5	0.25
Baden-Baden	H, B	3.0	70				0.44		5.1	0.37
Bad Füssingen	H, B	60.0	56				0.41		3.2	0.25
Langen	H						0.33		2.6	0.25
Gladbeck	H						0.28		2.2	0.25
Kochel am See	H						0.21		1.7	0.25
Griesbach	H, B, G	5.0	60				0.20		1.6	0.25
Weiden	H, B	2.0	26				0.20		1.6	0.25
Bad Ems	H, B	1.0	43				0.16		2.6	0.51
Hannover	H						0.15		0.3	0.06
Düsseldorf	H						0.12		0.9	0.25
Ehrenfriedersdorf	H	6.0	7-9				0.12		0.9	0.25
TOTAL		**444.4**					**104.61**		**709.8**	**0.22**

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2004

Locality	Ground or water temp. (°C)	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type	COP	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Germany		400000	30000	V, H, (W)	3 - 4		2200	

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2004

Use	Installed Capacity (MWt)	Annual Energy Use (TJ/yr = 10^{12} J/yr)	Capacity Factor
Individual Space Heating	2.83	15.1	0.17
District Heating	89.8	589.2	0.21
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying			
Industrial Process Heat			
Snow Melting			
Bathing and Swimming	11.98	105.5	0.28
Other Uses (specify)			
Subtotal	**104.61**	**709.8**	**0.22**
Geothermal Heat Pumps	400.00	3153.6	0.25
TOTAL	**504.61**	**3863.4**	**0.24**

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2000 TO DECEMBER 31, 2004 (excluding heat pump wells)

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)	3	7			28
Production	>150° C					
	150-100° C	1				3
	<100° C					
Injection	(all)					
Total		4	7			31