Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

GEOTHERMAL ENERGY USE IN GERMANY AT THE TURN OF THE MILLENNIUM

Ruediger Schellschmidt[1], Christoph Clauser[1] and Burkhard Sanner[2]
[1]Geowissenschaftliche Gemeinschaftsaufgaben (GGA), Postfach 51 01 53, D-30631 Hannover, Germany
[2]Justus-Liebig-Universitaet, Diezstr. 15, D-35390 Giessen, Germany

Keywords: direct use, non-electrical use, geothermal energy, update, Germany

ABSTRACT

By the end of 1999 direct thermal use of geothermal energy in Germany amounted to an installed thermal power of roughly 397 MW_t. Of this sum, approximately 55 MW_t are generated in 27 major centralised installations. Small, decentralised earth-coupled heat pumps and groundwater heat pumps are estimated to contribute an additional 342 MW_t. By the year 2002 an increase in total installed power of about 120 MW_t is expected: 82 MW_t from major central and 40 MW_t from small, decentralised installations. This would boost direct thermal use in Germany close to an installed thermal power of 517 MW_t. At present no electric power is produced from geothermal resources in Germany, whose annual final energy consumption at present amounts to about 9469 PJ. Final energy is defined as the fraction of primary energy which is supplied to the final consumer. It is less than the corresponding primary energy because of losses, mainly due to conversion and distribution. Related to one year this is equivalent to a total consumed power of approximately 300,000 MW. Almost 60 % of this energy is required as heat. The total technical potential for the direct use of geothermal energy in Germany is 2125 PJ a^{-1}, with a weighting according to the local variation in the demand for heat; this is equivalent to a maximum thermal power generation of about 67,380 MW_t. This corresponds to about 22 % of the country's annual final energy consumption, or roughly 37 % of its demand for heat. However, at present only about 6 ‰ of the existing maximum technical potential for direct thermal use of geothermal energy meets the demand for heat. If the vast potential of geothermal energy for direct thermal use was utilised to substitute fossil fuels, roughly 100 million tons less of CO_2 would be released to the atmosphere annually, equivalent to about 10 % of Germany's CO_2 output in 1998.

1. INTRODUCTION

Due to a lack of natural steam reservoirs geothermal energy cannot be converted into electric power to competitive prices in Germany at present. And the new technology for converting the heat of hot dry rock at depth is only currently being developed. However, direct use of geothermal heat takes place in a small number of large-scale centralised installations as well as in many decentralised units. This paper describes first the status of direct use of geothermal heat in Germany by the end of 1999, and the contribution from each type of installation, followed by a comparison between present use and existing technical potential for direct use of geothermal heat in Germany (Clauser, 1997a, 1997b). This potential is then compared with the demand for heat as result from the current final energy consumption and from the local distribution of this demand.

2. LARGE-SCALE CENTRALISED INSTALLATIONS

At present 27 installations for direct use of geothermal heat are operating in Germany (Figure 1), each with an installed power in excess of 100 kW_t (Table 1). 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 power installed is 54.7 MW_t. Brine or water temperature in all of them is below 110 °C at maximum (Table 1).

Not all of this thermal power is of geothermal origin. In some of the installations heat pumps are used (Table 1) 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). In large centralised hydrothermal heating units ß typically varies between 5-7. Thus, about 85% of their heat output is geothermal. Additionally, most of these heating units use auxiliary oil and gas burners to cover peak demand. The purely geothermal contribution to the installed power of the five major heating plants in Germany is 50% , or 20.1 MW_t (Table 1). In the remaining 22 installations no additional heating in needed to cover peak demand. The contribution of these units is on the same order as the installed power and equals 14.8 MW_t. The pure geothermal part of installed power for direct use in 27 major central units in Germany is therefore estimated to be 34.9 MW_t.

Under the prevailing economic and political conditions, multiple uses or cascade can help to improve the economic efficiency of direct use of geothermal heat. For this reason 16 of 27 installations listed in Table 1 are a combine 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 sedimentary basin, the Molasse Basin in southern Germany, or along the Rhine Graben (Figure 1). The five largest geothermal plants (Table 1) with an installed power of 40 MW_t are located in the north German or Molasse Basins. As these regions have the largest geothermal resources in Germany (Haenel and Staroste, 1988; Hurter and Haenel 1999), most new installations are also being developed here (Figure 1). The projects listed in Table 2 are scheduled for completion by the year 2002, yielding an additional installed thermal power of 81.5 MW_t. By the year 2002, a total geothermal power of about 136 MW_t is expected to installed in Germany in 36 major geothermal installations.

3. SMALL DECENTRALISED UNITS

Direct use of geothermal heat for space heating in small decentralised units is widespread in Germany. Depending of local conditions these units consist of earth coupled heat pumps (horizontal heat collectors, vertical heat exchangers), or groundwater heat pumps. The exact number of these units presently installed in Germany is unknown since no statistics are available. An exception is the Lower Rhein area (Koeln/Bonn, Figure 1). In this region the local electric power supplier (RWE) launched a program to support installation of electric heat pumps. Statistics are available for the time since 1993 (Figure 2). In 1998 RWE supported about 650 new heat pumps, 66% of which are earth coupled heat pumps.

Based on different sources, it is estimated that by the end of the year 1999 at minimum 18,000 small decentralised unites in Germany make use of the heat stored near the earth's surface. Judging from the mean electrical power consumption of 5.4 kW_t of electrical heat pumps in Germany , as well as from an average seasonal performance factor (ß) equal to 3-4, the mean installed geothermal power of each of these installations typical varies from 16-22 kW_t, with an average of 19 kW_t. A conservative estimate yields a total geothermal power of 342 MW_t presently installed in Germany in small decentralised units. A fraction of 2:3 (VDEW, 1996) of this sum is the purely geothermal contribution equal to 228 MW_t. Thus, decentralised units provide six times the installed thermal power of the large-scale centralised installations discussed above!

The future development of this sector is difficult to estimate. If the numbers of average heat pump sales of about 2200 per year in previous years (VDEW, 1998) is extrapolated to the period 2000-2002, it can be expected that 700 units of 19 kW_t each will be installed annually. This would increase the installed thermal power by about 13.3 MW_t. This means an increase of 39.9 MW_t by the end of 2002.

4. PRESENT USE AND FUTURE POTENTIAL OF GEOTHERMAL ENERGY IN GERMANY

A new, conservative estimate of the total thermal power currently installed for direct use of geothermal energy in Germany amounts to roughly 397 MW_t. The pure geothermal part of this sum yields 263 MW_t or 66%. Only about 13% of this is provided by large centralised installations. The prevailing part comes from approximately 18,000 small, decentralised units.

In 1997 the final energy consumption in Germany was 9469 PJ (1 PJ = 10^{15} J) (BMWi, 1999). A breakdown in Figure 3 shows that 59% of the final energy consumption in Germany was required as heat, be it for space-heating, hot water, or process heat (VDEW, 1998). A significant proportion of this heat demand could be supplied by geothermal heat. A significant proportion of this demand could, in principle, be supplied by geothermal heat. According to Kayser (1999) the technical potential for geothermal heat available annually from hot aquifers in Germany over a period of 100 yrs. amounts to 5140 PJ a^{-1}, corresponding to an installed thermal power of 162,877 MW_t (see also Erbas et al., 1999). However, often there is no demand for lack of industry or population although there is heat in place. And there is a tight limit for the maximum distance over which low temperature water can be economically delivered. Therefore, the fraction of the technical potential which occurs at centers of population or industry is only about 23 % of this total, amounting to 1165 PJ a^{-1} (Kayser, 1999). This would correspond to an installed power of 36,917 MW_t. Kaltschmitt et al . (1995) assessed the corresponding technical potential of heat storage near the earth's surface for earth-coupled and groundwater heat pumps. It amounts to an additional 960 PJ yr^{-1}, corresponding to an installed power of about 30,420 MW_t.

The total technical potential for the direct use of geothermal energy in Germany is therefore 6100 PJ a^{-1} or 2125 PJ a^{-1}, without or with a weighting according to the local variation in the demand for heat, respectively. These numbers correspond to 64% or 22% of the 1997 German final energy consumption of 9469 PJ. Thus, a good fifth of the demand for final energy in Germany could be supplied by the direct use of geothermal heat. Another two fifths are available for future use, if a new demand would tap these resources close to their occurrence. However, at present only about 6‰ of this large technical potential is actually utilised.

At present no electrical power is produced from geothermal resources in Germany. Only binary or Organic Rankin Cycle (ORC) power plants could be used for electrical power generation, because no high-enthalpy steam reservoirs are available. A successful development of the Hot Dry Rock (HDR) technology would change this situation fundamentally, because the price for HDR-generated electrical power is expected to be in the range of the present tariffs based on fossil or nuclear fuels (Rummel et al., 1993).

5. ENVIRONMENTAL CONSIDERATIONS

Fifty-nine percent of Germany's current final energy consumption is needed as heat. Most of this demand is at present supplied by fossil fuel. Substituting of this heat by geothermal energy would make a significant contribution to reducing the present CO_2 output.

A rough estimate (Clauser, 1997a, 1997b) shows that on the order of 100 million tons CO_2, could be reduced if geothermal heat was to replace CO_2-producing fossil fuels. in 1998 the energy-related CO_2 output in Germany was 894 million tons (BMWi, 1999). Therefore a reduction of 100 million tons CO_2 is equivalent to roughly 10% of the present annual output. Germany has committed itself to reduce the national CO_2 output by 25% before 2005, related to the 1990 figure of 1014 million tons CO_2. A large proportion of this reduction could be achieved by a more intensified direct use of the existing geothermal resources. Geothermal energy is also by far the most economic substitute for fossil fuels of all the renewable forms of energy (Figure 4). Compared to solar heat, for instance, which has a comparable technical potential, it is one order of magnitude more economical.

REFERENCES

BMWi (1999). *Energiedaten 1999 – Nationale und internationale Entwicklung*. Bundesministerium für Wirtschaft und Technologie (BMWi), Bonn. 72pp.

Clauser, C. (1997a). Geothermal energy use in Germany - status and potential. *Geothermics*, Vol.26(2), pp.203-220.
Clauser, C. (1997b). Erdwärmenutzung in Deutschland. *Geowissenschaften*, Vol. 15(7), pp. 218-224.
Erbas, K., Seibt, A., Hoth, P, and Huenges, E. (1999). *Evaluierung geowissenschaftlicher und wirtschaftlicher Bedingungen für die Nutzung hydrogeothermaler ressourcen*. Report STR 99/09, Geoforschungszentrum, Potsdam (Germany).
Haenel, R. and Staroste, E. (Eds.) (1988). *Atlas of Geothermal Resources in the European Community, Austria, and Switzerland*. Verlag Th. Schäfer, Hannover.
Hurter, S. and Haenel, R. (Eds.) (1999). *Geothermal Resources in Europe*. Lovell Johns Ltd., Oxford. in press.
Kaltschmitt, M., Lux, R. and Sanner, B. (1995). Oberflächennahe Erdwärmenutzung; In: *Erneuerbare Energien*, M. Kaltschmitt und A. Wiese (Eds.), Springer Verlag , Berlin, pp.345-366.
Kayser, M. (1999). *Energetische nutzung hydrothermaler Erwärmevorkommen in Deutschland – eine energiewirtschaftliche Analyse*. Doctoral dissertation, Faculty for Civil Engineering and Applied Geosciences, Tech. Univ. Berlin (Germany).
VDEW (1996). *Elektrowärmepumpen: Energie-Umwelt-Marktsituation 1996*. VDE Materialien, Vereinigung Deutscher Elektrizitätswerke e.V. (VDEW), Arbeitskreis „Wärmepumpen“, Frankfurt am Main. 48pp.
VDEW (1998). *Ergebnisse der Erhebung über elektrische Wärmepumpen zur Raumheizung 1997*. VDE Materialien, Vereinigung Deutscher Elektrizitätswerke e.V. (VDEW), Abt. Stromwirtschaft und Energieanwendung, Frankfurt am Main. 8pp.
VDEW (1998). *Endenergieverbrauch in Deutschland 1997*. VDE Materialien, Vereinigung Deutscher Elektrizitätswerke e.V. (VDEW), „Nutzenergiebilanzen“, Frankfurt am Main. 29pp.
Rummel, F., Kappelmeyer, O. and Herde, A. (Eds.) (1993). *Erdwärme*. Verlag C. F. Müller, Karlsruhe. 98pp.

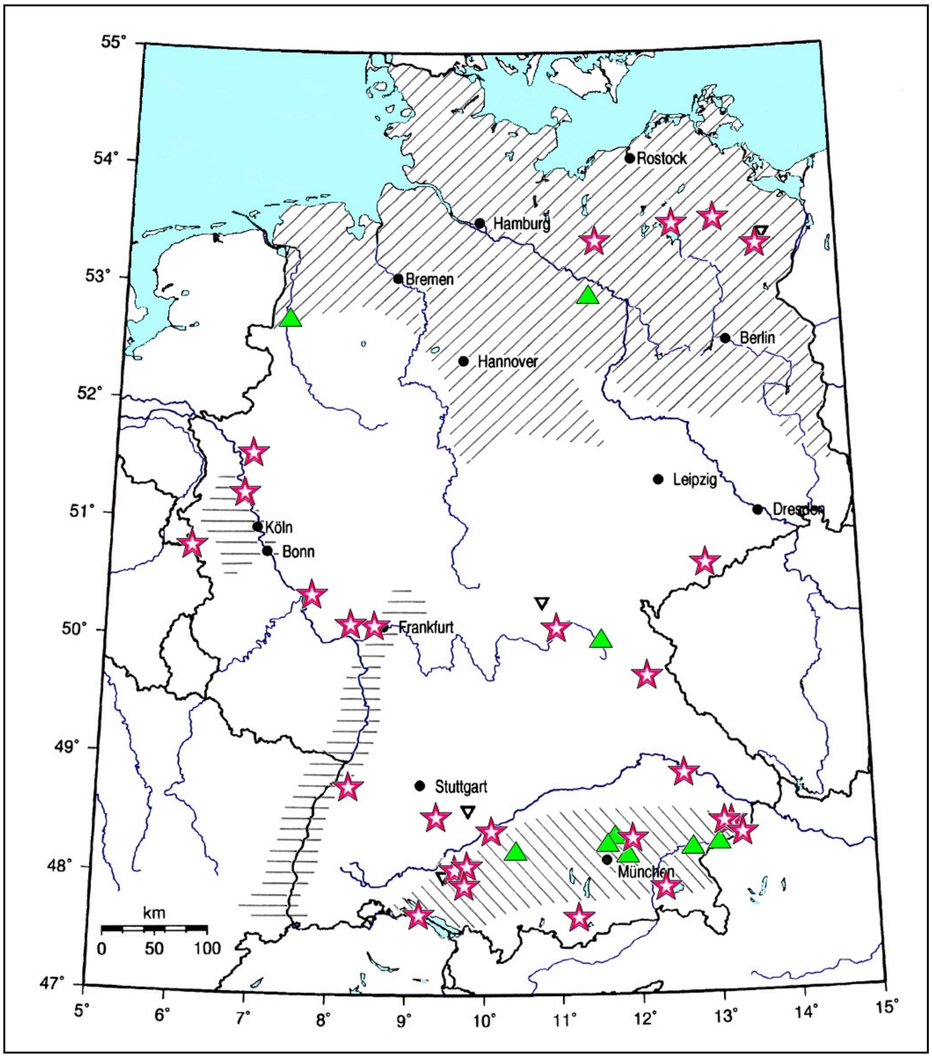

Figure 1. Installations for direct use of geothermal energy in Germany (stars: operating, see Table 1; filled triangles: planned, see Table 2; open triangles: shut-down. Large sedimentary basins are indicated by hachures. Rhein Graben: =; Molasse Basin: \\\; North German Basin: ///.

Table 1. Twenty-seven major central installations (installed power >100 kW_t) for direct use of geothermal heat in Germany (E: ground heat exchangers; G: greenhouse; H: hydrothermal space heating; S: thermal spa; ; W: potable water). Where known, geothermal contribution to installed power is given in parentheses.

location (longitude E, latitude N)	inst. power (MW_{th})	use	T (°C)	max. flow rate ($l\ s^{-1}$)	miscellaneous
Neustadt-Glewe (11.58, 53.37)	10.7 (6.5)	H	95	35	doublet, no heat pump
Neubrandenburg (13.27, 53.56)	10 (5.8)	H	54	42	2 doublets, heat pump
Erding (11.91, 48.31)	8.6 (4.5)	H, S, W	66	24	direct heat exchanger and heat pump in parallel; cooled thermal water supplied as drinking water (40 % of municipal demand)
Straubing (12.58, 48.87)	5.4 (4.1)	H, W	36.2	40	doublet, production of thermal and potable water
Waren (Müritz) (12.68, 53.52)	5.2 (1.5)	H	60	17	doublet, no heat pump
Wiesbaden (8.24, 50.12)	1.76	H, S	69	13	
Staffelstein (10.97, 50.10)	1.70	H, S	54	4	
Birnbach (13.09, 48.45)	1.4	H, S	70	16	doublet, 2 heat pumps
Biberach (9.79, 48.10)	1.17	G, S	49	40	
Buchau (9.63, 48.05)	1.13	H, S	48	30	
Endorf (12.30. 47.90)	1.0	H, S	60-65	4	singlet, use of high caloric in water soluted natural rock gas is planed
Urach (9.38, 48.51)	1.00	H, S	58	10	
Aachen (6.08, 50.78)	0.82	H, S	68		
Neu-Ulm (10.02, 48.40)	0.7	S	45-50	2.5	singlet
Konstanz (9.18, 47.67)	0.62	S	29	9	
Prenzlau (13.87, 53.32)	0.50	E	108	-	deep VHE of 2800 m depth
Frankfurt-Höchst (8.55, 50.12)	0.45	E	-	-	32 VHEs of 50 m depth each
Waldsee (9.76, 47.92)	0.44	H, S	30	7	
Baden-Baden (8.24, 48.76)	0.44	H, S	70	3	
Füssing (13.31, 48.36)	0.41	H, S	56	60	
Gladbeck (6.98, 51.57)	0.28 (0.18)	E	-	-	32 VHEs of 60 m depth each and 1 HHC provide heating and cooling to“Wiesenbusch“ office complex
Kochel am See (11.22, 47.65)	0.21	E	-	-	21 VHEs of 98 m depth each provide space heat to 35 apartments
Griesbach (11.18, 48.45)	0.20	G, H, S	60	5	
Weiden (12.16, 49.68)	0.20	H, S	26	2	
Ems (7.71, 50.39)	0.16	H, S	43	1	

location (longitude E, latitude N)	inst. power (MW_{th})	use	T (°C)	max. flow rate ($l\ s^{-1}$)	miscellaneous
Düsseldorf (6.79, 51.23)	0.12	E	-	-	73 VHEs of 35 m depth each provide space heat and cooling to offices in "Technorama" complex
Ehrenfriedersdorf (12.97, 50.63)	0.12	H	7 - 9	6	thermal use of mine water (depth: 100 – 250 m)

Table 2. Projects for direct use of geothermal heat in Germany currently being developed (year: anticipated year of completion, H: hydrothermal space heating, S: thermal spa, W: drinking water). Where known, geothermal contribution to installed power is given in parentheses.

location (longitude E, latitude N)	year	power (MW_{th})	use	depth (m)	T (°C)	flow rate ($l\ s^{-1}$)	miscellaneous
Simbach am Inn (13.02.48.27)	2000	20	H, S	2300-2400	90-100		doublet
Altötting (12.68, 48.23)	2000	16	H, S	2200-2300	90-100		doublet
Neufahrn (11.67, 48.32)	2000	10-15	H	1600-1800	80-85	83	base load for incinerating plant
Markt Schwaben (11.85, 48.18)	2002	12	H	2500-2600	80-85		doublet
Unterschleißheim (11.57, 48.28)	2000	9-10	H		90	60-70	doublet
Bayreuth (11.58, 49.94)	2002	6	H, S, W	1100	31	17	thermal spa and rehabilitation hospital, coolled water (10 °C) used totally as potable water
Krumbach (10.40, 48.20)	2000	6	H, S	1500-1600	55		singlet
Meppen (7.30, 52.70)	2000	2.5 (0.8-1.5)	H, S	1500	60	17 (?)	doublet
Arendsee (11.46, 52.87)	2001	?	H, S	1557	75.5	?	doublet

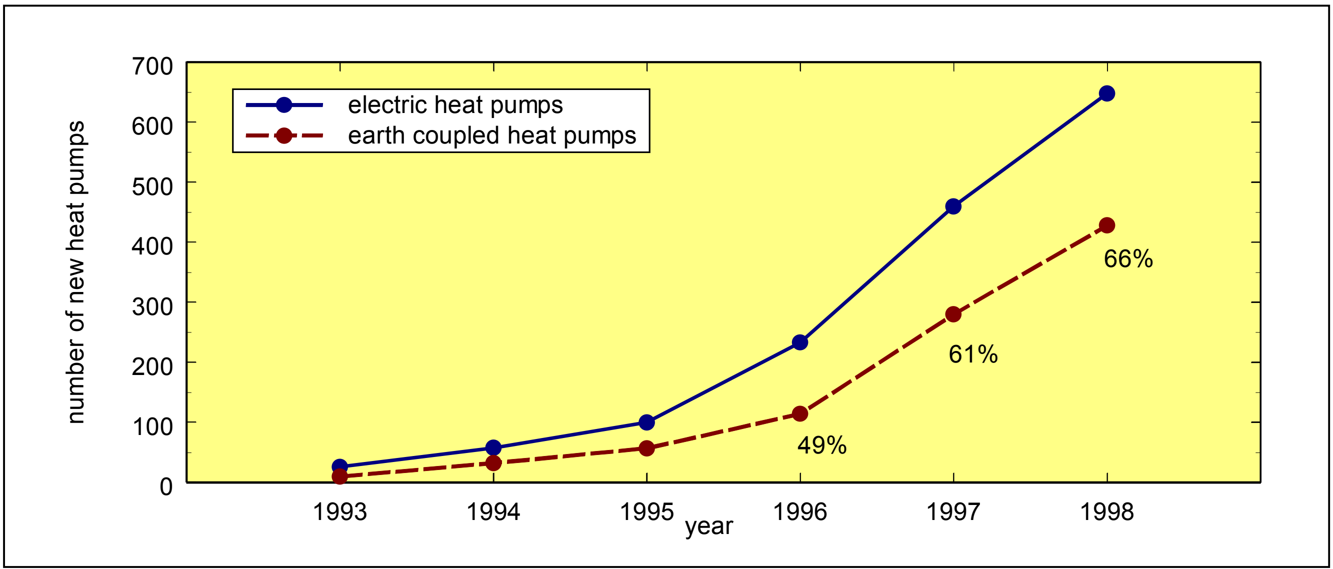

Figure 2. Electric heat pumps per year supported by the "Rheinisch-Westfälische Elektrizitätswerke" (RWE) since 1993 and the fraction of earth coupled heat pumps (data: RWE; support program "KeS SOLAR").

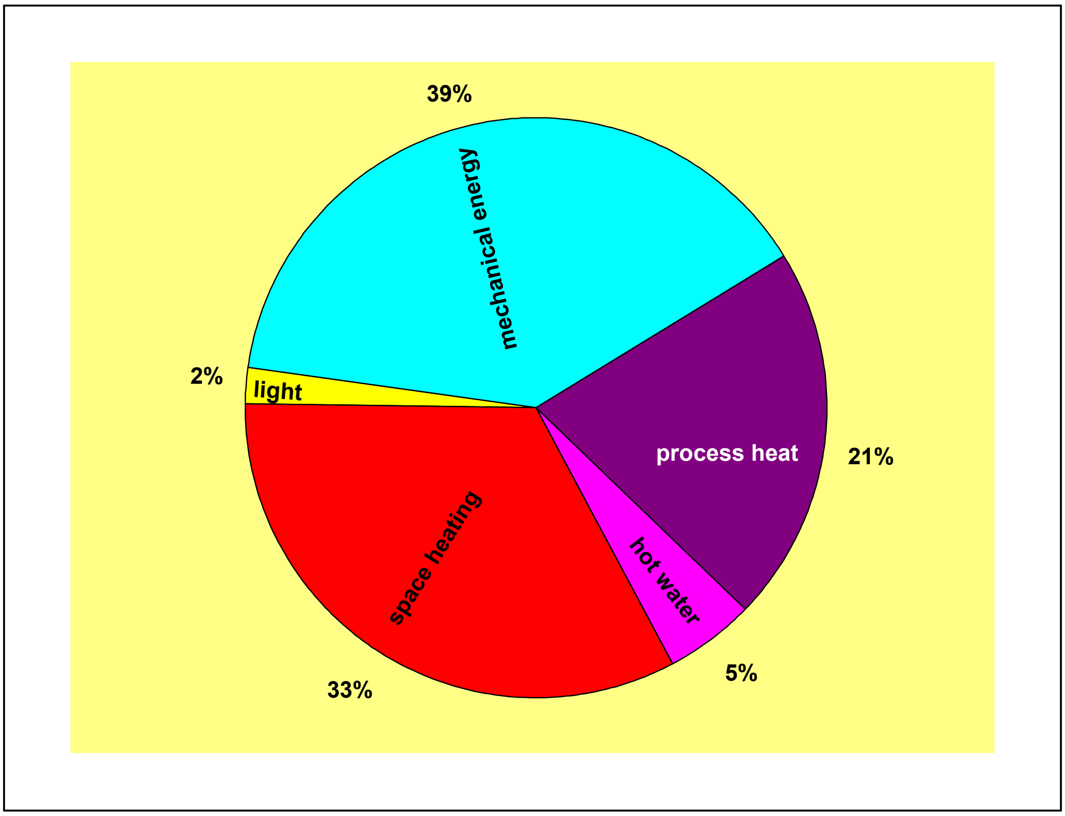

Figure 3. Final energy consumption in Germany according to usage (data: VDEW, 1998). Distribution shown is for Germany in 1997. Final energy consumption in Germany was 9469 PJ in 1997.

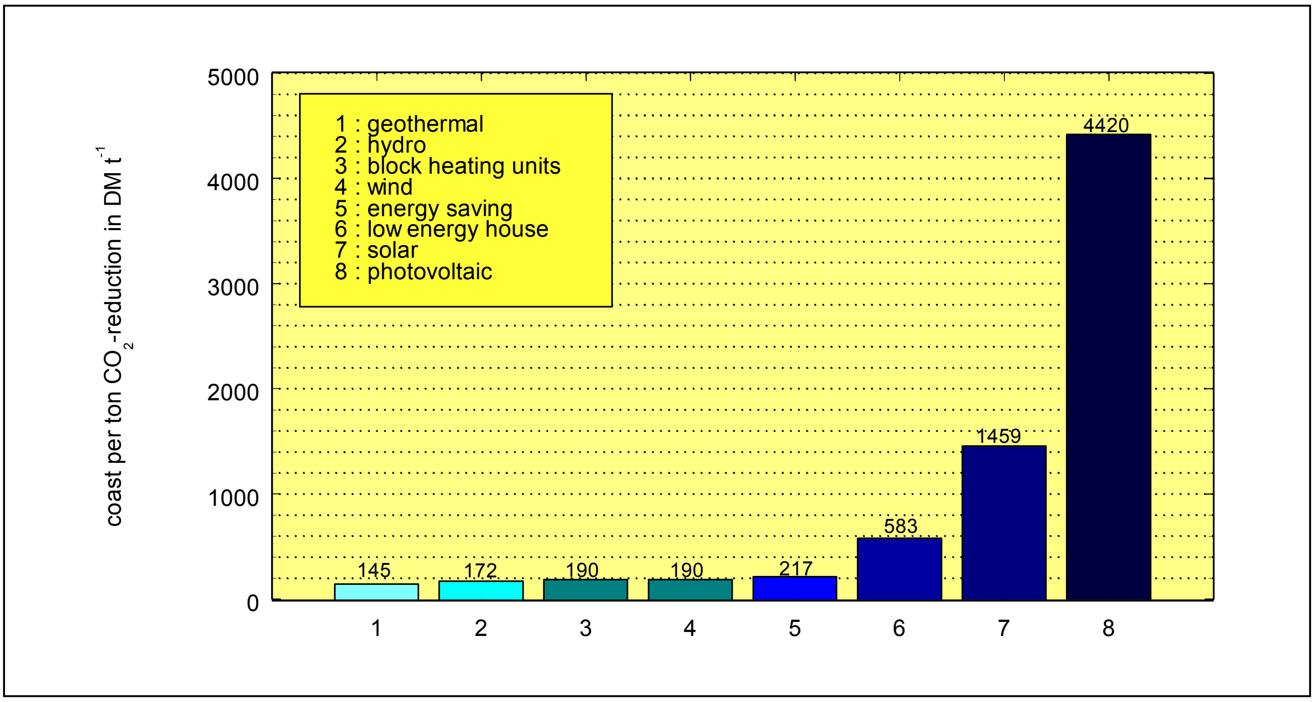

Figure 4. Cost of reducing 1 ton of CO_2 when substituting different renewable energies for fossil fuel in electricity or heat generation (data: Ministry of Environment, Energy, and Federal Affairs, State of Hessen, Wiesbaden, 1994 and Geothermische Vereinigung e.V., Stadtwerke-Erdwärmeforschung, Bad Urach, Germany, 1994).