Current status, prospects and economic framework of geothermal power production in Germany

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Abstract

In Germany, at the end of 2002, existed an installed capacity of 65 MW_{th} in larger plants and more than 400 MW_{th} in small and medium geothermal heat pump plants. The first geothermal power is expected for autumn 2003, with installed capacity of ca. 0,25 MW_{el}.

The economic situation on the electric power market is dominated by the new law on renewable energy (EEG), which states a fixed rate for geothermal power sold to the utilities (ca. 70-80 €/MWh, depending on size of the plant). Since the inception of this law in 2000, a sound economic basis for project development exists, and several new projects have been started, mainly in the Upper Rhine Graben, the Munich area and Northern Germany. The Geothermische Vereinigung (GtV) promotes a "1-GW-Scheme" to achieve an amount of installed geothermal electric power in Enhanced Geothermal Systems (like HDR) and deep hydrogeothermal deposits of 1 GW_{el} in the foreseeable future.

Keywords

Legislation, economic support, electric power prices

Legal regulations

As might be expected in a federal country, laws exist both on the federal level (*Bund*) and on the state level (*Länder*). Geothermal energy in Germany is governed by the Federal Mining Act (*Bundesberggesetz*, or BBergG for short).

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

A license for exploration and, if the resource has been proven, for exploitation gives a rather strong legal position to its holder. If necessary, even the (temporary) right for land use against the will of the owner can be obtained through court order, of course with fair financial compensation. The extension of a mining field according to such license is delineated on the earth surface and shown in a map, and in the vertical dimension it always starts at the ground surface and extends downward (theoretically down to the centre of the earth). When a mining license is given, other aspects like water protection and environmental issues are dealt with by the mining authorities in collaboration with the relevant offices, and the necessary approvals are included in the mining license.

An exception is stated in the mining act for the use of a *bergfreie* resource, if it is used on the same lot where it is exploited, and is used only for the construction and operation of buildings on that lot, belonging to the owner of the lot (§ 4 BBergG). In this case no license is required. However, even here the mining authorities might come into the play again, if § 127 BBergG is fulfilled, asking for a specific approval for boreholes which penetrate into the underground more than 100 m. Use of this exception is made for most of the ground source heat pump plants in the residential sector, and this fact is the explanation why so many borehole heat exchangers for heat pumps in Germany have a depth of 99-100 m.

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

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

The basic technical requirements for sound design, save construction and trouble-free operation of shallow geothermal installations (down to about 400 m) are given in the guideline VDI 4640 of the Association of German Engineers (*Verein Deutscher Ingenieure*, VDI) [1]. To facilitate the site-specific design of smaller plants, the Geological Survey of Nordrhein-Westfalen has compiled a database of ground thermal parameters down to 100 m depth for the whole area of the state, available on CD-ROM. Similar work is under way in other states also.

A particular problem recently arose from the fact that geothermal energy does not have a certain boundary like a coal seam, ore body or oil deposit. With the number of applications for mining licenses on geothermal energy rising, the need for proper sizing of the mining fields became apparent. A group of experts from different branches of the administration suggested a guideline on how to delineate mining fields in geothermal energy.

Now the case may arise, that a larger ground source heat pump plant, serving more than one owner and thus not eligible for the exception according to § 4 BBergG, has a mining license, and the site is inside the area influenced by a planned HDR plant. Of course, in practice these two plants would not have any impact on each other, with several kilometers vertical distance between the HDR heat exchanger and the shallow plant. Legally, the right to use the geothermal heat resides with the owner of the mining license, no matter what the depth of that use will be. So in said case, the constructors of the HDR plant would need to negotiate with the owner of the license to be allowed to exploit geothermal energy, and they most probably will have to pay the owner. In the worst case, the owner of a mining license for a shallow borehole heat exchanger could prevent the construction of a deep geothermal plant, and vice versa. Now, following an initiative by the Geothermische Vereinigung e.V., an amendment to the mining law is under discussion to allow for depth-specific mining fields for geothermal energy, in order to avoid the aforementioned problems.

Relevance of the Renewable Energy Act for geothermal energy production

In April 2000, the Renewable Energy Act (*Erneuerbare Energien Gesetz*, EEG) was set into force. The EEG is consistent with the directive on electricity production from renewable energy source of the European Union. In the predecessor of the EEG, the *Stromeinspeisegesetz* (StrEG), geothermal energy was not mentioned (fig. 1, left). During the 90s, the continuing lobbying of Geothermische Vereinigung e.V. for an amendment to the StrEG to include geothermal energy was met with refusal by the government with the reason given that no geothermal energy is produced within Germany and thus no price has to be paid for it.

Geothermische Vereinigung e.V. nevertheless continued to work for fair sales prices for geothermal power. Very helpful in this task proved some MPs in Berlin, in particular Hermann Scheer (SPD) and Hans-Josef Fell (Green, s. fig. 1, right). With the new law effective April 2000, geothermal energy for the first time was set on the same level as other renewable energies. Now there is a real chance to plan and install geothermal power plants on a foreseeable economic basis. The most important aspects are:

- The results from many years of R&D on HDR in Soultz-sous-Forêts now will be applied in Germany also. German scientists and engineers have contributed since a long time to the advancement of HDR-technology and in particular to the site in Soultz. Now, after the geological feasibility has been proven in Soultz (1997) and the first pilot plant is imminent (2004-2005), the necessary boundary conditions have been created for a deployment of Enhanced Geothermal Systems technology within Germany. A suitable and well documented site is existing in Bad Urach, and others are sure to follow, probably first in the Upper Rhine Graben.
- The necessary temperatures in Germany usually require a depth where normally now heat exchange is possible without EGS-Technology. Aquifers in deep, fractured-porous rocks will hopefully be made available for thermal use by stimulation. Such conditions can be found within younger Paleozoic and Triassic sediments in the German basins.
- A new assessment becomes possible for thermal water resources in Bavaria, in the Upper Rhine Graben and in Northern Germany, were already geothermal heating plants exist someplace. Electric power generation might become a new, additional component of existing plants (as in Neustadt-Glewe) or in yet-to-explore thermal water horizons (example in Unterhaching).

The positive development basically enabled by the EEG is further advanced by the federal government through the programme for investment into the future (*Zukunfts-Investitions-Programm*, ZIP). This resulted in a series of new projects and innovative technological fields, which allow a completely new perspective for geothermal power generation. This perspective is not only valid for Germany, because the technologies can also be used in the neighbouring countries, and eventually world wide.

Because of the long project preparation time in geothermal energy, typically 2-5 years, and because of some need to get up-to-date with R&D, the first geothermal power production inside Germany will not be starting before November 2003. (Neustadt-Glewe in Mecklenburg-Vorpommern will be the first site, s. Tab. 1)

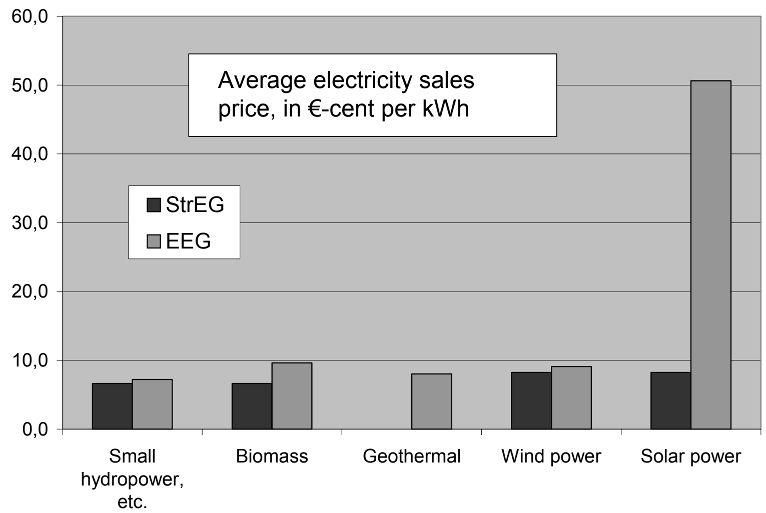

Fig. 1: left: Comparison of the average electricity sales prices according to StrEG and EEG (after data from [2])
right: Ceremony on November 7, 2002, for awarding the German Geothermal Award (Deutscher Geothermiepreis) of GtV to Hans-Josef Fell, MP (Green) in the Bundestag and instrumental to include geothermal energy into the EEG (photo O. Joswig)

Status of geothermal power production outside Germany

In a view to the electricity production from renewable sources world-wide (fig. 2), geothermal energy can clearly be seen. While the largest part of this power production (ca. 92 %) comes from hydropower, in production terms geothermal energy with 1.6 % is positioned much better than wind (0.64 %) and solar heat (0.05 %) (data for 1998).

When comparing the installed capacity to the annual production in fig. 2, the high electrical production from geothermal sources becomes apparent. While geothermal energy has only 1.1 %, wind accounts for 1.38 % and sun for 0.12 % of the installed capacity. If one considers the installed capacity required to produce a certain amount of electric power, on the basis of the data from [3], for wind a capacity 3.2 times higher and for solar about 3.5 times the capacity than for geothermal energy need to be installed.

Within the European Union, geothermal power has its firm place (fig. 3 left), however, with 1.2 % a little bit below the world-wide average. In Germany the statistical data for the year

2000 still show zero (fig. 3 right), and wind power has the largest share (because large hydropower is not eligible for fixed electricity prices within the EEG).

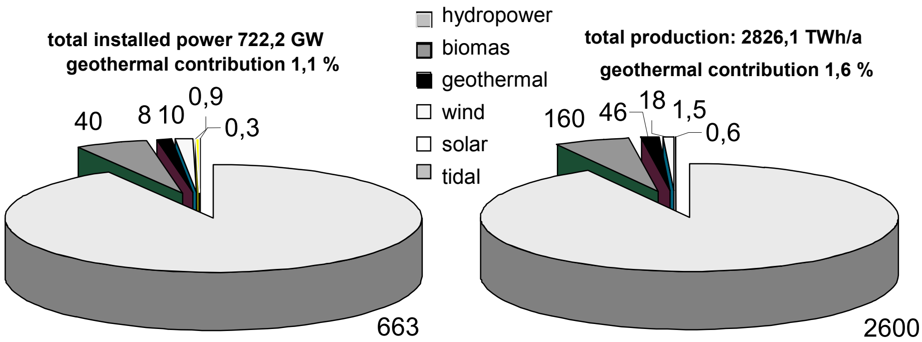

Fig. 2: Installed electrical capacity in GW (left) and annual power production TWh/a (right) world-wide, for the year 1998 (after data from [3])

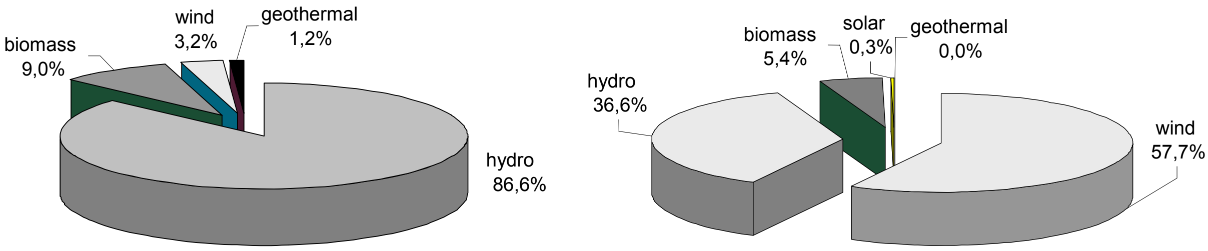

Fig. 3: left: Share of the various energy sources in the electric power generation from renewables within EU, after data from Eurostat for the year 1997
right: Share of different energy sources in the power production from renewables in Germany paid through the EEG for the year 2000 (Apr.-Dec.), after data from [4]

Fixed electricity prices according to EEG

When discussing numbers for the electricity price to be guaranteed by EEG, for the geothermal sector in Germany only the basic data from two projects were available, none of which yet had been completed (economic considerations for the European HDR research project in Soultz and the preliminary calculation for the ORC-plant in Altheim / Oberösterreich). The prices valid for 2002 are shown in fig. 4 in comparison to the other renewable energy sources. Meanwhile, the first plants have been calculated financially in respect to the site, technology and resource, and a number of new developments and innovations have been initiated by both EEG and ZIP. The data basis for calculation is much better now, and a discussion on the adaptation of the prices for geothermal power has been initiated.

The development of the annual electricity production from renewable sources and the sums paid in the framework of StrEG and EEG over the last decade are shown in fig. 5, left. After a relatively slow start in 2000 the sum jumped across the limit of 10 TWh/a. The total electric power consumption in Germany in the year 2000 was 480.3 TWh. This means that about 2.1 % of electricity in the year 2000 was paid according to StrEG or EEG. The average price paid did rise by 20.4 % (fig. 5, right), which is less than 2 % annually and thus lies in the range of the normal price increase. The average value for 2000 amounted to 84.25 €, which is close to the value for geothermal power (89,50 €).

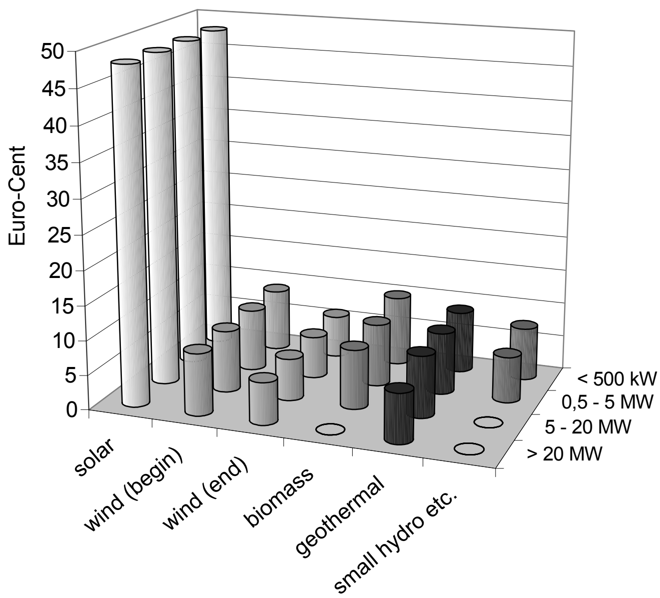

Fig. 4: *Comparison of the fixed energy prices after EEG for the year 2002 (showing a synopsis of the various plant sizes)*

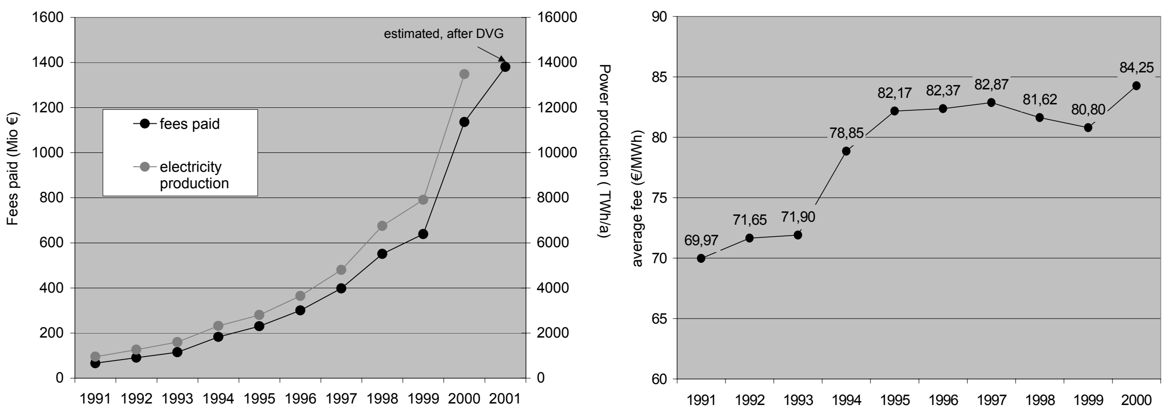

Fig. 5: *<u>left:</u> Development of the power production paid for by the StrEG (until 3/00) and the EEG (from 4/00), after data from [4]*
<u>right:</u> Development of the average fee paid through the StrEG (until 3/00) and the EEG (from 4/00), calculated from data from [4]

Recent experience shows that the prices for geothermal energy within EEG are to low at least in the initial phase of geothermal power in Germany. Only with additional support (mainly through the federal ZIP and some further support from individual states) is it possible to overcome the threshold of the geological, technical and economic risk for the first plants. There are still R&D-needs to be covered now, which will not be required at the same scale in future replication.

There is also a need to have a better targeted division of the guaranteed prices according to the different plant sizes. Plants that have been expected to be economically feasible with the price for plants smaller than 20 MW capacity will need a size of 25-30 MW to break even, so that there might be a trend to higher capacity. On the other hand, a number of plants in these early stages is characterised by a remarkably small power output (sometimes below 500 kW), and the cost reduction through scale effects cannot take effect. In this power class, new limits of 0.5 MW and 5 MW, including a substantial increase of the guaranteed price for the lowest class, might make sense, and would be consistent with the values for biomass.

Recent projects for geothermal power production in Germany

Table 1 gives a summary of the new geothermal power projects studied with support from the federal government. Most of the projects currently are in an advanced planning or even in a construction phase. The first plant which is expected to be operational could be Neustadt-Glewe, where the electricity production can be hooked to an existing geothermal district heating facility. In addition, there are some pure R&D-projects included in the programme, not intended to deliver any energy soon. The distribution of the projects reflects the geological situation with the main basins (fig. 6); the largest number is inside the Upper Rhine Graben.

Table 1: Current geothermal power projects in Germany, as supported by the federal government

Location	Number of wells	Depth	Temperature	Intended power
Neustadt-Glewe	2	2300 m	97 °C	0,25 MW_{el}
Unterhaching	2	3100 m	120 °C	ca. 2 MW_{el}
Bruchsal	2	2540 m	135 °C	?
Groß-Schönebeck	not determ., frac	4500 m	140 °C	0,8 MW_{el}
Offenbach/Pfalz	2	2500 m	150 °C	(?) 6,5 MW_{el}
Bremerhaven	1, deep BHE	5450 m	160 °C	(?) 0,07 MW_{el}
Bad Urach	2	4450 m	170 °C	1 MW_{el}
Soultz-sous-Forêts	3	5000 m	200 °C	3-5 MW_{el}

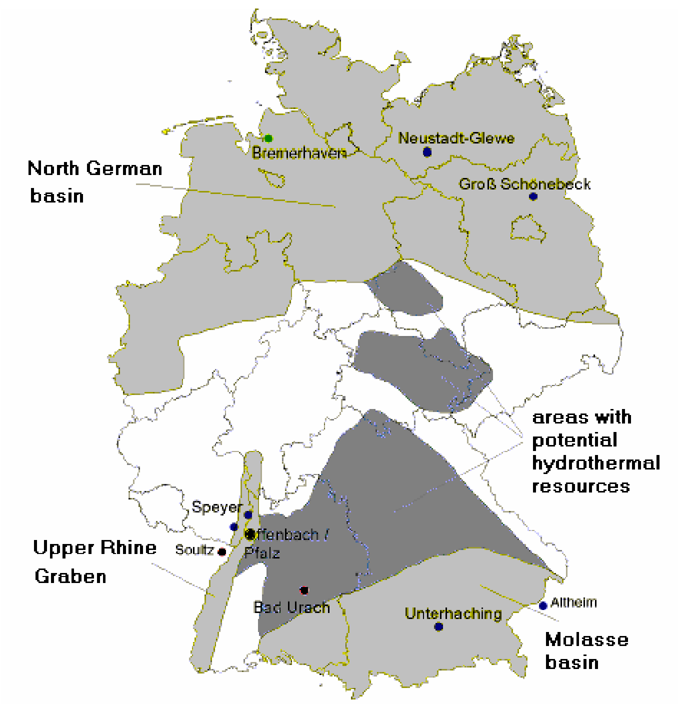

Abb. 6: Location of the geothermal power projects in and around Germany, and main basins in Germany (from [5])

Conclusions

The *Erneuerbare Energien Gesetz* EEG has triggered a great step forward in the development of geothermal power production under the German geological conditions. To overcome îndividual technical and economical barriers to the construction of the first plants, which cannot be handled by the EEG alone, additional support is available through the ZIP-Programme and other aid. In future, a fast spreading of geothermal power production inside Germany can be expected, provided the EEG will be prolonged smoothly. After a starting phase, a continuing reduction of the fixed prices for geothermal power within the EEG will be possible.

Geothermal energy today is the only renewable energy form that is completely independent of any seasonal and climatic changes (even the old-fashioned, but stable hydropower suffers from natural seasonal variation). This characteristic allows for a full-load-availability well in excess of 90 %, which could be proven in the practical reality (e.g. on the Azores, s. [6]). The inclusion of geothermal energy in combination with other renewable energy sources is the only way to guarantee the electric power required, while in parallel emission reductions in compliance to the Kyoto-protocol can be achieved.

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