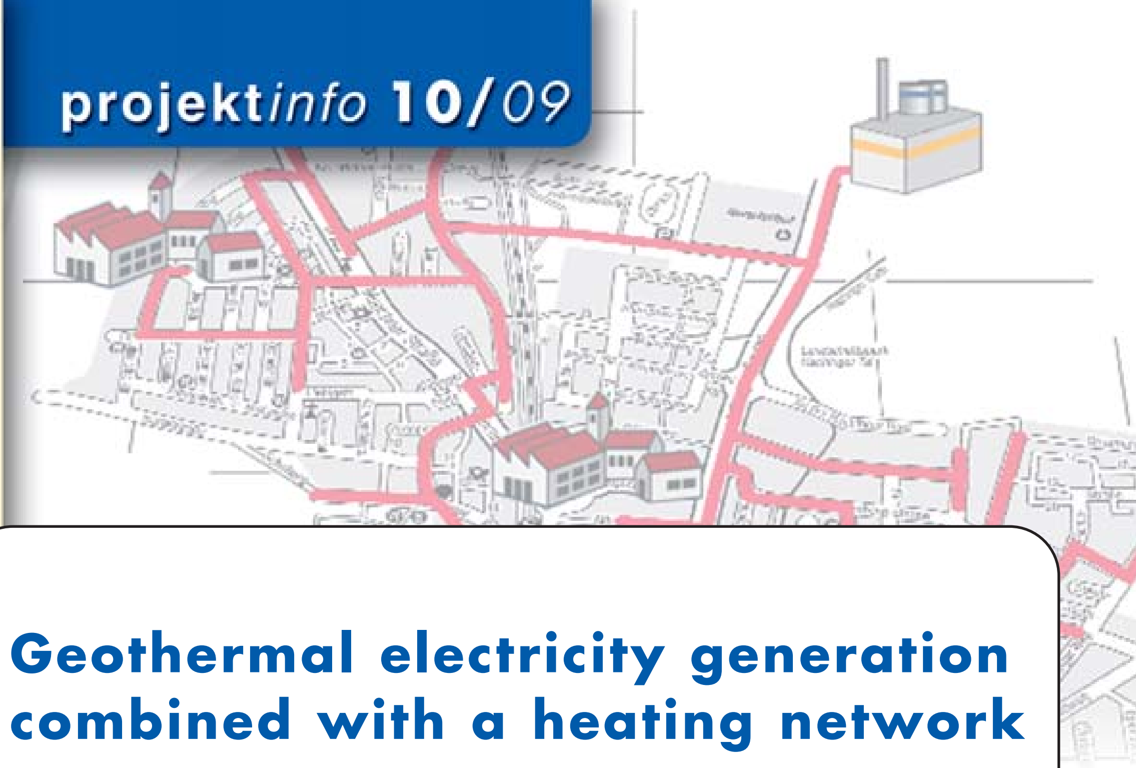
projektinfo 10/09

BINE
Informationsdienst



Geothermal electricity generation combined with a heating network

- The first geothermal power station in South Germany
- The temperature and rate of water delivery were higher than originally expected
- The main focus shifted from electricity generation to heating during the course of the project
- After only 18 months, geothermal energy covered 25% of the local heating requirements

Fig. 1

The first Kalina system for electricity generation in the EU commenced operation in Unterhaching. The geothermal power station building also contains the production pump for the thermal water and the above ground system with plate heat exchangers for the heating network.

The region between the Swabian and Franconian mountains and the Northern Alps, also known as the South German Molasse Basin, has large geothermal resources. Hot water at depths of 1,500 to 5,000 m has given rise to health resorts with thermal baths over the last few decades. In recent years, some communities have also begun to integrate geothermal energy into their local district heating systems.

The Unterhaching community, located south of Munich, has been using these geothermal resources in a communal heating network since 2007. The very first geothermal power station in South Germany commenced operation here early in 2009. The community initiated their own energy concept ten years earlier, establishing a heating atlas as the first step. This resulted in the development of a plan to cover at least 50% of the local energy requirements with more efficient systems by 2015. In 2001 the community council decided to construct a geothermal plant. Two wells in Unterhaching resulted in copious hot water reserves at temperatures above 120 °C. The original usage concept gave a primary role to electricity generation with district heating for municipal buildings assuming a secondary role. The greatly increased prices for fossil fuels and the unexpectedly high temperature and volume of water resulted in a change of project priority, with the main focus becoming the supply of district heating for the community. This resulted in a new district heating network that already covers 25% of the local requirements and is still being expanded. Only the excess heat is channelled into a power station that has been specially designed for low temperature heat. For the first time in the EU, the power station uses a mixture of water and ammonia as the working fluid (Kalina process).

Sample project management solutions were also created, e.g. in the areas of geological risk insurance, drilling contracts and end-customer tariff structures, which should assist similar projects elsewhere. The geological analyses and testing of a Kalina plant were subsidised by the German Federal Ministry for the Environment (BMU).

▸ Geology of the Molasse Basin

The fissure karst aquifers in the Malm, or upper jura, are a large reservoir of geothermal energy. The Malm rocks are located deep below a geological structure known as the South German Molasse Basin (Figs. 2, 3). The basin covers an area of 700 km from east to west and 250 km from north to south. Millions of years ago a primeval sea deposited lime, sand and clay here, which has subsequently been compacted to fine chalky limestone, carbonates and marl. Tectonic formation of fractures and water erosion has resulted in the so-called karst, which can be extremely water permeable in the regions near the fissures.

The layers of most interest for geothermal energy (upper or top Malm) lie at depths between 1,500 and 5,000 m, with temperatures ranging between 85 and over 140 °C. In the Southern Molasse, thermal water resources above 100 °C can be found at depths of approx. 3,000 m, which are suitable for geothermal electricity generation. The karstification recedes towards the south, meaning that test wells must be as close as possible to the geological fault zones in order to be successful. Breaks, fractures and fissures in these zones can provide high volumes of thermal water.

Test drilling for crude oil reserves in previous decades had already provided evidence of hot water reserves in the Molasse. The data obtained at that time was re-evaluated as part of the geothermal project to discover the local positions of the fault zones and thus determine the best locations to drill for hot water. In Unterhaching, the desired rock formation is located at depths ranging between 3,000 and 3,600 m and consists of fine porous limestone and dolomite. Both the temperature and available volume of water greatly exceeded the initial expectations.

Fig. 2: Geothermal potential in the Alpine upland

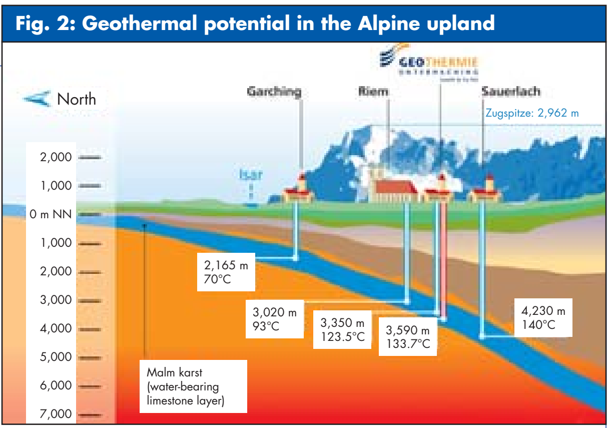
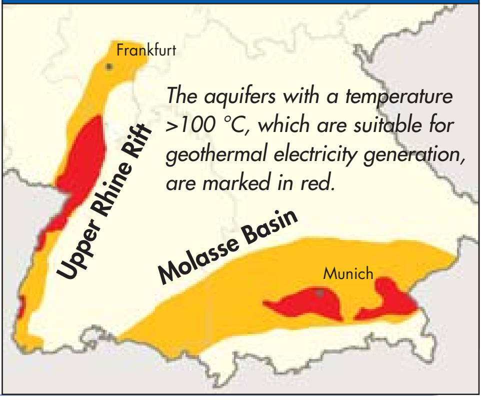


Fig. 3: Geothermal areas in South Germany



The aquifers with a temperature >100 °C, which are suitable for geothermal electricity generation, are marked in red.

▸ Geothermal plant

The Unterhaching geothermal plant (Figs. 4, 5) has two wells (double well principle). The thermal water is pumped to the surface via the production well. This then flows through thermal water pipes to the above ground plant with heat exchangers and after cooling flows back into the depths through the injection well to preserve the water level in the aquifer. Other components are a new district heating network, an electricity generation plant using the Kalina process and a fossil-fuelled redundant/peak load heat plant.

The two wells are about 3.5 km apart. After successfully overcoming various geological and technical difficulties a volume of 150 l/s was reached. One surprising result was that the water temperature in the injection well was higher than that in the extraction well. This resulted in brief consideration of a change in the flow direction of the thermal water circulation, which was then abandoned due to the extra costs that would have been incurred by subsequent changes to the plant.

The extracted thermal water contains 600 – 1,000 mg/l of salts (mainly: hydrogen carbonate) and also dissolved gases (e.g. methane and nitrogen). To avoid chemical precipitation, and prevent entry of oxygen into the aquifer, the thermal water circuit is permanently pressurised with nitrogen. The thermal water pipes between the wells are made of fibreglass reinforced plastic to avoid any potential corrosion problems.

Fig. 4: Unterhaching geothermal plant

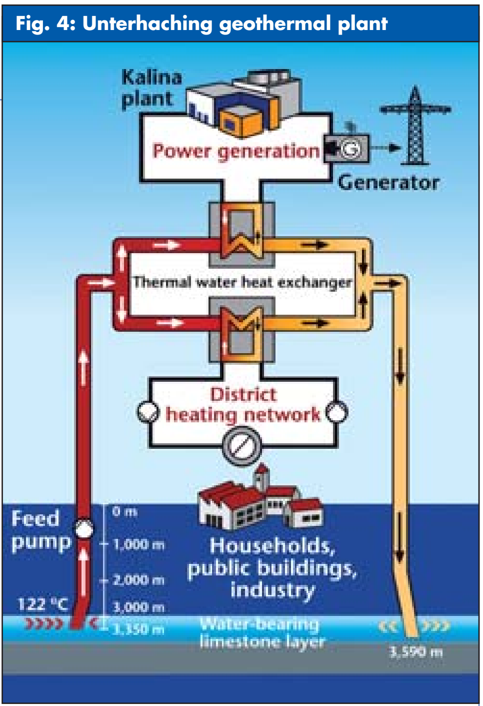


Fig. 5: Timetable and characteristic values of the Unterhaching plant

Timetable	
1995 – 1997	Municipal heating atlas
2001 – 2002	Preliminary geological investigation and feasibility study. Decision for a geothermal plant. Central condition: Geological risk insurance
2004	Production well
2006 – 2007	Injection well
2006 – 2007	Expansion of the heating network, above ground plant and the redundant heat plant
2007	Commencement of the geothermal heating supply
2006 – 2008	Construction and commissioning of the Kalina plant
Feb. 2009	Geothermal electricity generation commences
2. Jun. 2009	Official opening

Characteristic values	
Production well Well depth Temperature	 3,446 m 122 °C
Injection well Well depth Temperature	 3,864 m 133 °C
Output	up to 150 l/s
Geothermal thermal output **Fossil thermal output** (peak load, redundancy)	up to 38 MW up to 47 MW
District heating network (31.12.08) Connected load Annual heating load 2008	28 km length 30.4 MW (represents the heating requirements of approx. 3,000 households) 47,000 MWh
Geothermal electricity generation Electrical output Annual electricity generation	 3.4 MW (average value) 21.5 Mio. kWh (represents the annual consumption of approx. 6,000 households)
Annual CO_2 saving	Up to 35,000 t (on completion of all expansion measures)
Total investment (31. Dec. 2008)	approx. 80 million Euros

At full capacity, 4.7 billion litres of water pass through the plant annually. The entire plant requires only a single production pump. The required output and the high temperatures both represented a great challenge for the pumps that were available on the market. Since the middle of 2009 a prototype of a subsurface pump has been used, which is specially optimised for geothermal plants and can cope with the required output. The geothermal heat is coupled to the heating network and the electricity generation plant via two parallel heat exchangers.

▶ Energy concept

Geothermal energy has now assumed a permanent role in the local energy supply. The original primary emphasis on electricity generation was replaced by a primary emphasis on heating supply during the course of the project. In the light of increasing prices for fossil fuels, the local conditions made it more economically viable to use most of the available geothermal resources for blanket heating coverage and use only the excess heat for electricity generation. This is managed by an automatic system for controlling the distribution of the thermal water between the two processes according to the requirements of the connected district heating customers.

A new heating network, 28 km long, was laid in only 18 months. This is the largest newly built district heating network in Germany since the 1980's. It will be expanded to a connected load of 70 – 80 MW by 2020. The possibility of connecting to a district heating network was met with great interest by the citizens of Unterhaching. A transparent pricing structure with competitive working prices was a decisive factor in creating interest. A once-only connection fee and a monthly base price and meter fee are also required (**Fig. 6**). The pricing system is based on a sliding-price clause coupled via a fixed percentage to the indices for investment products, wage costs, electricity and gas prices. This allows a district heating system to provide comparatively cheap heating with no investment costs for private heating boilers. A connection load comparable to 3,000 households (as at: 12/2008) has now been reached. In addition to private homes, public institutions such as the Town Hall, schools, swimming baths and commercial premises are also district heating customers. A heat transfer station is installed in the connected houses (**Fig. 7**), with compact dimensions that allow it to be easily accommodated in the buildings.

The heating network requirements are currently covered over the entire year by geothermal heating. Due to the increasing connected load, and in the case of extremely cold temperatures, the fossil fuel heating plant can be switched into the system at peak load times. This has two 23.5 MW boilers that can be fuelled by crude oil or natural gas. If necessary, this heating plant can also supply the complete needs of the district heating customers.

Fig. 6: Pricing example for the Unterhaching district heating system

	Single family home	Terraced house
Estimated consumption	25,000 kWh/year Conversion: 1 m^3 Gas = 9.18 kWh; 1 l heating oil = 10.08 kWh	17,500 kWh/year
Annual consumption costs	2,106 €/year *	1,699 €/year *
Once-only connection costs	1,234 €* incl. heat exchanger and 5 m of district heating piping on private land	1,234 €*

Notes

1. The estimated consumption is based on an assumed annual efficiency factor that may vary in individual cases depending on consumer behaviour.

*2. * plus sales tax*

3. As at 10/2009 – valid until 10/2010

4. A current price list is available at www.geothermie-unterhaching.de

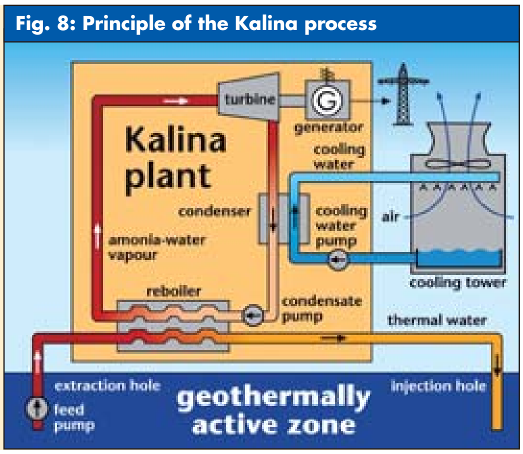
Fig. 7: Heat transfer station at the end consumer (up to 200 kW)

Kalina process

In order to generate electricity in the low temperature range between 0 and 200 °C, special generating plants using a different operating medium to water vapour are required. Alongside the Organic-Rankine Cycle (ORC) that uses a single medium (e.g. Isopentan) there is also the Kalina process (**Fig. 8**) that uses a mixture of water and ammonia. With a boiling point of – 33.7 °C, ammonia evaporates faster than water. With the mixture ratio used, the medium boils at 50 °C. This allows the medium to optimally absorb heat and drive a turbine over a large temperature range. The electrical efficiency factor of the power station is approx. 10 – 13%.

As in a normal power station, the geothermal heat is transferred to the working medium via an evaporator in a closed circuit. This heats up, expands and then contracts via a turbine driving a generator. The working medium is then re-liquefied in a condenser, which is connected to cooling towers via a separate cooling circuit at the Unterhaching plant.

Fig. 8: Principle of the Kalina process



▶ Project management

The Unterhaching community had two main targets: the commercial viability and the technical quality of the project. Certain risks (e.g. discovery risks, technical reliability of components) were unknown at the start of the project and could only be determined and calculated in the course of the project. In the light of the many individual decisions required, the community decided on collaboration with an external project manager. A commercial sensitivity analysis on the question of “electricity or heating driven system” was performed in collaboration with the project manager and a tariff structure containing a long-term sliding-price clause was developed for the heating network customers.

The development of special drilling contracts suited to geothermal requirements is worth mentioning. Both contract partners in Unterhaching agreed to a fixed price contract based on the amount of drilled meters, a first with this kind of contracts. A geological risk insurance was also newly developed in order to cover the geological economic risks for the Unterhaching community. This type of insurance was required by the community council in 2001 as an essential part of the project, but no suitable types of insurance were available on the market at this time. A number of insurance companies now offer this type of product.

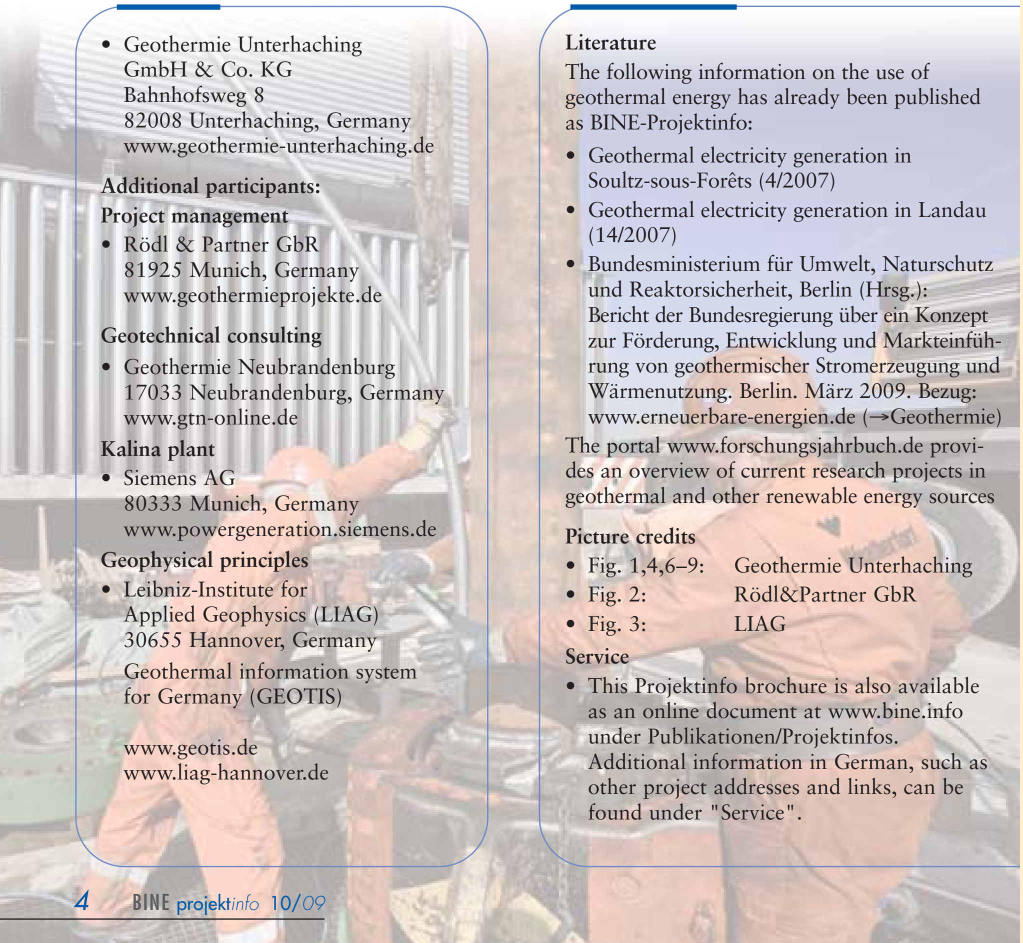
▶ Conclusion and prospects

The Unterhaching geothermal power station has been producing electricity since the beginning of 2009. The customer acceptance of district heating is high and a decision has already been made to extend the network. The community is on the way to achieving a long-term, economically viable, environmentally friendly local energy supply. This is also a locational advantage. From the commissioning of the heating network in 2007 to the official opening of the electricity generation plant, the Unterhaching geothermal plant has saved a total of 22,500 t of CO_2. The additional electricity generation and subsequent completion of the expansion of the heating network will eventually result in annual CO_2 savings of approx. 35,000 t. In particular, the significantly expanded heating network has resulted in a large increase in the investment costs over the course of the project. Amortisation of these costs is expected in approx. 15 years. A community investor has the advantage of being able to make longer term investments.

One challenge was the integration of the plant in an already established community. This required certain compromises in location decisions. The project showed the economic advantages offered by a combined used of geothermal resources for supplying electricity and heating. Local district heating networks are a key element in this scheme in order to use geothermal and other renewable energy sources in a consumer-oriented manner.

Further geothermal research and development work is still required in the future. Among other topics are improvements in the drilling technology, improvements to the electricity generation technology and the development of special geothermal deep pumps. The Geotis database system (see below) has been improving the access to local geothermal resource data since 2009. This makes it easier to assess the geothermal risk. Partially due to the successful example provided by Unterhaching, over 100 geothermal permission fields have now been awarded for the Bavarian Molasse Basin.

Fig. 9: Generator and ammonia tanks



▸ PROJECT ADDRESSES

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  www.geothermie-unterhaching.de

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  81925 Munich, Germany
  www.geothermieprojekte.de

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- Geothermie Neubrandenburg
  17033 Neubrandenburg, Germany
  www.gtn-online.de

Kalina plant

- Siemens AG
  80333 Munich, Germany
  www.powergeneration.siemens.de

Geophysical principles

- Leibniz-Institute for
  Applied Geophysics (LIAG)
  30655 Hannover, Germany
  Geothermal information system
  for Germany (GEOTIS)

  www.geotis.de
  www.liag-hannover.de

▸ ADDITIONAL INFORMATION

Literature

The following information on the use of geothermal energy has already been published as BINE-Projektinfo:

- Geothermal electricity generation in Soultz-sous-Forêts (4/2007)
- Geothermal electricity generation in Landau (14/2007)
- Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Berlin (Hrsg.): Bericht der Bundesregierung über ein Konzept zur Förderung, Entwicklung und Markteinführung von geothermischer Stromerzeugung und Wärmenutzung. Berlin. März 2009. Bezug: www.erneuerbare-energien.de (→Geothermie)

The portal www.forschungsjahrbuch.de provides an overview of current research projects in geothermal and other renewable energy sources

Picture credits

• Fig. 1,4,6–9:	Geothermie Unterhaching
• Fig. 2:	Rödl&Partner GbR
• Fig. 3:	LIAG

Service

- This Projektinfo brochure is also available as an online document at www.bine.info under Publikationen/Projektinfos. Additional information in German, such as other project addresses and links, can be found under "Service".

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