Germany Country Report

Lothar Wissing

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IEA Geothermal

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Projektträger Jülich, Erneuerbare Energien PTJ-ESE, Forschungszentrum Jülich GmbH, 52425 Jülich. Email: l.wissing@fz-juelich.de

Figure 1 Sauerlach Geothermal Power Plant courtesy Stdtwerke München, SWM

1. Introduction and Overview

The use of geothermal energy could, theoretically, meet Germany energy demand several times over. Considerable efforts have been made to tap this potential with exploration and development occurring in the most suitable regions. Development has occurred in advancing both drilling and downhole pump technology, and facilities have been constructed for converting extracted geothermal heat to electricity.

The regions where the most suitable conditions exist include the Molasse Basin in Southern Germany (mainly in Bavaria), the Upper Rhine Graben in South West Germany and the North German Basin. These areas have high heat flows and high natural temperature gradients, and hydrothermal geothermal energy is being exploited in these parts of the country.

Information from the German Geothermal Association (BVG) identified 33 geothermal facilities in operation across Germany as of February 2016. Most of these exclusively generate heat, with a cumulative installed capacity of 280 megawatts (thermal). Nine of the geothermal plants generate electricity, either exclusively or in combination with heat energy production. The power plants have an installed capacity of about 40 MWe restricted to an operational running capacity of about 35 MWe (February 2016). Refer to Table 1 the end of the report.

Deep geothermal energy is being increasingly used in applications that use heat. Matching the geological conditions, the structure of demand and the economics of projects identifies projects involving direct heat utilization have better prospects for being economically and successfully implemented than do projects that only generate electricity.

2. National Programme

The energy concept developed by the German Federal Government in 2010 envisages far-reaching restructuring of the energy supply system in Germany by 2050. Important goals are the reduction of primary energy consumption by 50 percent and increasing the proportion of renewable energy to cover 80 percent of the demand for electricity and 60 percent of the gross final energy consumption.

If the energy transition continues to run successfully the energy system in 2050 will be completely different from the current structure of energy demand, supply and distribution. The technologies

used to realise this are to a large extent either currently not technically available or are not economically feasible. Energy research forms a strategic element of the energy policy in order to generate technical innovations in the medium to long term that will enable this energy transition.

In 2011, the 6th Energy Research Programme "Research for an environmentally friendly, reliable and affordable energy supply" commenced. The goals of the programme are to accelerate the modernisation of the German energy supply system, strengthening German international business competitiveness and securing and expanding technology options.

The Federal Ministry for Economic Affairs and Energy (BMWi) is responsible for leading the 6th Energy Research Programme and for funding applied research and technological developments in all energy technology areas except for bioenergy.

The basic principles for research funding are described in the 6th Energy Research Programme. An overview of research activities and results are published in "Innovation Through Research" publications (see references at the end of the chapter). The 2015 publication is the first in the series to cover the entire spectrum of research funded topics supported by BMWi in both energy efficiency and renewable energies.

3. Industry Status and Market Development

Apart from funding carefully selected research projects, the Federal Government is also creating incentives for new projects by remunerating geothermal electricity under the Renewable Energy Sources Act (EEG) and by offering drilling cost subsidies. In December 2015 the feed-in-tariff was fixed at 25.2 Euro-cents per KWh. This was an amendment to the EEG adopted by the Bundestag (Lower House of Parliament).

The German Government market incentive programme (MAP) promotes renewable energy systems that provide space heating, hot water, cooling and process heat. It was revised in March 2015 and includes programmes for smaller buildings, larger buildings and commercial use. The smaller buildings programme is administered by the Federal Office of Economics and Export Control (BAFA). Commercial use is a key component of the KfW Banking Groups renewable energy program. Several geothermal technologies are supported by the MAP; it subsidizes the installation of efficient heat pump systems in residential buildings using a repayment bonus that depends on the installation size.

For heat and power plants using deep geothermal energy, a repayment bonus for the plant is available and depending on the depth drilled the drilling cost can be supported. Further, part of the exploration risk can be covered by a KfW-program.

The geothermal market predominantly comprises small and medium-sized mechanical engineering enterprises and larger enterprises, whose portfolios belong more to the conventional energy sector, such as the hydrocarbon industry.

4. Research, Development and Demonstration/Deployment

The potential offered by deep geothermal energy as a continuously available renewable energy source needs further realization and research, advancement and development work has been carried out towards this end. There have been improvements in the areas of drilling technology, plant construction and downhole pump technology. New methods have been developed to

appropriately determine target areas for drilling and in drilling technology directional drilling can be carried out with more precision than was possible a few years ago.

Due to the local conditions, such as the composition of the thermal water or the geological structures, each geothermal production facility has unique aspects. A more individual approach is therefore necessary in the planning phase, compared to other more off the shelf renewable energy technologies. In view of the significant potential and expected contribution of geothermal energy to an energy system based on renewable energy in the future, the Federal Ministry for Economic Affairs and Energy (BMWi) is continuing to support relevant research projects. The BMWi primarily provides funding to projects that are dedicated to complete systems – such as pumps. Further research is required in order to economically utilise deep geothermal energy and to fully exploit the heat energy potential.

The research projects currently being funded encompass all stages of the geothermal energy value chain. The primary goal is to further reduce the cost of projects in order to make geothermal energy economically viable nationwide. Contributions towards the achievement of this goal are made by technological developments in all project phases: in project planning, the exploration of the target heat source, the drilling, testing and construction phases and the operation of completed facilities. In particular, deep boreholes must be completed more quickly and at reduced cost because they account for a significant part of the investment costs. The design and operation of completed heat or power plant facilities needs to be more efficient, more reliable and with lower maintenance requirements. Alongside technical developments in geothermal energy, concepts for improved public relations work are a fundamental component of a successful project. And last but not least, the conditions must be created to allow geothermal energy to be utilised in those areas that have not yet been explored or which are less suited.

Major success has in particular been achieved in the Molasse Basin in Southern Germany. Heat from deep geothermal energy can already be reliably utilised in this area. The GRAME project supports the long-term goal of supplying the entire heating requirements in the Munich region using renewable energies. Geothermal energy is set to make a decisive contribution here. The seismic measurements to map the underground for this project began in 2015.

In the area of geothermal research, the BMWi approved funding for a total of 21 new projects funding 17.3 million euros in 2015 (2014: 15 new projects with around 12.7 million euros). At the same time, around 13.4 million euros was invested in ongoing research projects (2014: around 15.6 million euros).

4.1 Research Highlights

Geothermal Heat for Munich

Munich is located in the Molasse Basin in Bavaria where the underlying geological formations are particularly suited for the extraction of geothermal heat. The rocks are part of Malm, a geological formation that due to its special structure behaves like a hot thermal water aquifer. By 2040 Stadtwerke München (SWM) intends to provide the entire district heating for Munich from renewable energies, with geothermal energy contributing the majority of the energy.

SWM, as the coordinator, aims to lay an important foundation for this vision with the GRAME project. Work is required to determine the best locations for extracting heat from underground and how it is integrated into the existing district heating network. The project partners SWM and

the Leibniz Institute for Applied Geophysics (LIAG) are planning to create a three dimensional image of the subsurface and use it to develop the extraction strategy. The results will contribute to optimised exploitation of the geothermal resources within the Molasse Basin and the utilisation of the potential for both direct heat utilization and the generation of electricity. The goal is to extract about 400 megawatts of heat and possibly to generate up to about 50 megawatts of electricity.

The project partners are using 3D-seismic techniques to determine the structure of the reservoir and to determine the most promising locations for drilling. The project aims to advance 3D-seismic technology to gather more precise data on the underground structure. The measurements are being taken over an area of 170 square kilometers. Conducting 3D-seismic measurements beneath an urban area is breaking new ground as geothermal investigations on this scale have never before been carried out in this region. Amongst other things, traffic and construction work on the surface, generate incessant vibrations that influence the measured data.

Once the measured data has been recorded, a grid of boreholes will be drilled that will take into account the underlying geology and the infrastructure of the City. At the end of the project, a concept design for extracting geothermal heat will have been developed moving SWM closer to achieving its 2040 vision.

New Pressure Retention Valve

When pipes or filters in thermal water systems become blocked the transfer of heat is hindered and the efficiency of the plant reduces. To avoid scale deposition and the outgassing of the thermal fluid the company “Global Engineering & Consulting-Company (Gec-co)” and its academic partner the University of Erlangen-Nürnberg have developed a new controllable pressure retention valve as part of the “Pressure Retention Valve” project. The valve is installed in a production well at a depth of approximately 500 to 700 metres. It is positioned below the water level in the well and keeps the pressure of the entire water circulation system above the degassing pressure. The company was nominated for the European Geothermal Innovation Award 2015 for this development, which is awarded by the European Geothermal Energy Council (EGEC) and Fair Offenburg.

The concept and the innovative idea with its installation below the water level differentiates it from other types of valves available on the market making it ideally suited for the conditions found in deep geothermal wells. Due to its special design, the valve can also be configured with redundancy.

Online Thermal Water Property Determination

Before the construction of a new geothermal heat or power plant can begin an economic viability assessment is required to secure investment. The possible thermal output of the proposed plant is important and depends on the physical and chemical properties of the extracted thermal water. The precise evaluation of these properties is the goal of the PETher project that is being coordinated by the Karlsruhe Institute of Technology (KIT) along with partners GeoThermal Engineering (GeoT) and Global Engineering & Consulting-Company.

Relevant properties are the specific heat capacity, dynamic viscosity and thermal conductivity. These are dependent on the temperature, pressure, dissolved minerals and gas content of the water. The standard procedure used involves, taking water samples and sending them to a

laboratory and this can change the parameters of the samples. Therefore, KIT has developed in situ measurement to evaluate heat capacity and the dynamic viscosity of the thermal water. The measurements are carried out in reservoir-like conditions in the flow of water under in situ pressure and temperature conditions. The next steps for the PETher project is to install a test arrangement in a German geothermal power plant in order to test and further develop the methodology.

Advances in Downhole Pump technology

The pump is currently the most vulnerable component in a geothermal energy installation. The thermal water is pumped hundreds of meters up the borehole to the surface at fluctuating loads depending on the heat demand required to be met. Submersible pumps, which are installed together with their integrated electric motor in a well below the water level, have become the established pump technology in geothermal energy developments. In comparison to other pump installations, the efficiency of the geothermal pumps is higher and service intervals are longer than for pumps in other service duties.

The challenges related to thermal water, pressure and particulate are great. The pump and its metal components are permanently exposed to the corrosive waters, while water-borne particles (e. g. carbonates) can accumulate. The seals must be reliable enough to protect the motor and overheating has to be avoided. Furthermore, geothermal energy applications require significantly higher flow rates and outputs compared to oil extraction. The average lifespan of pumps adapted from the oil and gas business is only a few months. Less than what is required for economically viable geothermal plant operation.

The goal of the project is to increase the reliability of the pumps, avoid downtime and further increase their efficiency. Considerable success has already been achieved through the work of Baker Hughes and Flowserve.

Baker Hughes has developed a globally unique high temperature test arrangement (HotLoop) to accelerate research. It provides the combination of high temperature and high drive capacity that has so far not been available. The test arrangement produces an accelerated ageing of the pumps and enables wear and damage to be identified more quickly. It has helped engineers to deliver design improvements that have led to improved reliability in the operation of submersible pump systems. Their efficiency has also been improved.

A particularly noteworthy improvement involved the radial bearings in the pumps that now achieve significantly longer service times. In the boreholes in Dürrnhaar and Sauerlach, pumps fitted with these radial bearings were successfully deployed for four months without any notable wear. Pumps fitted with conventional bearings only achieve service intervals of between four and six weeks in the same boreholes due to calcification of the bearings. In addition, new “Flex” pump designs were developed that are more efficient and can flexibly pump variable volumes depending on the time of year heat demand. The insulation and radial bearings in the motors were also redesigned reducing maintenance related downtime. In parallel, the engineers are working on a high temperature pump sensor system. It is designed to precisely monitor the operational condition of a pump.

The results achieved are promising developments on the path to improving the economics and operational reliability of downhole pumps required for geothermal heat and power plant facilities.

5. Future Outlook

The German Government supports the development of renewable energies with a bundle of support mechanism, e.g. feed-in-tariffs, funding for research. Results of this are the 2015 renewable energy share of gross electrical consumption is about 32% and the renewable heat and cold energy supply increased to 13.2% in 2015.

Numerous efforts have already been made to develop the potential of geothermal energy as a continuously available renewable energy source. These include the exploration and exploitation of suitable reservoirs, the development of drilling technologies, and innovations in plant construction to use the extracted heat for power generation or for direct heat purposes.

At end of 2015 there were 33 deep geothermal electricity and heating plants in operation, 3 under construction and 30 are planned (BVG).

The market for geothermal heat pumps has increased to 320,000 units but the growth rate has slowed down. The investments in geothermal energy remain at a constant level of about 1 Bn € per year (heat pumps and deep geothermal power plants).

The development of geothermal district heating for Munich with the goal to supply up to 100% of the energy for house heating, attracts a lot of attention in Germany and worldwide. The 3D-seismic measurement campaign in an urban area with thousands of geophones and vibrating trucks over a 6-month period found wide acceptance by the population. This acceptance provides optimism for the future of further geothermal developments in Germany. Beside the geothermal production of electricity, the direct use of heat in densely populated areas is becoming a focus.

6. Publications and Websites

Federal Ministry of Economic Affairs and Energy: www.bmwi.de

BMWi publications in English: http://www.bmwi.de/EN/Service/publications.html

Innovation durch Forschung: Erneuerbare Energien und Energieeffizienz: Projekte und Ergebnisse der Forschungsförderung 2015
https://www.bmwi.de/DE/Mediathek/publikationen,did=763340.html
("Innovation Through Research 2015: Annual Report on Research Funding in the Renewable Energies Sector", English version expected in August 2015)

Project Management Jülich (Public Funding Agency): https://www.ptj.de/renewable-energy

Database of all projects sponsored by the Federal Economics Ministry in renewable energies: www.forschungsjahrbuch.erneuerbare-energien.de

6th Energy Research Programme of the Federal Government: http://www.bmwi.de/EN/Service/publications,did=477502.html

EEG – Renewable Energy Sources Act: http://www.bmwi.de/EN/Topics/Energy/Renewable-Energy/auctions-for-funding-renewable-energy.html

German Geothermal Association (BVG): http://www.geothermie.de/

Geothermal Information System for Germany (GEOTIS): http://www.geotis.de/index.php?loc=en_us

Table 1 German geothermal Power Plant data

Region	Location	MWe	MWth	Power Plant Type
Upper Rhine Graben	Landau	3.6	33	ORC
	Bruchsal	0.44	5.5	Kalina
	Insheim	4.3		ORC
South German Molasse Basin	Unterhaching	3.4	38	Kalina
	Durrnhaar	7		ORC
	Kirchstockach	7		ORC
	Sauerlach	4	5	ORC
	Oberhaching	4.3	5.5	ORC
	Traunreut	5.5	12	Kalina

IEA Geothermal

Executive Secretary
IEA Geothermal
C/ - GNS Science
Wairakei Research Centre
Ph: +64 7 374 8211
E: iea-giasec@gns.cri.nz