Geothermal Energy in Bavaria

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The Geothermal-Alliance Bavaria: Research to strengthen the geothermal sector

According to the Bundesverband Geothermie, 36 operational deep geothermal projects are currently located in Germany, of which two are in the construction phase and five are purely utilized for research purposes. In addition, 30 projects are being planned. Of the 36 projects, 26 are located in Bavaria. This includes 22 operational projects, two planned projects and two research projects [1]. *Figure 1* shows the locations of these Bavarian projects alongside projects, which are not used to produce power or heat, but for balneological purposes. Therefore 90% of thermal energy and 80% of electrical energy generated in Germany is produced in Bavaria – a handsome sum. All the more reason for the Bavarian government to unite and financially support the research of the deep geothermal sector. Although the majority of deep geothermal projects are successful, there is always room for improvements in all operative areas for this relatively young technology.

Since 2016, the Bavarian State Ministry for Science and Art funds the interdisciplinary research project "Geothermal-Alliance Bavaria" (GAB), which is being coordinated by the Munich School of Engineering at the Technical University of Munich. In total over 30 researchers from

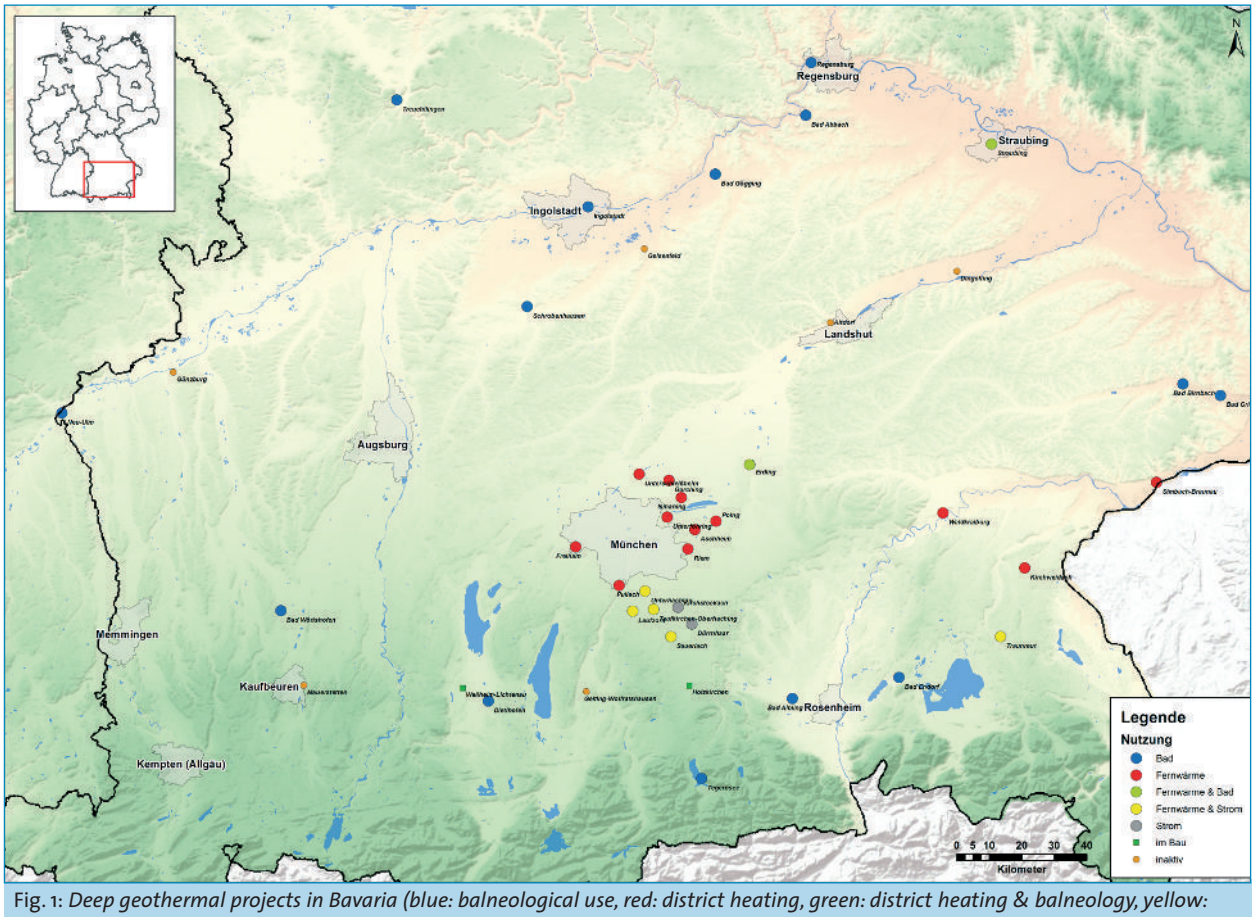

Fig. 1: *Deep geothermal projects in Bavaria (blue: balneological use, red: district heating, green: district heating & balneology, yellow: district heating & power, grey: power). Source: Flechtner/TUM.* ■

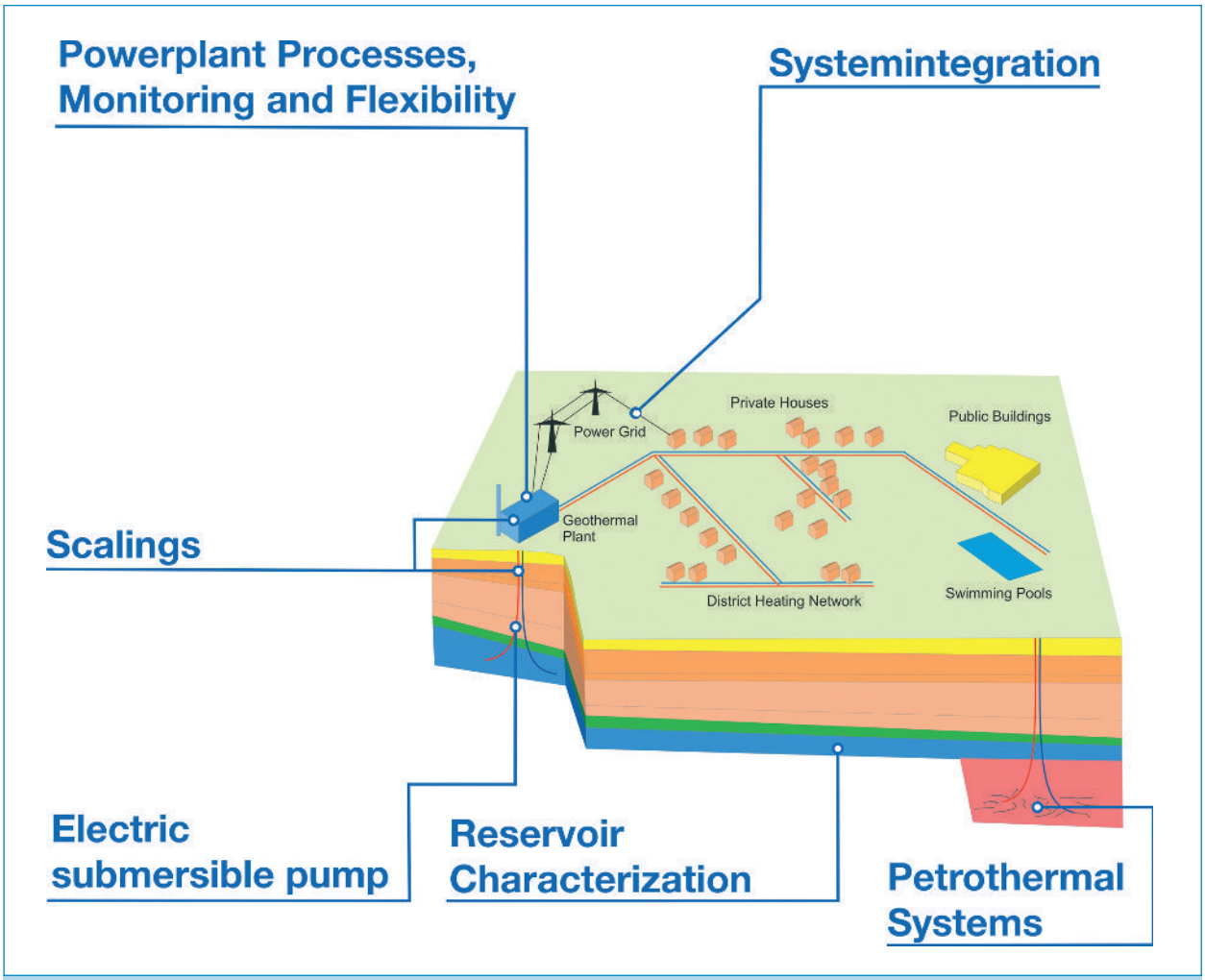

Fig. 2: *Research areas of the Geothermal-Alliance Bavaria. Source: Aubele & Flechtner/TUM.* ■

the Technical University of Munich (TUM), the Friedrich-Alexander-University Erlangen-Nürnberg (FAU) and the University Bayreuth work on solving many different research questions with the aim to improve the economic efficiency and minimize the risks of deep geothermal projects. This shall subsequently improve the competitiveness and the acceptance of this local energy source.The significant characteristic of this collaborative research project GAB is the comprehensive approach, combining all aspects of a deep geothermal project, from the exploration and characterization of the reservoir to the operation and monitoring of the power or heat plant. The individual fields of research are illustrated in *Figure 2* and described in detail below.■

Understanding of the reservoir

The focus of this research field is to characterize the Upper Jurassic aquifer system, which underlies the sediments of the South German Molasse Basin as well as investigate the deep geothermal potential of the unexploited Northern Bavaria region. In the matter of the reservoir understanding, the research concentrates on reliable predictions of flow rates and temperatures and the long-term behavior of an exploited reservoir. Hereby it is not only important to make backed statements for the operational projects but especially for projects in planning. The hydraulic evaluation of fault zones in comparison to the mass facies regarding crucial parameters such as permeability and porosity is one of the core areas of interest. In this context, particularly worth mentioning is that for the first time a fiber optic cable is being installed in a deep geothermal borehole for research purposes, to further understand the process within the hydrothermal reservoir. Through constant and depth dependent monitoring by means of fiber optics, one can detect and record temperature- and flow-zones within the aquifer as well as measuring shock waves. The latter is in particular significant for a better understanding of the processes that could lead to seismic events and their connection to deep geothermal projects. Furthermore, work is being carried out to analyze and further understand the stress regime of the area, which can contribute to assess the risk of seismicity. A comprehensive seismic campaign

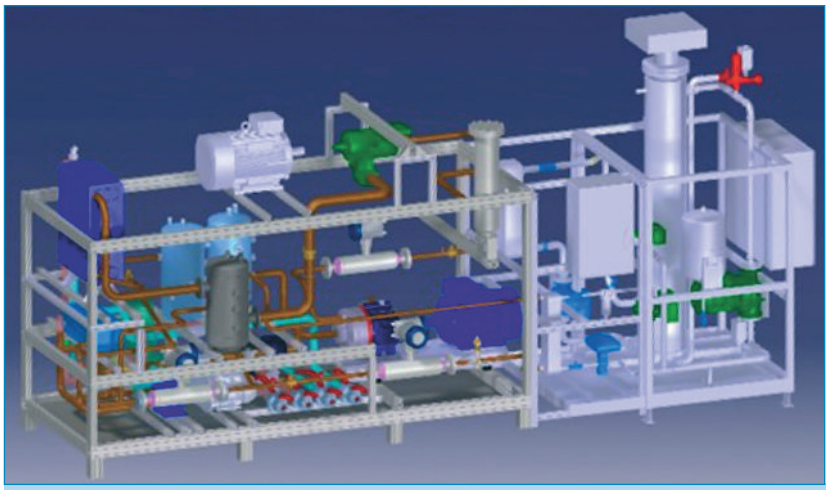

Fig. 3: *20kWel ORC-test rig. Source: Eyerer/TUM.* ■

is planned for Northern Bavaria, which will enable researchers to get an insight into the deeper underground and the existing geothermal anomaly. ■

Thermal water cycle: scalings and submersible pump

The research fields regarding the thermal water cycle focus on the operational problems caused by scalings as well as the technical requirements of the submersible pump. Many plants and pumps suffer under the high wear and tear caused by scalings. The GAB will develop a prognostics-tool to optimize maintenance as well as better understand the kinetic formation conditions of the scalings. The goal is to reduce or stop the formation of scalings by looking at the plant set-up and adjusting the operating strategy. Therefore researchers will and have undertaken extensive sampling campaigns at existing boreholes, laboratory analysis of the thermal water and geochemical modelling. In addition, a tool to predict malfunctions of the submersible pump will be developed, which can contribute to optimize maintenance intervals and therefore reduce costs regarding this component. This will be achieved by developing mathematical models for the individual components of the submersible pump. Building on that, a suitable control method will be developed [2]. ■

Efficient and flexible power plants

One of the main research fields within the GAB focuses on increasing the efficiency and flexibility of geothermal power plants aiming to improve profitability. The topics of thermodynamic optimization and flexibility of power-heat-cogeneration will be experimentally analyzed using a self-constructed 20 kWel Organic-Rankine-Cycle (ORC-) test rig *(Figure 3)*. Experiments regarding the evaluation of different working fluids can also be carried out using the test rig. Alongside the experimental approach, the optimization of the power plant will also be worked on using simulations. Throughout the ongoing activities, a study was published which estimated the potential of geothermal power generation in Germany [3]. ■

Monitoring

The aim of this subproject is to develop and validate a monitoring tool for geothermal plants. The monitoring tool will monitor components within the plant and help detect the formation of scalings. The detailed knowledge of the processes within the plant result in a higher availability of the plant and help optimize the plant efficiency. Ultimately, the re-

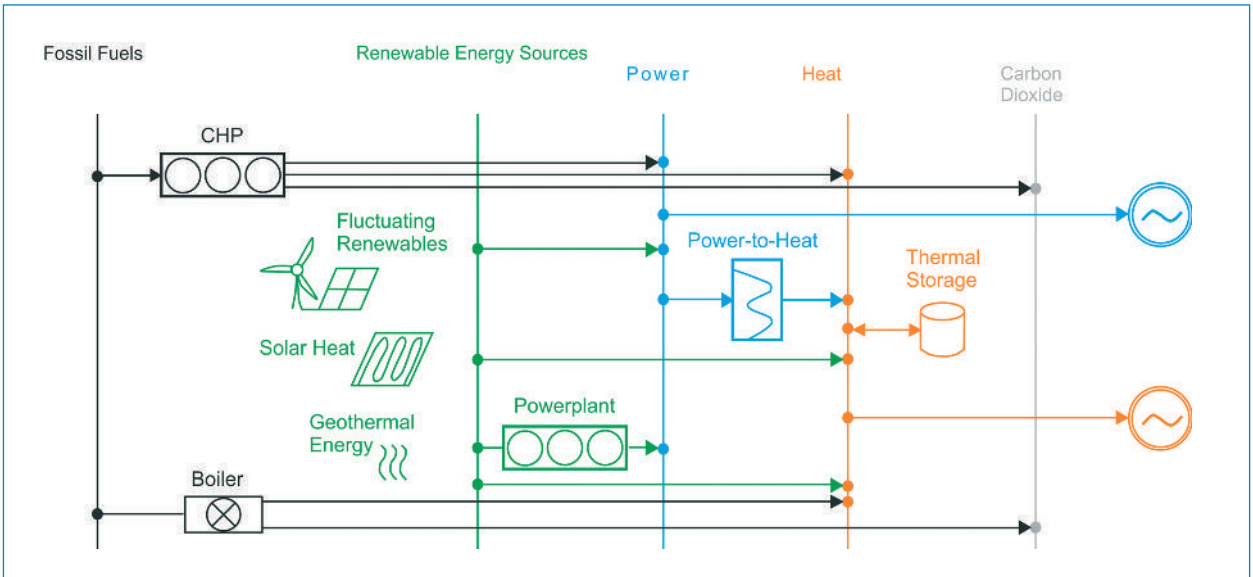

Fig. 4: *Position of the geothermal system within the energy system. By means of heat-power-cogeneration, the geothermal system can contribute to the power and heat production. Source: Aubele/TUM.* ■

search is aimed to improve economic efficiencies of deep geothermal power plants. ■

Geothermal energy within the power grid

One particular challenge is the integration of the geothermal sector into the current energy system, which is increasingly dominated by volatile renewable energies. The GAB is trying to answer questions regarding the costs and potential of deep geothermal systems as well as evaluating the contribution of deep geothermal energy towards the energy supply reliability. Deep geothermal energy can play a significant role for a greenhouse gas neutral energy supply, especially for urban areas. *Figure 4* shows how the geothermal system fits within the energy system of the future, which itself will rely less on fossil fuel supply.

All research carried out within the GAB can fall back on a growing data pool, thanks to collaborations with many Bavarian geothermal plant operators. This clearly shows the cooperative nature between research and industry. The results of the scientific effort can be directly implemented and contribute to strengthen this young technology. ■

Education, education, education

Of great importance for the GAB is the education of young researchers in the field of deep geothermal systems. By implementing a separate study program called Geothermal Energy, which is jointly undertaken by the FAU and TUM and supported by many guest lecturers coming from industry or research, the GAB lays the foundation for an upcoming generation of geothermal professionals. The study program of this four-semester master study includes modern exploration methods, fundamentals of the reservoir geology and petrology, rock mechanics, tectonic and stress field analysis, basics of drilling and pumping technologies as well as power engineering, business administration, public relations and mining and environmental law [4]. ■

Seedfunding

The GAB has an allocated funding budget to support smaller research projects, which relate to the ongoing research topics. The funding is limited to Bavarian universities and distributed yearly based on a selection process [5]. ■

Communication, Networking and Information

Next to completing the above mentioned research topics, the GAB poses as a communication and networking platform for stakeholders of the deep geothermal community. The GAB offers a unique point of contact for the research community, to identify and combine research questions, connect scientists, provide a home for young scientists and engage in concerns of operators and authorities. In addition, the GAB team provides information for citizens and educational work on the subject “deep geothermal energy” in a scientifically sound and neutral way.■

References

[1] Bundesverband Geothermie (2018): www.geothermie.de/fileadmin/useruploads/wissenswelt/Projektliste_Tiefe_Geothermie_2018.pdf, Date: 07.05.2018

[2] Kullick, J.; Hackl, C. M. (2017): Dynamic Modeling and Simulation of Deep Geothermal Electric Submersible Pumping Systems. Energies 10 (10), 1659, doi:10.3390/en10101659

[3] Eyerer, S.; Wieland, C.; Schifflechner, C.; Spliethoff, H. (2017): Hydrothermale Geothermie in Deutschland - Potential zur Stromerzeugung. Geothermische Energie, Heft 87, 2017/2, S. 26-27

[4] Homepage der Friedrich-Alexander-Universität (2018): https://www.gzn.nat.fau.de/studium/im-studium/master-geothermiegeo-energie/, Date: 07.05.2018

[5] Homepage der Geothermie-Allianz Bayern (2018): https://www.mse.tum.de/gab/forschung/seedfunding/, Date: 07.05.2018 ■

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Energy revolution in the fast lane

Erdwärme Grünwald is continuing on its path to becoming a holistic energy supplier.

Erdwärme Grünwald GmbH (EWG), a wholly owned subsidiary of the municipality of Grünwald, has completed a district heating network of around 100 km in just seven years - including the service lines for more than 2,000 residential and commercial units already connected to geothermal district heating and the interconnector to Geothermie Unterhaching. Grünwalder's heating customers, the environment and the ecological footprint of the community benefit from this speed.

The geothermal system of Erdwärme Grünwald in Laufzorn: right: the geothermal heating plant, in which the combined heat and power plant for own power generation and the power-to-heat plant are placed, in the foreground the information pavilion, rear left the ORC power plant ■

Extensive energy portfolio

In addition, EWC produces green electricity in its own ORC power plant, operates a combined heat and power plant for its own power generation and a power-to-heat plant to compensate for voltage differences in the public power grid. EWG has increased their participation in the Geothermie Unterhaching Produktions GmbH & Co KG in agreement with the neighboring community Unterhaching mid-December 2017 from 50% to about 95%. In addition, in February 2018, in a joint seismic campaign with Stadtwerke München and IEP Innovative Energie Pullach, EWG paved the way for an expansion of geothermal activities in the south of Munich and in the southern district of Munich.

This success story is based on the forward-looking decisions of the Grünwalder city council and the competent commitment of the 12-member EWG team: with Andreas Lederle and Stefan Rothörl in the management, the technical team led by Horst Wagner for the stable operation of all energy-technical systems and the Sales and Customer Advisory Team. "In the case of EWG, the spirit is right," says EWG Managing Director Andreas Lederle, "renewable energy generation and distribution is a complex topic. To ensure this sustainably at a high level is only possible in a strong team."

10 years of Erdwärme Grünwald

In 2018 the EWG celebrates its tenth anniversary. On October 8, 2008, the community Grünwald acquired 100 percent of the geothermal project initiated by the company Astherm GmbH in the neighboring community of Oberhaching-Laufzorn and launched a successful duplicate bore the following year. The strike was confirmed in June 2010: up to 140 liters / second with a temperature of 127 degrees Celsius. Two

The geothermal system of the Erdwärme Grünwald in Laufzorn is harmoniously embedded in the landscape. To the left of the heating plant and in front of the ORC power plant is the duplicate bore: Production and re-injection wells are each over 4,000 feet deep; EWG is producing a robust 120 liters / second with a temperature of 127 degrees Celsius ■

months later, the construction of the district heating network began, in October 2011, the first geothermal district heating flowed in the Struwwelpeter Kindergarten in Grünwald. As early as the summer of 2012, EWG also connected major customer Bavaria Film to geothermal district heating - the world's first film studio to source its heat exclusively from geothermal energy.

Since the end of 2017, after the last metres of the Grünwalder district heating network was laid, every household in Grünwald now has the opportunity to connect to geothermal district heating in addition to the districts of Wörnbrunn, Oberdill and Gasteig. Of course, there is no obligation to connect - the district heating network is growing gradually and, as of May 2018, has around 1,100 Grünwalder heating contract customers with a total of over 2,000 connected residential and commercial units: including private customers, companies, the Grünwalder cooperative and all municipal real estate such as town hall, schools, kindergarten, the amusement park and the House of Encounter.

Supply security a top priority

The ultimate goal of Erdwärme Grünwald is the security of supply in Grünwald - and thus the permanently stable and robust operation of the power generation plants in Laufzorn. This concerns both the production of heat in the geothermal heating plant and the production of green electricity in the ORC power plant. EWG therefore relies on continuous operation in all parts of the plant - at any time of the day or season. Because this continuous operation, in the optimal operating window with continuous 120 liters / second, means the least possible load on the system parts e.g. through thermal fluctuations. Thus EWG produces green electricity even in winter, only much less than in summer, and produces green electricity even at peak loads of the district heating network, for example, in the morning, only much less than in the course of the day.

Of course, the heat supply has priority - so only produces as much green electricity as the heat supply allows. So the leftover thermal energy after that goes into the electricity production in the ORC power plant - and automatically. Because the plant control in Laufzorn is designed in such a way that district heating and electricity production are always exactly coordinated, depending on the time of the day and the season.

The power plants in Laufzorn ...

... include various modules: Production and injection well, each about 4,000 m long, the subsurface pump at about 780 meters depth, the frequency converter from ABB, the geothermal heating plant with reserve and peak demand oil boilers, the CHP for own power generation, the ORC power plant, that generates green electricity and feeds into the general power grid, as well as the power-to-heat system, which removes excess electricity from the grid and thereby contributes to the stability of the power grid.

“The entire system is comparable to an orchestra,” says the EWG Managing Director Andreas Lederle, “Every instrument does its best, so - to take the metaphor further - the sound is right. Our team around the technical director Horst Wagner does an outstanding job here; he succeeded in harmonising all the modules in Laufzorn so that they work robustly and reliably. Thus, we ensure the best possible availability of the technical equipment through professional operational management. This permanently guarantees the security of supply in Grünwald. “So the first EWG submersible pump ran for 30 months in continuous operation,

the second, as of the editorial deadline May 2018, already 25 months.

Cooperation with science

Because the energy industry is developing rapidly, the technical possibilities and legal requirements are also developing. This is the responsibility of EWG through close cooperation with science among other things. EWG works closely with the "Geothermal Alliance of Bavaria", an interdisciplinary research project of TU Munich, University of Erlangen-Nuremberg and University of Bayreuth on aspects of deep geothermal energy. EWG MD Andreas Lederle is also involved in the advisory board of a project of the Federal Ministry of Education and Research on deep geothermal energy. "We are at the forefront of being able to meet the ever-changing requirements at an early stage," says Andreas Lederle. "We attach great importance to the further development of our systems, keyword digitisation, and to tangible benefits for our customers. This will allow us to sustainably grow in the face of the diverse demands placed on us as an energy supply company. "

EWG is constantly engaged in dialogue with Grünwalder citizens, companies, associations and organisations, as well as with domestic and foreign delegations including from schools, colleges and the energy industry. Guest at WGC have already included delegations from Ireland, Belgium, Italy, Finland, Ukraine, Belarus and Switzerland, Indonesia, China, Japan and Central America. They all share an interest in a geothermal plant, which shows how professionally a municipal utility company can harness the earth's renewable energy.

"The use of geothermal energy is a hot topic worldwide," says Erdwärme Grünwald MD Andreas Lederle, "we are very pleased that the global geothermal industry wants to learn from EWG. We have earned the reputation of being a flagship organisation through our proactive overall approach and long-term stable operations. We are happy to share our experiences."

Meeting place for energy experts, students, interested citizens and delegations from all over the world - the Information Centre of Erdwärme Grünwald in Laufzorn. Copyright Sascha Kletzsch ■

Grünwald's answer to climate change

With the use of the Laufzorn geothermal spring, the Erdwärmer Grünwald takes the energy revolution into its own hands and provides a clear answer to climate change. Grünwald took the citizens early on the path of the energy revolution. The acceptance of geothermal energy in Grünwald is high.

Beteiligung an der Geothermie Unterhaching ➔

Around 50 prospective geothermal PhD students from all over the world visited Erdwärme Grünwald on the occasion of the "European Geothermal PhD Days" at the renowned ETH Zurich ■

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"The energy revolution does not end at the edge of the community"

EWG increased their participation in the Geothermie Unterhaching Produktions GmbH & Co KG in agreement with Unterhaching mid-December 2017 from 50% to about 95%.

The team for a strong, solid foundation of geothermal energy Unterhaching Produktions-GmbH & Co.KG: from right Andreas Lederle, Managing Director of Erdwärme Grünwald and Geothermie Unterhaching Produktions-GmbH & Co.KG, Grünwalds 1st Mayor Jan Neusiedl, Unterhachings 1st Mayor Wolfgang Panzer and Wolfgang Geisinger, Managing Director of Geothermie Unterhaching Produktions-GmbH & Co.KG and Geothermie Unterhaching GmbH & Co KG.s ■

Since 1 January 2014, Erdwärme Grünwald GmbH (EWG) has held a 50% stake in Geothermie Unterhaching Produktions-GmbH & Co. KG (GUHP); the other 50% were owned by Geothermie Unterhaching GmbH & Co KG (GUH). The heat network of the two municipalities began in spring 2013 - for mutual benefit. Since then, the two geothermal companies have been able to meet their heating needs during maintenance work on the submersible pump or at the heating plant using geothermal energy from the partner. This saves expensive heating oil and protects the environment. In addition, the EWG also uses geothermal energy from Unterhaching for its heat supply or electricity generation in the ORC power plant Laufzorn.

In mid-December 2017, EWG and GUHP reorganised their ownership structure: Since then Erdwärme Grünwald GmbH owns 94.96% of Geothermie Unterhaching Produktions-GmbH & Co. KG. At the same time, it was decided to finally switch off the Kalina power plant in Unterhaching.

"The geothermal heat network between geothermal Unterhaching Produktions GmbH & Co. KG and Erdwärme Grünwald existing since April 2013 has proven itself," agree Unterhachings 1st Mayor Wolfgang Panzer and Grünwalds 1st Mayor Jan Neusiedl, "because we give each other regenerative redundancy during maintenance work. In addition, geothermal energy from Unterhaching can also be used by the EWG. With the new shareholding arrangements since mid-December 2017, we have placed Geothermie Unterhaching Produktions-GmbH & Co.KG on a strong, solid foundation. This secures the future viability of geothermal energy and is another big step towards a climate-friendly heat supply in both communities."

"The energy revolution does not end at the edge of the community" says Grünwalds 1st Mayor Jan Neusiedl, "and the valuable, the energy resource under our feet, definitely not. This geothermal heat energy should be promoted together. As municipalities Grünwald and Unterhaching both think long term. Both communities benefit from inter-municipal cooperation. For us, the security of supply to our citizens comes first - and this is increased by the fact that the communities network. We see the expansion of the district heating network as a long-term infrastructure project."

Security of supply in the district heating network Unterhaching

The basis for the security of supply in the district heating network Unterhaching is and will remain the December 2013 heat supply contract between the GUHP and Geothermie Unterhaching GmbH & Co. KG (GUH), which is responsible for the grid, with a term of at least 30 years; it applies unchanged.

Geothermie Unterhaching already supplies more than 50% of Unterhaching households and businesses with geothermal district heating. In 2018, the mark of 14,000 inhabitants, which are supplied from deep geothermal energy, will be passed. "This is how we operate Germany's largest geothermal district heating network," says Wolfgang Geisinger, Managing Director of Geothermie Unterhaching GmbH & Co KG.

Operation, maintenance and servicing of the heat network from Laufzorn to Unterhaching are carried out by the EWG team around Horst Wagner.

BEITEN BURKHARDT

Geothermal Energy and Procurement Law in 2018

According to the Act against Restraints of Competition (Gesetz gegen Wettbewerbsbeschränkungen – GWB) municipal energy providers are contracting authorities which are obliged as such to comply with the provisions of applicable procurement law. With regard to contracts in connection with activities in the field of energy supply these provisions are contained in the Sectoral Contracting Directive (Sektorenverordnung – SektVO).

From a current threshold value of 443,000.00 EUR, for example, sectoral contracting entities, as a rule, have to invite tenders for supplies and services EU-wide. In so doing, above all, eligibility and selection criteria chosen deliberately will yield and lead to economic and legally compliant results which comply with requirements both under budgetary as well as funding law, if applicable.

On the other hand, non-compliance with procurement law, for example, by the awarding of contracts without tender or in a wrong procedure could, apart from the nullity of the contract, in particular, result in significant damage claims asserted by disadvantaged competitors.

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Broad knowledge on shallow geothermal energy at the GeoCentre of Northern Bavaria

In the heart of Franconia, located in the Metropolitan Region of Nuremberg, the GeoCentre of Northern Bavaria is well known for their scientific expertise in the field of shallow to very shallow geothermal energy. Included in the Department of Geology, under the direction of Prof. Dr. Harald Stollhofen, the working group of Dr. David Bertermann deals with scientific research on shallow geothermal energy. The research projects range from basic research to applied industrial projects.

In the field of shallow geothermal energy, the "shallow geothermal working group", headed by Dr. David Bertermann, accomplishes an important contribution to the portfolio of the Chair of Geology at the GeoCentre of Northern Bavaria. National research projects, in close collaboration with industrial and academic partners within Germany, as well as international EU-funded research projects of the Horizon2020 funding line are among the day-to-day work of shallow geothermal working group. By modern laboratory equipment, as well as measuring instruments for the use in the field, physical soil and rock parameters can be determined and included in (economically) scientific evaluations. Current research projects are both focused pedological and geological. Within an industrial project, physical soil parameters are determined and meaningfully linked to evaluate the thermal conductivity, compaction sensitivity and climatic water balance of the underground.

In two other EU-funded research projects under the umbrella of Horizon2020, the shallow geothermal working group is entrusted with the management of more geologically based work packages.

The aim of the € 5,804,849 funded EU project Cheap-GSHPs (www.cheap-gshp.eu) is to reduce the installation and operating costs for shallow geothermal systems across Europe. This cost saving is to be achieved by the development of new drilling

New designed composite pipe spiral probe ■

Demonstration site of the EU-funded project "Cheap-GSHPs" in Erlangen-Eltersdorf ■

techniques up to 15 m depth, together with the further development of various ground source heat exchangers. New installation methods for unique coaxial and spiral probes are developed, tested and monitored. Climate data and underground information are collected within the project and included in the evaluation. Thus, the application possibilities in buildings and residential complexes of the developed systems are optimized for heating and cooling purposes - adapted to the respective climatic zone and geological underground conditions of the respective installation site.

The staff of the GeoCentre of Northern Bavaria, Dr. David Bertermann & Johannes Müller, supporting this European project, provides essential know-how for shallow geothermal energy and the geological understanding in general. Geological information from literature and fieldwork are collected across Europe and, together with measured values from laboratories, they are collected and summarized digitally. In addition, a database is created out of selected samples and their thermal properties are defined. The FAU also participates in the monitoring of the test field Erlangen-Eltersdorf.

There, newly developed spiral probes were installed and tested in close cooperation with the company REHAU AG + Co. The new design of the probes has been adapted to fit with large-dimensioned hollow augers. The site handling is extremely user-friendly and the probe is easy to install due to material properties, a composite pipe out of PE, aluminum and PE-Xa.

In addition, the laboratory and thermal response tests will investigate whether different backfill materials can improve or support the performance of this new type of geothermal probes. Further, measuring technology will be installed on all four spiral probes in order to monitor the test field in detail for about two years and to obtain valuable data on the entire system. The project „Cheap GSHPs“ received funding by European Union's Horizon 2020 research and innovation program under Grant No. 657982. ■

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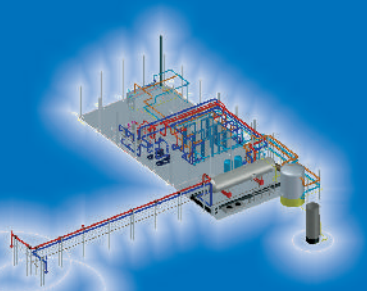

Corrosion resistance and rapid construction progress

New all-GFRP district heating system handles aggressive thermal waters in the Netherlands

gec-co planned and implemented the Netherlands' first all-GFRP geothermal district heating plant for greenhouses in February 2017. The plant is designed to significantly extend the intervals between maintenance due to thermal water-related corrosion. Now, long-term operational experience can be examined.

District heating system

The Project Partners

Engineering company gec-co applies its experience and expert knowledge to plan and upgrade geothermal plants for heat and power generation. gec-co executed the entire planning of the surface installations for the geothermal project of Aardwarmte Vogelaer. The hot side of the plant, exposed to thermal water, consists entirely of glass fiber reinforced plastic (GFRP). To complete the facilities, the Dutch contractor Verkade Klimaat built the plant including transfer stations to the greenhouses and the district heating network.

gec-co Global Engineering & Consulting-Company GmbH of Augsburg, Germany was founded in 2007 by Dipl.-Ing. Thorsten Weimann, MBA. The company is leading in Germany in planning and project management of deep geothermal plants and drilling technologies. gec-co plans power and heating plants, performs profitability calculations and accompanies investors, municipalities and builders around the world through all project phases, from the official permit and construction to full operation of a geothermal plant. The experts of gec-co handle communication tasks and are actively involved in several research projects for the German government and the EU. Additionally, the company is also active as part of the administrative office of the German Geothermal Association (BVG e.V.).

For over 80 years **Verkade Klimaat** has been an active player in branches like air conditioning, greenhouse building, non-residential building sectors as well as energy conservation and user convenience. Founded in 1933 by Martinus Verkade, Verkade Klimaat's focus region is the Dutch municipality of Westland, south of The Hague. Verkade Klimaat's solutions are characterized by reliable technology, compliance with standards and decades of experience.

The Project

Aardwarmte Vogelaer is a consortium of seven Dutch greenhouse operators (Optiflor, Fachjan, Kwekerij Apartus, Amazone Pflants, Gebr Grootscholten Handelskwekerij, Kwekerij Barendse and Zuidgeest Growers) in the Westland region. Now, these operators have upgraded their greenhouses to use heat from deep geothermal energy. Previously, the greenhouses were heated with natural gas.

The connected greenhouse complex produces primarily vegetables (including bell peppers) and flowers. Since the expiration of subsidies for natural gas heating in the Netherlands, heat supply based on geothermal energy have become more and more economically feasible. As a result, deep geothermal energy is a competitive market alternative to other technologies, offering a better cost/benefit ratio. In a depth of 2,400 meters, a thermal water aquifer in sandstone with temperatures up to 85 °C was tapped and is now utilized with injection and production wells. The project is located in Poeldijk in the immediate vicinity of residential areas, which meant that noise protection played an essential role during the entire planning and realization phase. Now, Aardwarmte Vogelaer

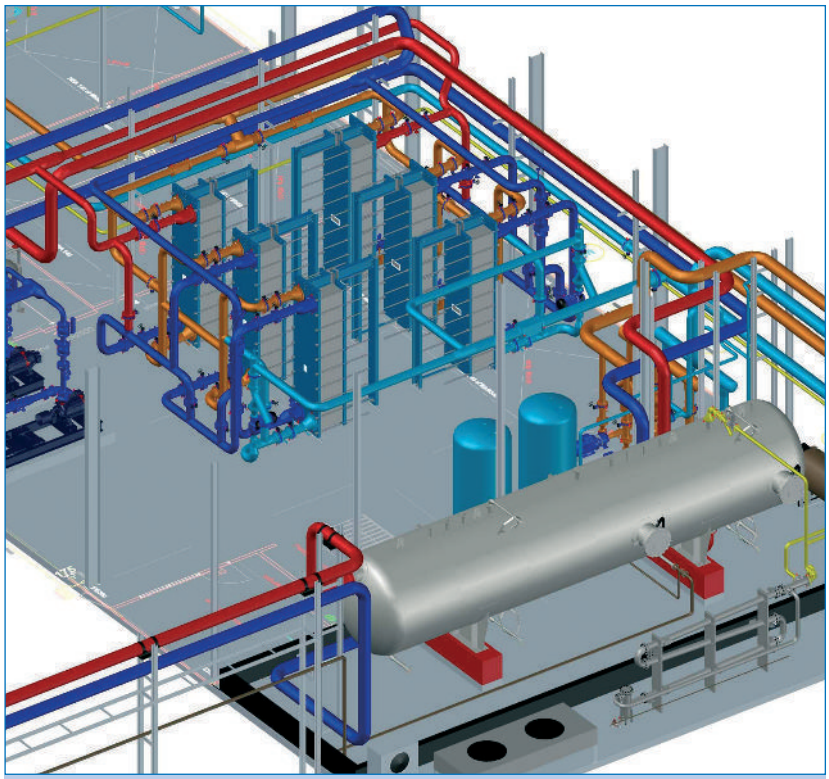

Fig. 1: Section of the 3D-drawing for the geothermal heat plant in Poeldijk, showing exceptionally well the heat exchanger and the degasser. Source: gec-co Global Engineering & Consulting-Company GmbH ■

saves approximately 13.5 million cubic meters of natural gas annually because of the implementation of the geothermal heating plant. This means a reduction in carbon dioxide generation of approximately 24,000 tons per year (corresponding to the output of about 9,000 households).

Basic Data - Heating Plant

Plant operating temperature: 85 °C
Plant operating pressure: 10 bar
Flow rate: 150 l/s
Thermal output: 35 MW_{th}
Borehole: Geothermal doublet (each with approx. 2,400 m true vertical depth)

The Plant / Plant Planning

Because of the extremely high amounts of sodium chloride in the thermal water, large parts of the above-ground facilities were conceived and constructed completely using glass fiber reinforced plastic. On top of that, measurement technologies recommended by the Dutch geothermics association TNO were taken into account. Small metal sheets or "coupons" are used to continuously measure corrosion levels in the thermal water for various types of metals. Furthermore, the plant features an inhibitor dosing system in order to prevent corrosion.

Based on the technical due diligence formulated by gec-co (feasibility and costs), basic and detail engineering were created using AutoCAD Plant 3D.
In particular, the basic engineering included:

- Conceptual design based on technical due diligence
- Technical specifications (P&ID / configuration and production data)
- Fundamental definition of dimensions for equipment
- Layout planning
- Establishment of basic documents for approval planning

The detail Engineering included the following specific aspects:

- Pipe layout planning
- Installation and layout planning
- Configuration, design and specification of components
- Instrumentation and control engineering
- Startup planning
- As-built documentation

3D plans, pipeline isometrics and 3D models were generated according to process engineering standards *(Figure 1)*. To date, 3D plans for the construction of

Fig. 2: Section of the completed plant with successfully installed heat exchangers (Height: 4,5 m; Weight: 6,5 t). Source: gec-co Global Engineering & Consulting-Company GmbH ■

Fig. 3: One-pass heat exchangers under installation condition.
Source: gec-co Global Engineering & Consulting-Company GmbH ■

geothermal heating plants were unknown in the Dutch market. The new quality of the planning documents allowed the plant facilities to be fitted perfectly into an existing building, specified and designed by an architect. gec-co played a key role in the specification and selection of the heat exchangers and other main components (for example injection pumps). On-site parameters led to the recommendation of robust single-pass plate heat exchangers instead of conventional multi-pass heat exchangers. Furthermore, because of the high natural gas concentration in the thermal water at Poeldijk, a gas separator was installed featuring a gas-fired boiler generating 6 MWth. The heat generated by the gas is now also fed into the geothermal-powered district heating network. The plant has been in operation since February 2017 *(Figure 2)*.

In particular, the use of single-pass heat exchangers *(Figure 3)* in geothermal heating plants is unprecedented in the Netherlands. This novel concept employs a new heat exchanger design different from those conventionally used in the past. Until the realization of the geothermal energy project in Poeldijk, three-pass heat exchangers were most commonly used; however, these exchangers frequently suffered from leaks as a result of the aggressive thermal water. The single-pass heat exchangers now being used, each weighing 6.5 tons, have fewer plates, helping avoid excessive expansion and leaks. In addition, they reduce maintenance and idle time, since no piping has to be uninstalled. The piping connections are all located on one side *(Figure 4)*. Instead of five parallel three-pass heat exchangers, two parallel heat exchanger lines were installed, each consisting of three devices in series. Compared with parallel three-pass heat exchangers, the serial single-pass heat exchangers create a redundancy and make it possible to maintain the exchangers one at a time. Thus, when one heat exchanger is non-operational for cleaning or maintenance purposes, five other heat exchangers are still available. And not only the way the heat exchangers are used is innovative compared to the formats of the past; each heat exchanger is equipped with double-block-and-bleed valves on both the thermal water and fresh water sides. A bleeding connection is built in between these block valves, so that the respective heat exchangers can be securely blocked off and repaired during ongoing operations. The heat exchangers are designed into the plant building in an easy-to-maintain manner and are accessible from three sides using lift platforms.

Another innovation concerns the use of **booster pumps**. In comparable projects in the Netherlands, these pumps are used to increase pressure after the degasser. Experience has shown that the rigid connection of booster pumps and injection pumps results in difficulties and pressure peaks. The intelligent plant design in the Poeldijk project avoided the use of such pumps. gec-co's planning ensures secure outgassing with slightly higher system pressure in the degasser. As a result, the failure-prone

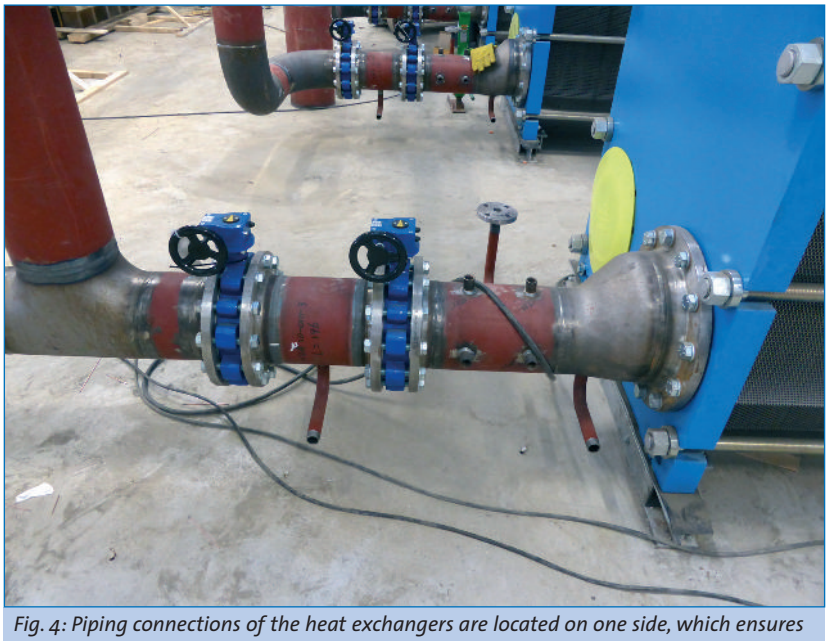

Fig. 4: Piping connections of the heat exchangers are located on one side, which ensures the ease of maintenance.
Source: gec-co Global Engineering & Consulting-Company GmbH ■

Fig. 5: GFRP pipes delivered on the construction site of the geothermal heat plant in Poeldijk.
Source: gec-co Global Engineering & Consulting-Company GmbH ■

booster pumps can be omitted; cutting costs and increasing the system's operational stability. This innovative configuration and realization is at the same time a pilot project for all plants of this type to be built in the future.

The **degasser** separates the extracted thermal water into its various phases. In the case of the Aardwarmte Vogelaer greenhouse project, the thermal water yields about one cubic meter of natural gas for every cubic meter of water extracted. The hot water is then fed into the heat exchanger, while the gas is routed to a gas-fired boiler and used to generate additional heat. The current extraction rates allow for a gas yield of up to 350 cubic meters per hour.

In order to keep the plant stable during filter cleaning, the system and the associated waste water are diverted into a separate **blow-down tank** in order to increase operational stability and allow filter cleaning at low pressure. Air bleeding is thus securely decoupled from the main system, with a correspondingly lower pressure for rinsing the filters with nitrogen, meaning a significant increase in workplace safety. In practice the plant is also capable of depositing carbon dioxide for subsequent use in the greenhouses. However, this technology is still too expensive compared to conventional carbon dioxide feeds.

Another special feature is the construction of the entire plant using **glass fiber reinforced plastics** (GFRP) *(Figure 5)*. The thermal water analysis for the Aardwarmte Vogelaer project indicated that the thermal water contains corrosive substances, lead and radioactive elements. Possible lime deposits, as found for example in Bavaria's Molasse basin, occur only peripherally. As a result, the aggressive thermal water dictated the selection of materials: glass fiber reinforced plastics are particularly resistant to the corrosive substances found in the thermal water. Furthermore, a piping configuration was chosen which is especially favorable to the flow in order to avoid corrosion as well as pressure-induced precipitation and deposits. GFRP pipes are also less expensive to install and maintain, since they are not susceptible to corrosion and exhibit fewer signs of wear. Moreover, the individual GFRP components have a generally longer service life.

Other plant-typical components, for example the **filter system** *(Figure 6)*, are also custom-tailored to meet the needs of the thermal water system. The filter system's two-step configuration protects the heat exchanger from sand, small and even miniscule particles. Filtration takes place between the degasser and heat exchanger using both, cartridge and basket filters. The cartridge filters were configured to be particularly fine (down to 0.5 micrometers) for the specific purpose of maintaining the inject-ability of the injection well. Filtration design also took ease of maintenance into account.

Plant components such as the air bleeding system and overpressure protection as well as the automation and control systems have also been specially configured to meet the requirements of the project and the heating plant.

Operational Experience

In the meantime the geothermal Aardwartme Vogelaer heating plant has been in operation for approximately a year and a half. The district heating network, with its maximum connected rating of 35 MWth, has been expanded to a total of 20 kilometers in length (flow temperature 85 °C, return temperature 30 °C) and completely fulfills all expectations placed on the all-GFRP plant. After 16 months in use, none of the GFRP plant components used (especially piping and instrumentation) show any signs of wear or corrosion.

The innovative heat exchanger concept with its modular single-pass system in particular provides significant cost savings. The modular heat exchanger configuration made it possible to repair a heat exchanger section impacted by corrosion and replace it with higher-quality material without shutting down the entire plant. Further, the combination of the thermal water system with a degasser is also performing well beyond expectations. In the meantime the ongoing high-quality filtration by the filter systems shows that it is possible

Fig. 6: Filter system with cartridge filters in the heat plant.
Source: gec-co Global Engineering & Consulting-Company GmbH ■

to deactivate the installed re-injection pumps. This reduces the plant's own energy consumption and cuts costs.
In general the innovative plant concept has proven itself in all respects (operations and maintenance). The plant components are optimally matched to one another thanks to early planning activities.

The Future

In the future all geothermal heating plants are to be equipped in the same manner as the Aardwarmte Vogelaer plant. Here, especially the elimination of booster pumps is decisive. The objective is to keep geothermal heat generation costs low in order to ensure that geothermal power is competitive with natural gas and other technologies. The particular advantage of deep geothermal in causing low or no energy costs has to be manifested in terms of appropriately durableable plant technology. Fewer components means lower maintenance costs and shorter idle times. GFRP elements have also been used in German geothermal projects for some time now with the objective of reducing costs and extending the intervals between maintenance due to wear. The project process, unusual in Germany, is becoming more widespread in the Netherlands as well. In the Netherlands the plant is as a rule already constructed during the drilling phase, while in Germany the planning and construction of the plant usually doesn't begin until after the results of the pump tests are obtained. By drilling and building in parallel, Aardwarmte Vogelaer/Verkade Klimaat and gec-co were able to achieve considerable cost savings in the planning and construction of the heating plant, since complicated re-planning processes were eliminated and no waiting periods were necessary. The low heat generation costs of the geothermal plant are leading other greenhouse operators to rethink their approaches. Potential independence from energy imports, benefits associated with producing their own methane gas and carbon dioxide as well as the resulting low heat generation costs make it possible for Dutch greenhouse operators to remain competitive in terms of price and performance in the international foodstuffs market. In particular, in the context of the cost discussion in Germany concerning deep geothermal plants, the Dutch model (early planning, construction of the plant during drilling operations) is the answer to increased cost-efficiency in the future. In the meantime, as local and regional vegetables become increasingly popular, deep geothermal heat has also grown more attractive for greenhouse operators in Germany. Thus for example in the Bavarian town of Kirchweidach near Munich, vegetables for the region are being grown and harvested in a greenhouse that uses geothermal heat – another project featuring the involvement of gec-co. ■

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Power and heat for "Holzkirchen" – the long road to success

Failure and getting back up

In order to ensure a climate friendly and independent energy supply, the municipality Holzkirchen decided to take on the challenge of geothermal energy and they received their geothermal exploration permit back in 2006. Despite all the adversities that had to be faced, the project is well on the way to become a complete success. As a geothermal project of the second generation Holzkirchen always drew on the experience gathered by the early pioneers in the greater Munich region and relied on in-depth planning preparations. In 2011 the geological expectations were validated with 3-D seismic imaging. The profitability analysis had been positive and they had also convinced the banks, thereby securing the loan financing. The use of municipal equity capital was supposed to be protected from total loss by obtaining exploration risk insurance. In accordance with the energy concept, all of Holzkirchen could have been supplied with district heat and a power plant with approx. 6 MWel could have been built. This undertaking was agreed upon unanimously by the market town council ("Marktgemeinderat") in March 2012. The exploration risk insurance was its foundation. [GGSC] – supported by geologists and the insurance broker – negotiated with the Munich Re, which was the only provider in the market. For policies like these you need to be proficient with the interfaces between geology, drilling technology, power plant efficiency and insurance law. The insurance policy had almost been completely negotiated, when the insurance provider pulled out of the market in summer 2013, after he was struck by two events of loss in other projects (Traunreut and Geretsried).

Without insurance Holzkirchen faced the risk of losing well beyond 20 Million € in case of reduced or complete absence of the drilling success; this was not sustainable for the municipality and the carefully planned project – the drilling contracts were ready to be signed – had (de facto) failed. The search for alternative insurance concepts was without success. Holzkirchen had to develop a completely new approach. Without exploration risk insurance it was absolutely essential to reduce the risk investment (i.e. costs for drilling) to an acceptable level. For this purpose it was even evaluated to workover a former hydrocarbon borehole. In this context [GGSC] counseled on questions of mining law (i.e. acquiring backfilled boreholes) and supported the purchase of documents from the person who was previously responsible as to mining law. The geological review of these documents however showed that the borehole was unsuitable for the intended purpose. In the end, all profitability analyses and scenario comparisons generated by [GGSC] favored an approach with reduced drilling diameter, in order to realize geothermal supply despite the limited available risk capital. This approach with "lean" drilling doublet and smaller power plant (~ 3 MW_{el}) was – after thorough review and extensive debate – agreed upon by the market town council in April 2015.

The team from [GGSC] was counseling Holzkirchen in all economic, financial and legal matters of the geothermal project for more than ten years. This includes the highly successful collaboration with all the employer's advisors, in particular "Erdwerk GmbH" in the field of geology and drilling technology, "enpros consulting GmbH" during the procurement of the power plant and the insurance broker "NW Assekuranz". The same applies in regards to "renerco plan consulting GmbH" or rather "Süddeutsche Geothermieprojekte GmbH & Co. KG" (the former joint venture partner). ■

Project status and upply strategy

In 2016 the selected drilling rig (which had already previously

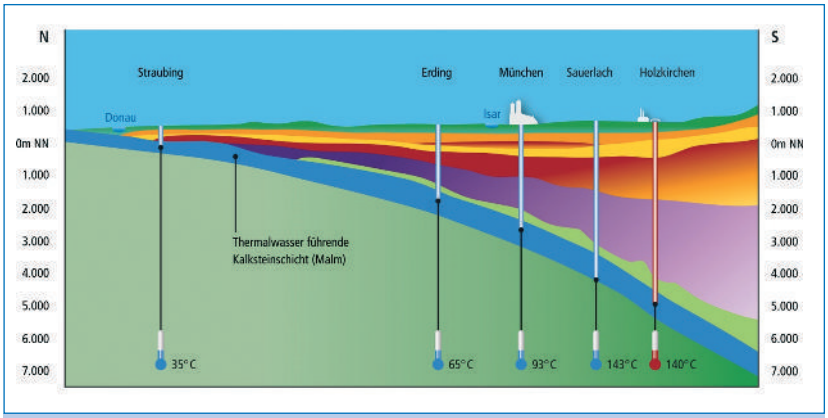

Fig. 1: Quelle: Hoch 3 GmbH, München ■

been used for the first Bavarian geothermal project in Pullach) started its operation. The drilling had been concluded in 2017. It was possible to extract geothermal water with a water flow of 55 l/s and a temperature of 152°C at a depth of approx. 5,000 meters. The conservative planning (140°C) has been greatly exceeded.

This made it possible to operate a power plant with an annual average output of approx. 3.3 MWel and a peak output of approx. 4 MWel, as well as to ensure the long-lasting supply of approx. 35 GWh heat p.a. to the "Gemeindewerke Holzkirchen GmbH" (i.e. the local utility company), in order to provide the local residents and businesses with environment-friendly district heat. The start of supply with district heat is scheduled for autumn 2018. The power plant is currently being built by Turboden. First feed-in is expected for February 2019. The employer fully relies on companies with experience in the geothermal sector and on proven technology. They did choose an ORC-plant (Organic Rankine Cycle); a Kalina-plant had consciously been ruled out during the EU-wide tender process in spring 2016.

The new supply concept revolves around the supply of heat. Unused / surplus heat is being utilized for the generation of electricity. During the term in which the feed-in tariff is legally secured by the German renewable energy sources act ("Erneuerbare Energien Gesetz – EEG") the energy will be supplied to the grid for as long as it is less expensive to cover the own power requirements with energy purchases from the local utility. The long term market potential in Holzkirchen is approx. 60 GWh p.a. It is planned to provide approx. 35 GWh p.a. for district heat after final expansion stage of the drilling doublet.

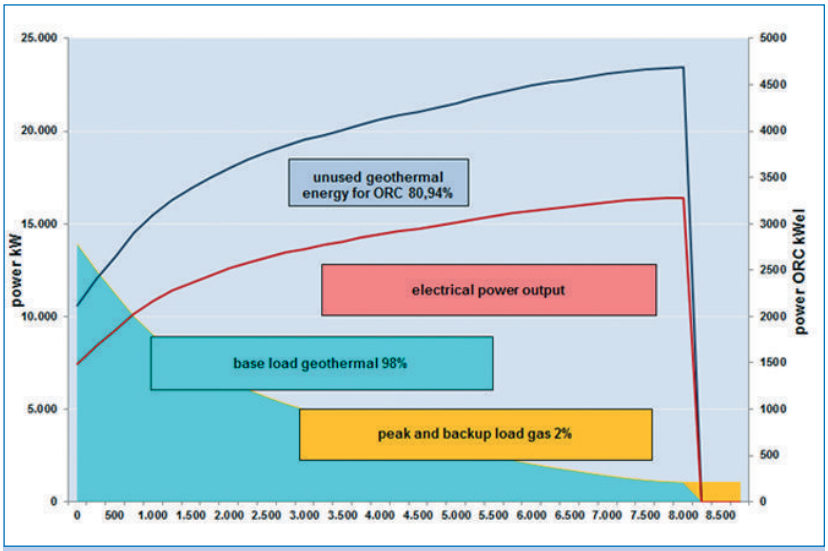

Fig. 2: ■

The drilling doublet provides approx. 24.5 MWth for the supply with electrical energy (water flow of 55 l/s, pumping temperature of 152°C with a loss of 2 Kelvin at the heat exchanger and a return flow temperature of 40°C at the wellhead). The illustration shows the energy / supply concept (including i.a. the annual load curve) at the final expansion stage:

The geothermal energy theoretically available at a performance level of 24.5 MWth greatly surpasses the peak demand for heat supply. The required heat is indicated by the turquoise and orange area. The unused geothermal energy potential is indicated by the dark blue line; in relation to whole year approx. 81 % of the available amount of energy is not used for heat supply, but rather fed in to the downstream energy cycle. ■

Profitability

Already back in 2009 [GGSC] – in cooperation with planners and project engineers – created a complex dynamic project simulation with integrated budget / forecast ("Planungsrechnung", the [GGSC] financial model), depicting all financial flows, based on MS-Excel and with consideration of various scenarios over a term of 30 years, in order to evaluate the profitability and to subject all conceivable scenarios to a stress test.

This sophisticated simulation model – integrating economically, technically and energetically significant parameters – with variability of all relevant project parameters was used as the basis for the

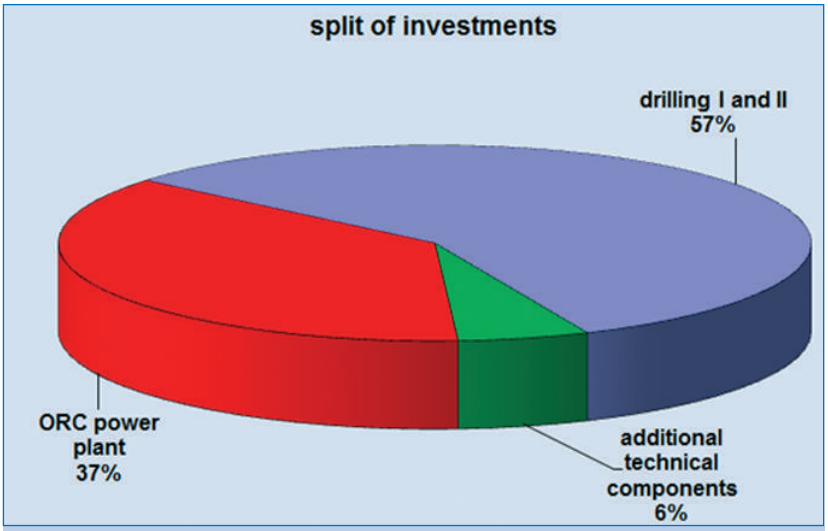

Fig. 3 ■

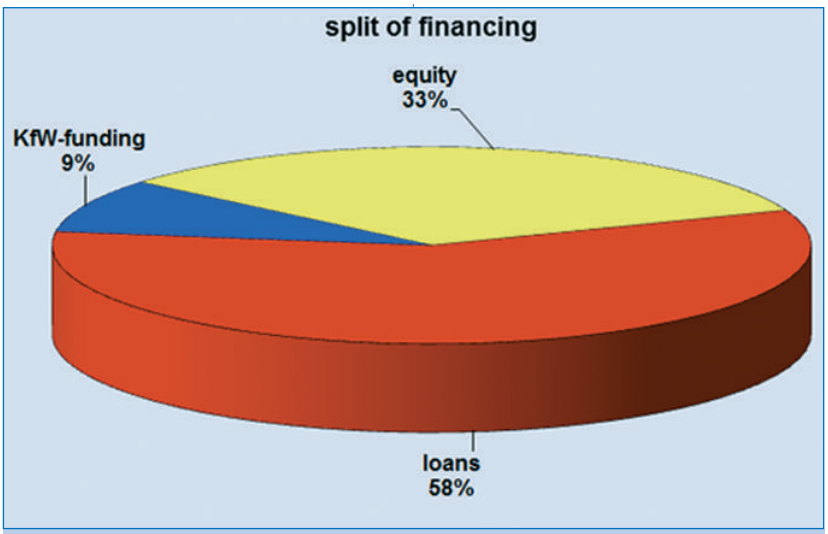

Fig. 4 ■

project implementation decision, negotiations with banks and applying for public funding for financing the project. The simulation model is being regularly updated and adapted to the current project situation / demands to this date.

The project finance volume amounts to approx. 62 million € (35.5 million investment for the drilling doublet, 23 million € for the power plant and 3.5 million € for additional technical components, including negative cash flows and interest during the construction phase). The investments can be broken down as follows:

The project company doesn't build its own district heating network but delivers heat to the parent company "Gemeindewerke Holzkirchen GmbH". They already have a network of 25 kilometers at their disposal which they are planning to expand even further.

[GGSC] has assisted Gemeindewerke Holzkirchen and its project company with structuring the project financing from public banks. The project is being financed with loans from a consortium of three partners – BayernLB, LfA and Kreissparkasse Miesbach-Tegernsee (36 million €). The remaining 20.5 million Ä are provided by the municipality and the Gemeindewerke. [GGSC] led the talks with the consortium until the final financing decision for the drilling doublet and the thermal power station was made. It should be noted that Holzkirchen was the first time ever that funding from the KfW Development Bank (program EE-Premium) could be utilized for a combined heating and power project.

The project will be able operate profitable after its commissioning date in 2019. Its revenue (the dark blue line) will essentially be tied to the development of the heat supply. The cash flows are always able to cover the debt service, which was of great importance to the financing banks. The assets at disposal are always above the red line which shows the debt servicing to the banks. The following illustration shows the anticipated development of earnings in the heating and power project Holzkirchen during the next 26 years:

The project return is appropriate for a combined heating and power project. Such projects typically show a total return on investment between 5 to 8 %. The profitability can be increased further with additional drillings due to lessons learnt and economies of scale.

As everything is on track, all involved parties are expecting that the profitability forecast will be confirmed in reality. ■

Private Investor Test

Certainly the economic aspects are paramount when handling a geothermal project but there are also numerous legal issues. This already begins with the financing. There are strict requirements by European law, in order to utilize "government" funds for financing (in this case equity injection for the project). To check the compatibility with European state aid law – or rather ensure to prevent non-conformity – an in-depth audit is

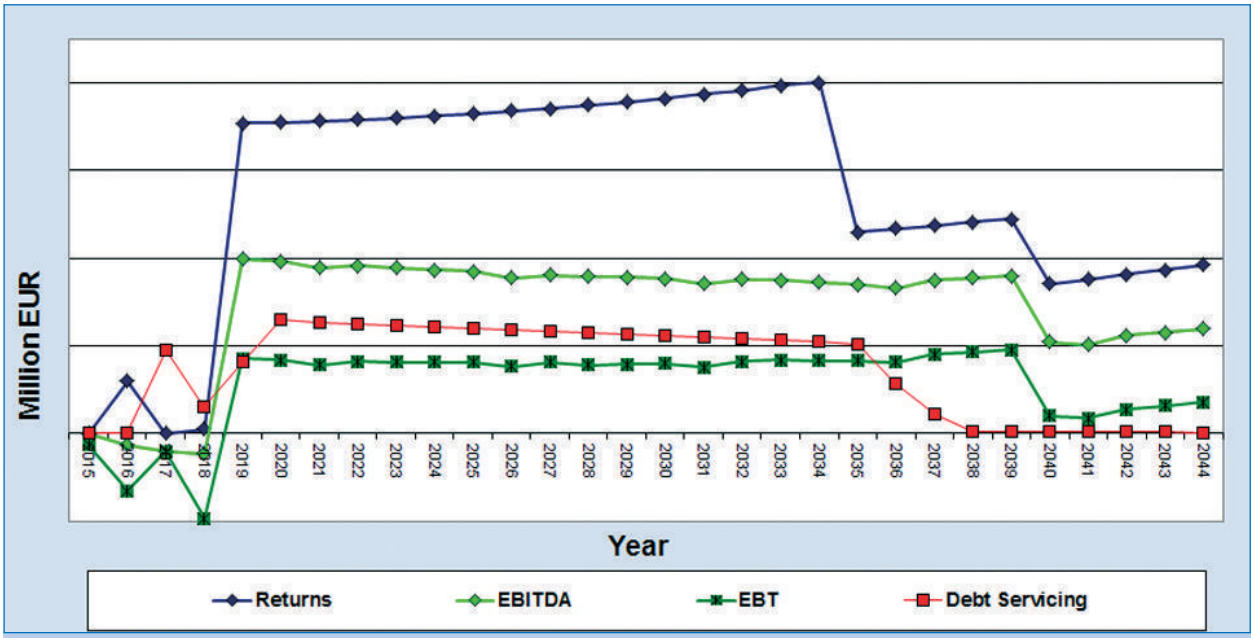

Fig. 5 ■

necessary to check whether or not the finance injection is in accordance with standard market conditions (so called Private-Investor-Test). This task was performed by [GGSC] for the old project as well as for the new one. This includes i.a. the determination of the costs of capital and returns, which are then compared based on various economic methodologies. ■

Drilling contract model and tendering

In spring 2012 [GGSC] together with Erdwerk developed a tendering model which (contrary to the previously common practice) wasn't based on a main contractor but rather stipulated the EU-wide procurement procedure of 15 separate lots.

The underlying contracts as well as the tender documents (including the contract award criteria) had been a novelty in the drilling industry but are now established and have found their way into other projects. Negotiating this new concept – which was unusual to the industry – was a long process. The contract award recommendation was finished in summer 2013.

After the drilling doublet with wide diameter was canceled, a new opportunity showed itself in autumn 2014: historically low drilling costs were the foundation for a project concept with reduced dimensions. Already in spring 2015 the tender documents had been finalized and the tender process was initiated. It was again [GGSC] and Erdwerk who brokered the deals with contractors and service providers, handled the content of reports for the tender process, evaluated the bids and – as early as summer – awarded the first lots with long lead items. Meanwhile the negotiations for the remaining lots were being finalized and awarded, so that this time the drilling works could be started already nine months after the official call for tender. During the drilling phase [GGSC] counseled and supported the employer against unjustified contractor claims and assisted with claim settlements, thereby realizing high six-figure sum savings for the project. ■

Supply contract for the power plant and tendering

In parallel with the drilling [GGSC] also extensively supported Holzkirchen with the procurement of the power plant. [GGSC] had already played an important role during the market exploration to select the consulting engineers. Thereafter [GGSC], together with the selected engineer firm enpros, conducted the market exploration for prominent suppliers of geothermal power plants, in order to tailor the contract model and tender documents the best way possible to meet the main objective: commissioning completion before 1st of January 2018. According to the legal situation at that time, missing this deadline would have resulted in an annual decline of the feed-in tariff (so called "Degression" under the German renewable energy sources act) which would have meant a loss of approx. 5 million € for the project. After successfully exploring the market, it was decided no neither use a main contractor nor to award 20 separate lots. Holzkirchen chose the middle ground and opted for a cost, time and interface sensitive approach. To achieve this goal, enpros and [GGSC] drafted the EU-tender documents for the four most urgent lots: ORC, thermal water

cycle as well as process control and electrical engineering. They also custom tailored the contracts to include severe penalties for missing relevant deadlines and performance values which are relevant to the generated revenue (i.a. availability, power-plant output, auxiliary power requirement, pressure loss).

All this was interrupted by the new German renewable energy sources act, which among others postponed the "Degression" to the year 2021. Together with the employer it was decided to put all negotiations on hold until the testing results from the secondary drilling were in. The results attested a geothermal water temperature of 152°C and therefore a pleasantly high thermal output of the drilling doublet. Based on this, the tender documents were extensively adapted to the new situation and negotiated with the bidders one more time. The plant was ordered in August 2017; the remaining lots were awarded step-by-step until April 2018. In this phase [GGSC] also represented the employer's interest in front of the Public Procurement Tribunal ("Vergabekammer Südbayern") due to a complaint by one of the bidders for the thermal water system. The proceedings had been stopped due to the new tender documents which had anyway been revised. The new approach led to approx. 200,000 € savings for the employer. ■

Insurance concept

During every step of the project [GGSC] together with NW-Assekuranz advised the employer on different insurance matters. This included questions regarding liabilities in accordance with federal mining law during the drilling phase and the operation of the power plant. During the drilling phase the employer's all risk insurance (including lost-in-hole) was of paramount importance. The insurance broker NW-Assekuranz and [GGSC] negotiated the policies hand in hand and supported the employer during the construction supervision and claim management. Multiple claims were settled; in summary highly satisfactory for the employer. The construction, transportation and erection all-risk insurances were being negotiated simultaneously with the power plant supply contract. ■

Other legal topics

[GGSC] also counseled Holzkirchen on various individual issues at all stages of the project. This included the choice of an "Anstalt des öffentlichen Rechts" (a special legal form for municipal companies) as optimal legal form, to enable the innovative financing model which was used for the very first time for a project like this. Furthermore, [GGSC] designed the heat supply contract between Geothermie Holzkirchen GmbH and Gemeindewerke. Questions in the area of mining law and renewable energy law also played an important role. [GGSC] for example provided a legal opinion regarding the gross power remuneration ("Bruttostromvergütung") and the definition of commissioning completion ("Inbetriebnahme") as to the German renewable energy sources act.

After all these efforts, all those involved are looking forward to the successful commissioning completion of the power plant in 2019! ■

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