Interreg North-West Europe
DGE-ROLLOUT

Possible Integration of geothermal energy in the Weisweiler district heating network

Deliverable T3.4.2

RWE Power AG

with contributions from Fraunhofer IEG & GSB

May, 2023

Disclaimer

This report compiles company information and data from RWE Power AG as well as data and results from reports and deliverables of other WPs to a technical concept for the development and integration of DGE into the DHN to Aachen at the Weisweiler site.

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Contents

Introduction

In Weisweiler, western NRW, Germany, east of the city of Aachen and close the borders to Belgium and the Netherlands (see Fig. 1), RWE Power AG runs a lignite fired power plant for electricity production of ca. 2 GW. Close by lignite is produced from the open pit mine Inden (see Fig. 1) from ca. 200-400 m depth. In addition to electricity, the plant delivers ca. 160 MWth heat to a regional DHN, whereof ca. 85 MWth are provided to the city of Aachen. With the phase-out of lignite combustion by 2029 RWE will shut down lignite production and plant operations. Hence the company is looking for sustainable, climate neutral, and decarbonized solutions for future heat production and grid implementation at the Weisweiler site.

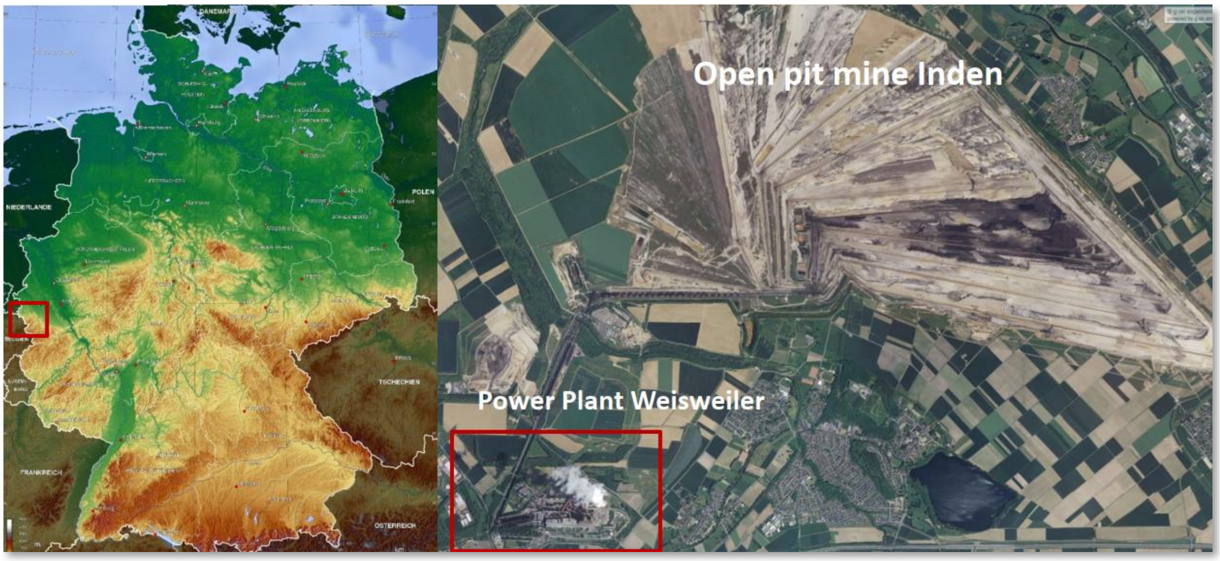


Figure 1: RWE's lignite power plant Weisweiler is located east of the city of Aachen in westernmost NRW, close to the borders to Belgium and the Netherlands (left); the open pit mine Inden, which provides lignite for the power plant, is located right NE of the plant.

Based on existing geological data, former investigations and results from DGE ROLLOUT (see DGE-report Del. T3.4.1: Subsurface model DGE aquifers Weisweiler), DGE could be one of the possible solutions to deliver part of the heat for the DHN. For this attempt RWE defined a designated geothermal research field close to the power plant (see Fig. 2). In RWE's renewable energy strategies, the power plant Weisweiler is a key pilot site and demonstrating field for testing DGE. This report provides a conceptual design for a possible technical integration of DGE into the existing heating network.

Figure 2: Location of the geothermal area SW of RWE's lignite power plant Weisweiler (left); the western part of the geothermal area will be used for a drilling campaign by Fraunhofer IEG and RWE and form the basis for a field laboratory and full-scale demonstrator of DGE exploitation and grid implementation (right). The main pipeline for district heating (blue) can be easily reached.

Current situation of heat supply from Weisweiler Power Plant

One of the heat sources for the district heating network (DHN) at the City of Aachen is the Weisweiler lignite power plant using combined heat and power application, Figure 3. Heat is extracted from the water-steam process of the power plant in an efficient way by means of partial steam extractions from the turbines, since these extraction points (bleeds) can be chosen at the appropriate temperature and pressure point. The heat is fed into the district heating network by means of a heat exchanger, which keeps fluids of the power plant process and the DHN separately.

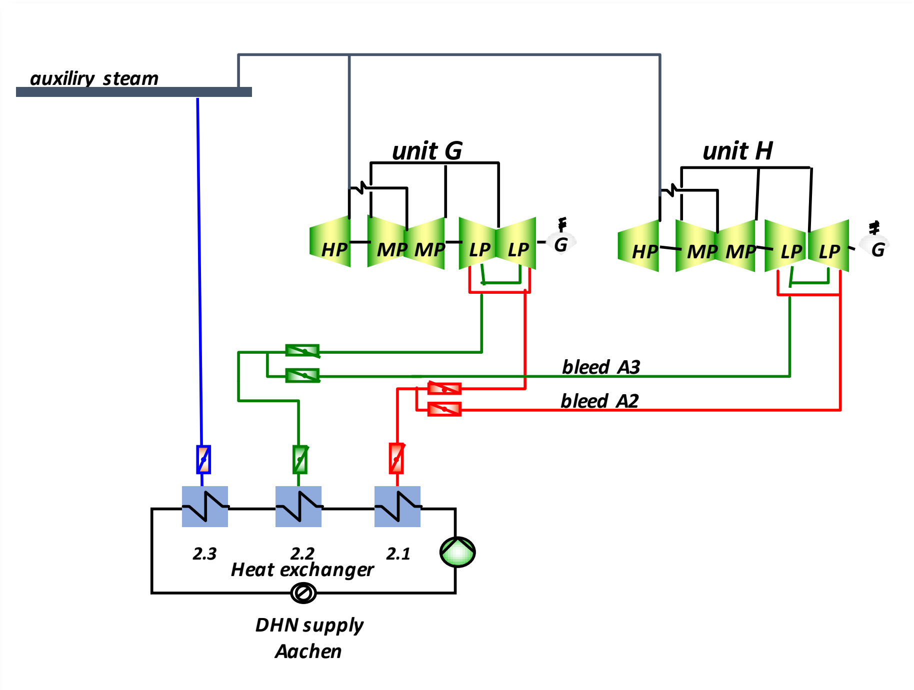


Figure 3: Heat supply to district heating network at Weisweiler Power plant

The simplified flow scheme of the DHN-side can be found in Figure 4. In cold winter time with a maximum heat extraction of 85MWth, the temperature spread (supply 130°C, return 70°C) amounts to 60K.

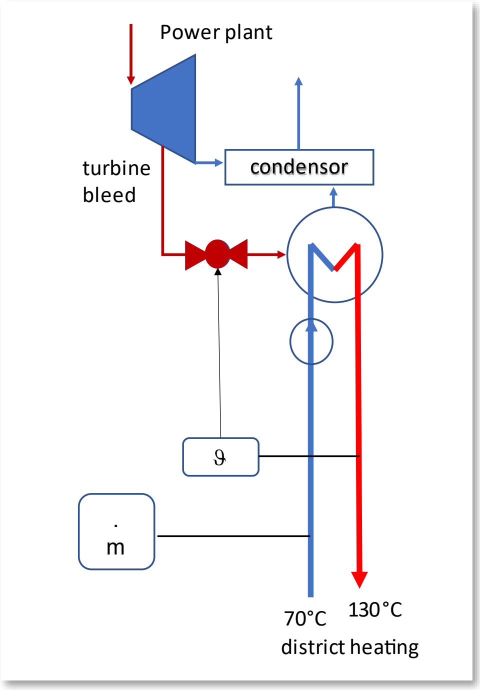


Figure 4: Simplified flow scheme of district heating supply of City of Aachen

Options to integrate geothermal heat into the district heating network

Integration of geothermal heat can be realized by different options, depending on temperature und flow of the geothermal source and depending on requests for redundancy.

Direct integration into the district heating line as a pre-heater in the return flow (as depicted in Figure 5) would be applied, if the temperature would be above the return temperature but still below the supply temperature.

In case redundancy of the heat exchanging systems is required, the heating of a partial flow of the DHN would be applied. The available flow and especially the temperature of the geothermal water is crucial, whether a heat boost, e.g. by a heat pump, has to be applied, see Figure 6.

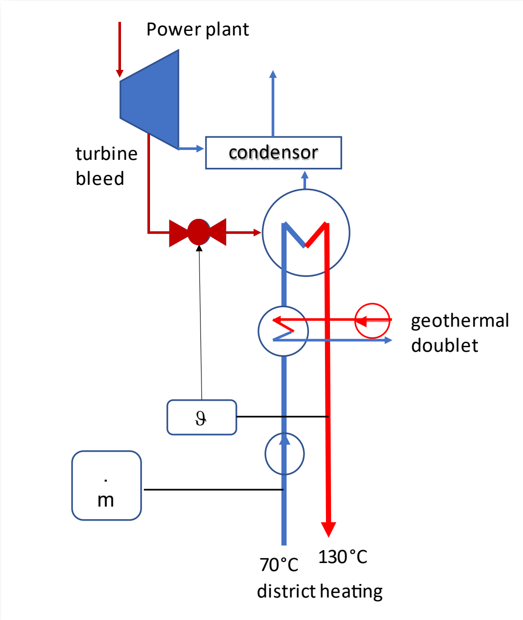


Figure 5: Geothermal heat integration by pre-heating

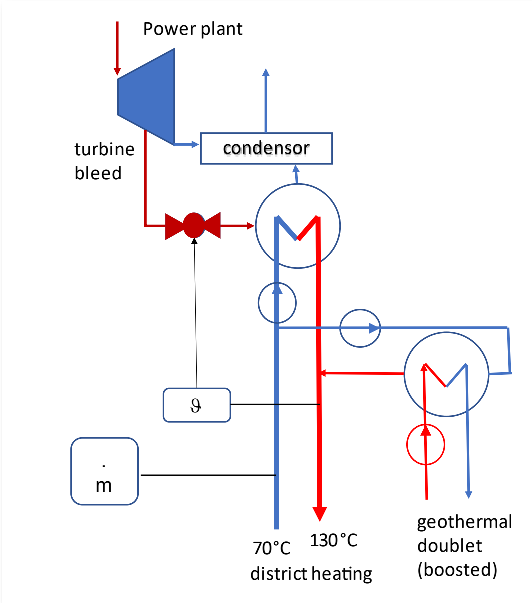


Figure 6: Geothermal heat integration by parallel heating

In the following, only the redundant case is discussed since this can be balanced separately from the main network flow.

To investigate several scenarios, basic calculations have been made for geothermal mass flow of 100 kg/s and different temperature levels. These are rough calculations making assumptions for temperatures, mass flows and boosting efficiency (COP=Coefficient of Performance).

We will distinct 3 cases of different temperatures of the geothermal well:

A) a high temperature well (140°C) which can be applied immediately by means of a heat exchanger (Figure 7), or
   A') with a subsequent boosting of the mass flow to extract more heat (Figure 8),
B) a low temperature well (70°C) which would require full temperature boosting by a heat pump (Figure 9) and
C) a medium temperature well (100°C) which can be applied by partial direct use of the geothermal heat and additional temperature boosting afterwards (Figure 10).

Case A), assuming a well temperature of 140°C, would mean a "once through" process which can be controlled by the partial flow of the DHN medium through the geothermal heat exchanger, to meet the required temperature of the DHN. This process has the highest thermal efficiency, since no electrical power for a heat pump is required. Adding a heat pump (Case A') would allow for lower return temperatures of the geothermal doublet and therefore for higher heat use but requires additional energy.

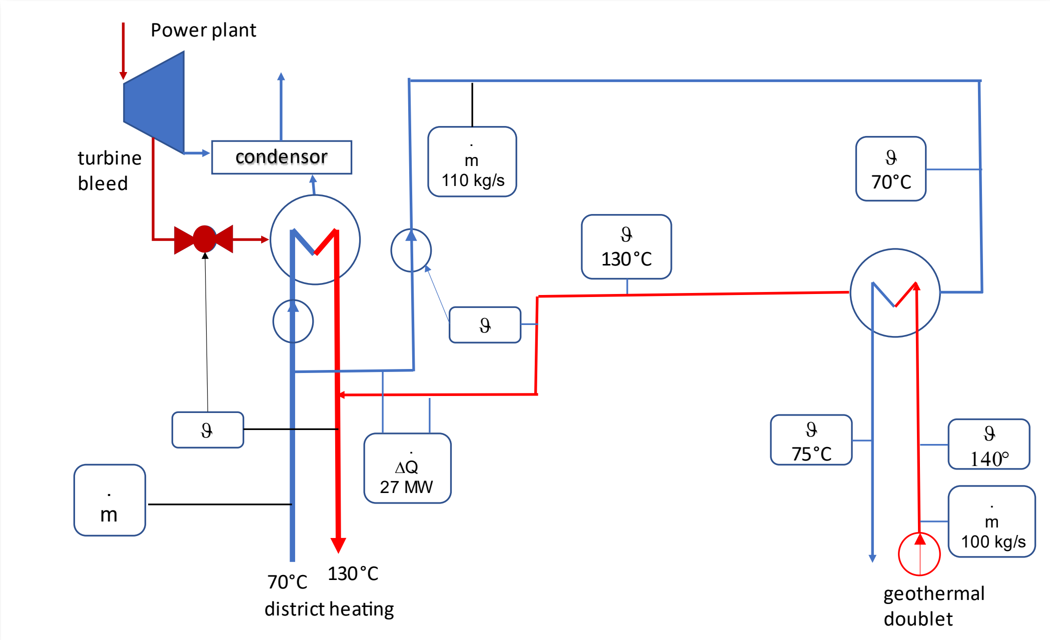


Figure 7: Case A) Geothermal heat integration in case of high temperature geothermal well

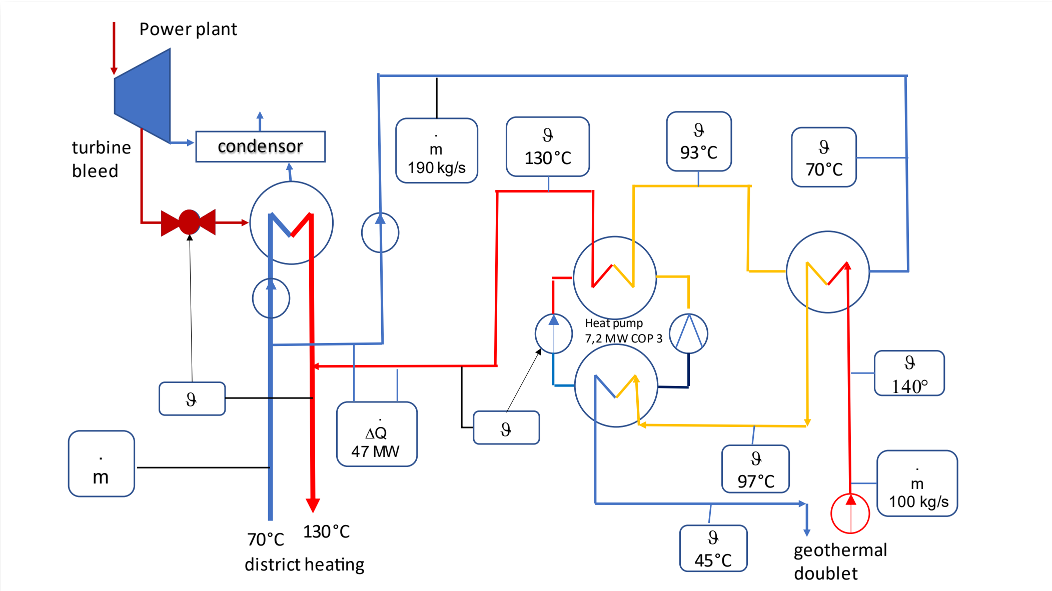


Figure 8: Case A') Geothermal heat integration in case of high temperature geothermal well

Case C), based on a well temperature of 70°C, would mean complete boosting of the geothermal heat source to allow for heat transfer to the DHN, which would require additional electric energy for the boosting. Control of the heat flow could be realized via heat pump power.

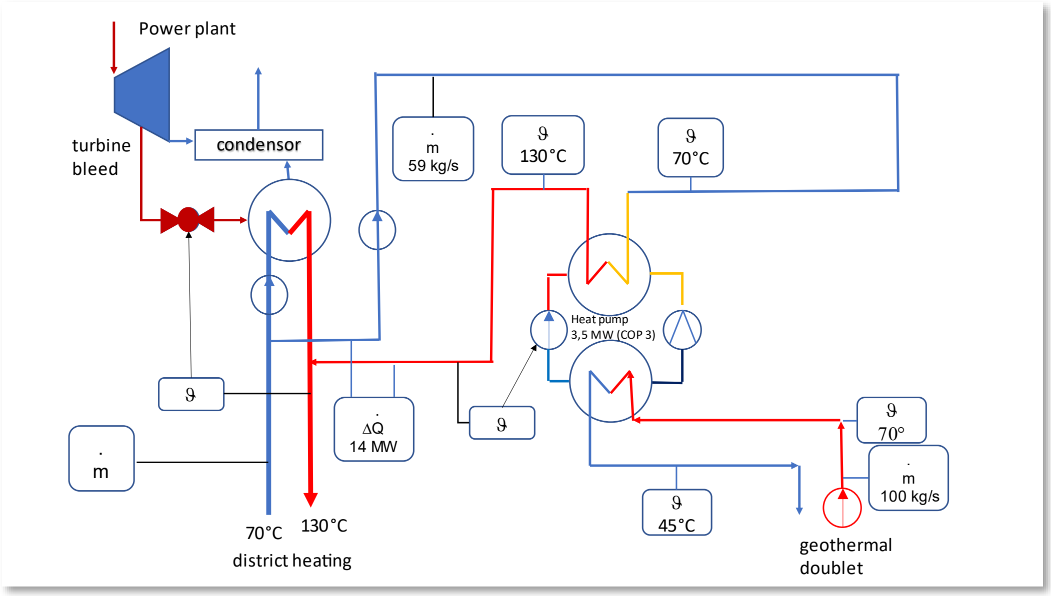


Figure 9: Case C) Geothermal heat integration in case of low temperature geothermal well and temperature boosting by heat pump

Case B), assuming a medium well temperature of 100°C, would require a two-step heat transfer, the first step directly using temperature from the well and in the second step the boost of the remaining temperature, to meet the required temperature of the DHN.

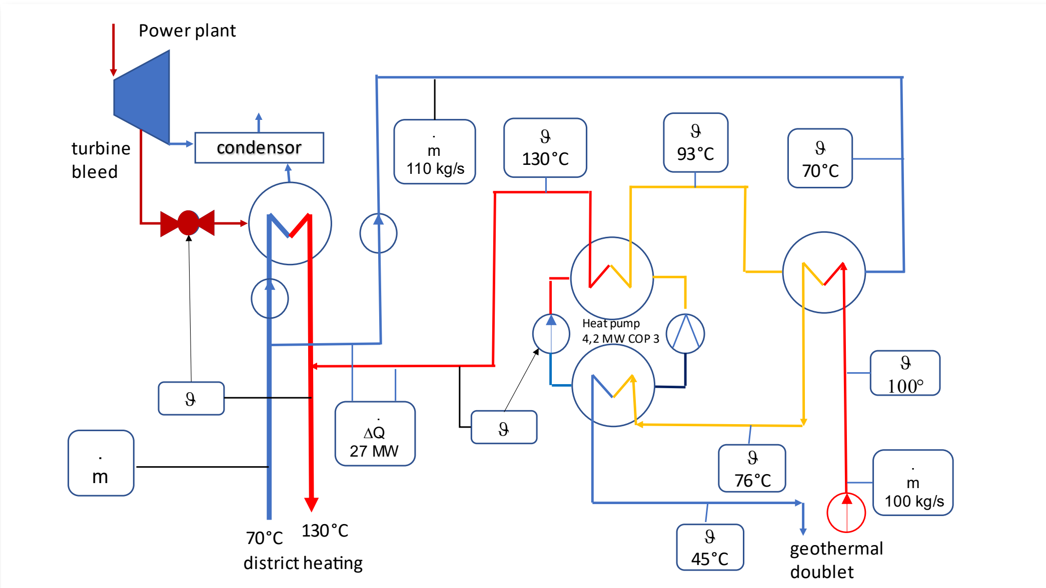


Figure 10: Case B) Geothermal heat integration in case of medium temperature geothermal well and partial temperature boosting by heat pump

Table 1 shows the different efficiencies, depending on the amount of electricity needed, to boost the system to the required temperatures. It can be stated, that the implementation of geothermal energy would favor low temperatures in DH Networks, to minimize boosting temperature spreads which increases efficiency. However, to maintain the total heat flow, the mass flow has to increase with decreasing temperatures, there will be an optimum, whether to spend energy into boosting the temperature or into pumping to increase the mass flow of the circulating network medium.

Table 1: Examples of geothermal heat integration in case of medium temperature geothermal well and partial temperature boosting by heat pump (mass flow geothermal = 100kg/s, district heating temperatures: return = 70°C, delivery = 140°C

	Temperature geothermal well	Return temperature geo fluid	Total heat to DHN	Electricity for boosting (COP=3)	Thermal efficiency of DGE
A)	140°C	75°C	27 MW	0 MW	100%
A')	140°C	45°C	47 MW	7,2 MW	85%
B)	100°C	45°C	24 MW	4,2 MW	85%
C)	70°C	45°C	14 MW	3,5 MW	75%

Concept of a geothermal doublet

The study area is a designated area for exploration on potentials of DGE, because the general structure in the subsurface, the presence of potential reservoirs and the occurrence of hot thermal springs in the city of Aachen imply very good conditions for the production of heat from the deeper subsurface. From mapping campaigns, it is expected that two of the most potential DGE reservoirs in NWE, that have already been exploited for hydrothermal heat production in Belgium and the Netherlands, are present and widely distributed also in the deeper subsurface of Weisweiler and its vicinity. One is the shallower Lower Carbon Kohlenkalk and the other one is the deeper mid-Devonian Massenkalk. Based on the regional subsurface model of the Geological Survey NRW the formations are expected to occur in depths up to 5000 m (see. Fig. 11). Outcrops of both formations south of Weisweiler in the northern Eifel region indicate that the power plant Weisweiler is located above a NE-SW-trending syncline structure, where both formations are expected in greater depth. Consequently, an infiltration of water in the northern Eifel region migrating to greater depth towards the center of the Inde Syncline is expected to provide a source for thermal water in the subsurface. Furthermore, the outcropping rocks (Fig. 11, right) indicate the presence of dense fracture systems, related to strong tectonic deformation in that region, and the frequent occurrence of karst structures in the carbonates, which both can be related to potential fluid migration pathways in the subsurface.

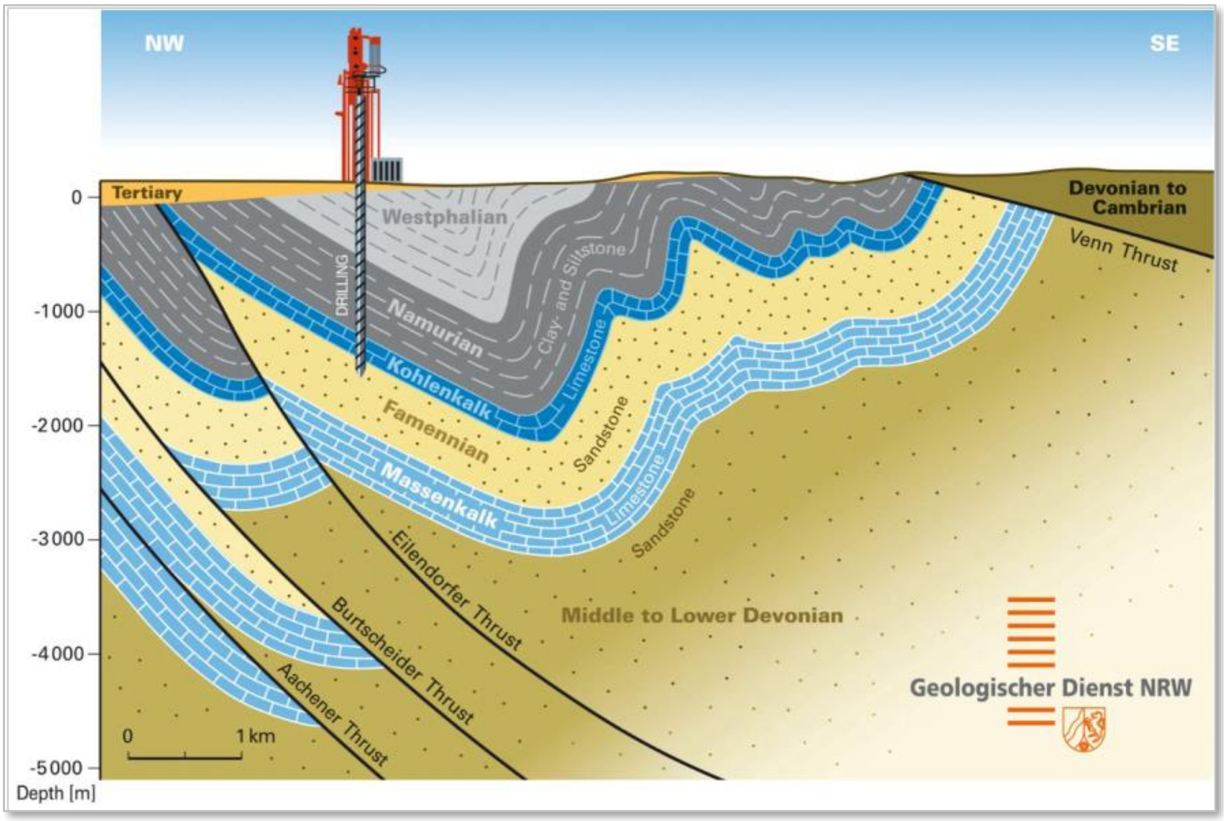
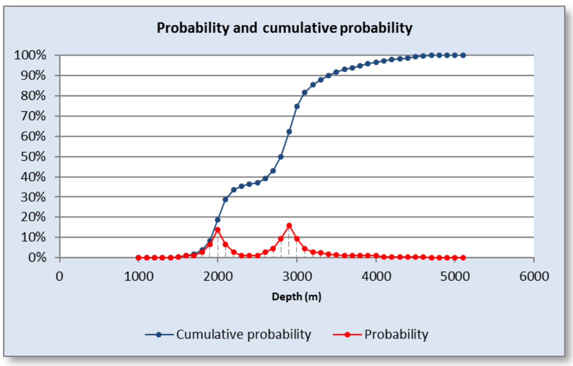


Figure 11: NW-SE section cutting through the Inde Syncline after Fritschle et al., 2021. Overview of the assumed subsurface structure and lithologies at the Weisweiler site; the potential geothermal carbonate reservoirs (blue) are exposed at surface in the SE, while they may occur in up to >4000 m depth further NE in the region of the power plant.

At the Weisweiler site, the top Kohlenkalk is expected at ca. 1350 m depth and the top Massenkalk at about 2500 m depth (Fig. 12). Both layers' production thickness was estimated to 200-400 m (Fritschle et al., 2021).



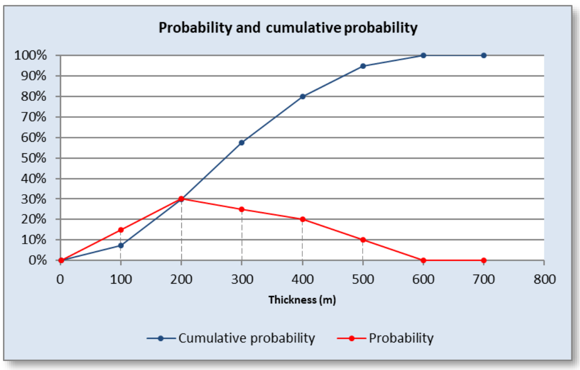


Figure 12: Probabilities of depths and thicknesses of reservoir rocks in the subsurface of the Weisweiler study site.

Based on the 3D subsurface model Weisweiler (see DGE-report Del. T3.4.1) drilling deeper wells from 1350 (top Kohlenkalk) to ca. 2500 m (top Massenkalk) will allow to reach the reservoir targets and test their production rates. Expected formation temperatures range between 50°C and 85°C. If deeper occurrences of the reservoirs from tectonic movements along faults are considered, as indicated by the modelling approach, even depths of >4000 m and temperatures of more than 130°C can be expected. Reservoir temperatures were estimated based on average gradients (Fig. 13).

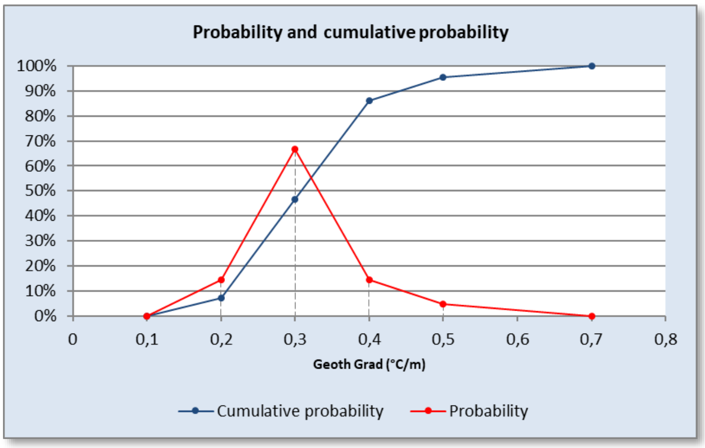


Figure 13: Probability of temperature gradient (increase of temperature with depth, °C/m).

The transmissivity of the reservoirs was estimated to an average value of 250 m2/d (Fig. 14).

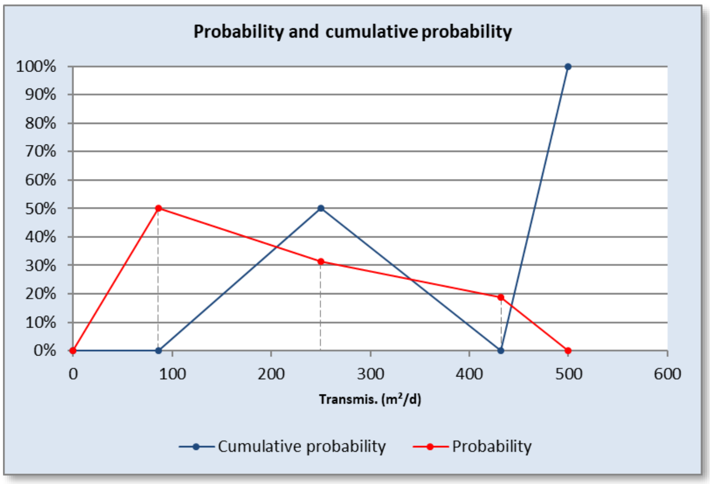


Figure 14: Probability of transmissivity of reservoir rocks.

Resulting in possible flow rates of 60-216 m^3/h calculated though a cautious estimation of 50-60 l/s (Fig. 15).

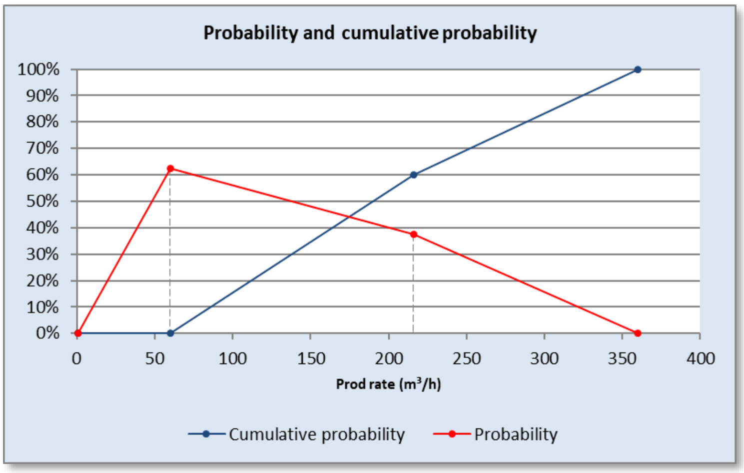


Figure 15: probability of flow rates of reservoir rocks.

Three scenarios define the target reservoir for a deep geothermal installation at the Weisweiler lignite power plant in Germany. Firstly, the Lower Carboniferous Kohlenkalk lime- / dolostones can provide heat at a relatively shallow depth. In a second scenario, the deeper Middle to Upper Devonian Massenkalk limestones are targeted. A third scenario includes production from both reservoirs, also including the possibility that both Kohlenkalk and Massenkalk may also occur twice or more at greater depth levels below three thrust faults, thus thrusted and stacked several times (Fig. 11, left).

Based on an evaluation of the site (Figs. 12-15), the geotechnical probability of failure has been estimated to 25%. Indicators cover a complex structural geology with thrust faults (Aachener, Burtscheider, Eilendorfer) and normal faults (Merode, Weisweiler) within the Inde Syncline, limited data (No deep drillings, no deep seismics), the proven existence of reservoir rocks in outcrops in the vicinity of the syncline, and a potential risk of induced seismicity and potential risk of minor earthquakes according to the regional classification as seismic hazard risk zone 3 (Fritschle et al, 2021).

For exploitation and production, heat recovery is to be obtained via classic geothermal doublets with production from the NE flank of the Inde Syncline and reinjection through the center or deeper northern flank of the structure (Figure 16). This would most likely allow for circular flow and heating up of the produced water. Since the production and reinjection wells could be drilled in the designated “geothermal research field” (see Fig. 2) close to the main pipeline of the DHN (Fig. 2, right, blue line), there is no need for extensive pipe construction for grid implementation at surface.

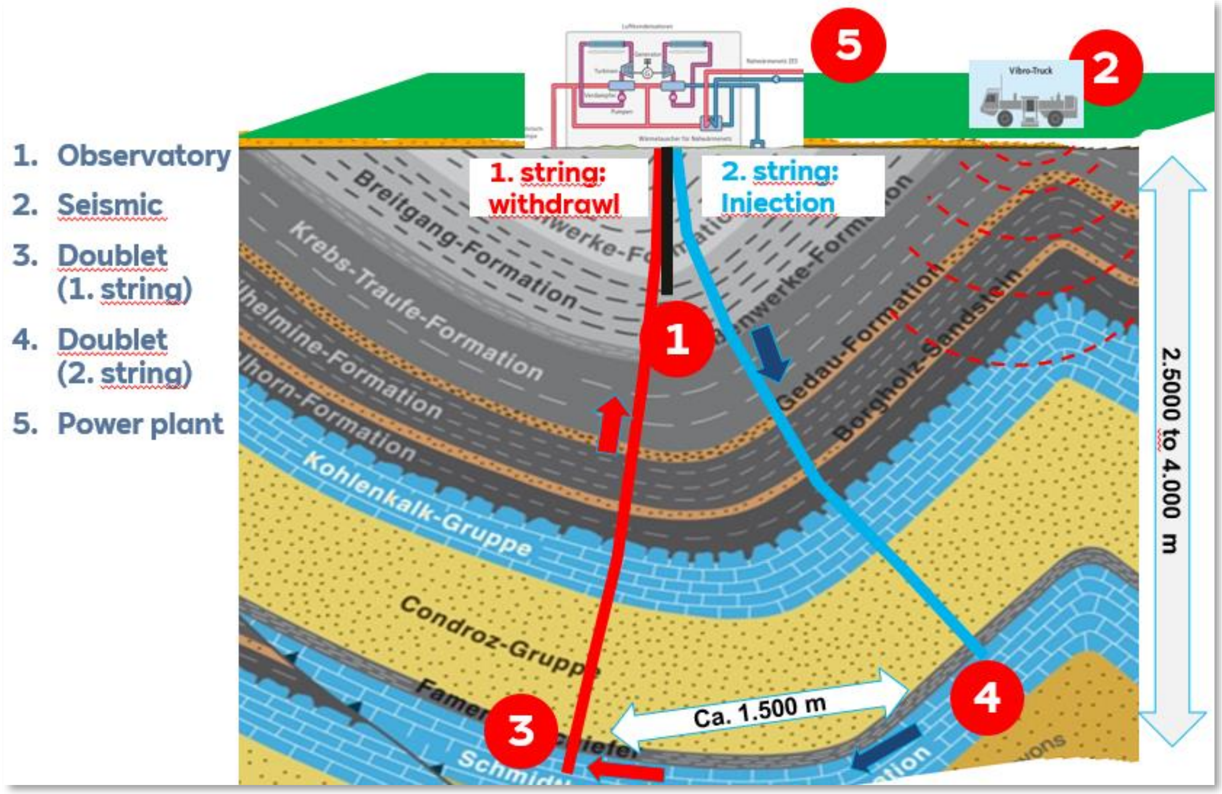


Figure 16: Concept of a doublet at the Weisweiler site for heat production.

For a long-term strategy of DGE implementation to the regional DHN via geothermal doublets, a spacing of 500-1500 m between production and injection wells in the reservoir, corresponding to a maximum draw down in wells and a minimal lifetime of 35 years, has been assessed. According to that, a distance of in average 5000 m (1500-10000 m) between individual geothermal doublets was set to prevent interaction between production sites.

Cost calculation

Costs for exploration and exploitation of the DGE field Weisweiler may roughly include ca. 5-10M€ for 3D seismic far- and near-field exploration, ca. 10M€ for a deeper exploration and test well, ca. 10-15M€ for the production and reinjection well each, and at least 5-10M€ for surface infrastructure and grid connection, summing up to ca. 40-60M€ for a first production doublet. Additional doublets could be drastically reduced in costs if further pre-production exploration surveys are not necessary. This may result in an invest of ca. 1,5-2,5M€ per MW installed doublet capacity.

With respect to the varying production scenarios from individual or several reservoirs, the reservoir temperatures and flow rates, doublets in this region could produce up to 30 MW of heat at temperatures between 50°C and 130°C. At annual production times of about 8500 h, a best-case scenario of 30 MW (120l/s, 130°C) and a pricing of e.g. 3 Cent/kWh, a doublet could generate up to 7.65M€ per year (or 11.5M€ for 4.5 Cent/kWh, etc). With moderate flow and temperatures in the wells, producing rather 8-15 MW of heat, doublets would rather generate an annual income of 2-4M€ at 3 Cent/kWh or 3-6M€ at 4.5 Cent/kWh. Much lower production rates, especially if temperatures are lower and require contributions from heat pumps for grid implementations (see above), could cause an economic inefficiency of a doublet (Fig. 17).

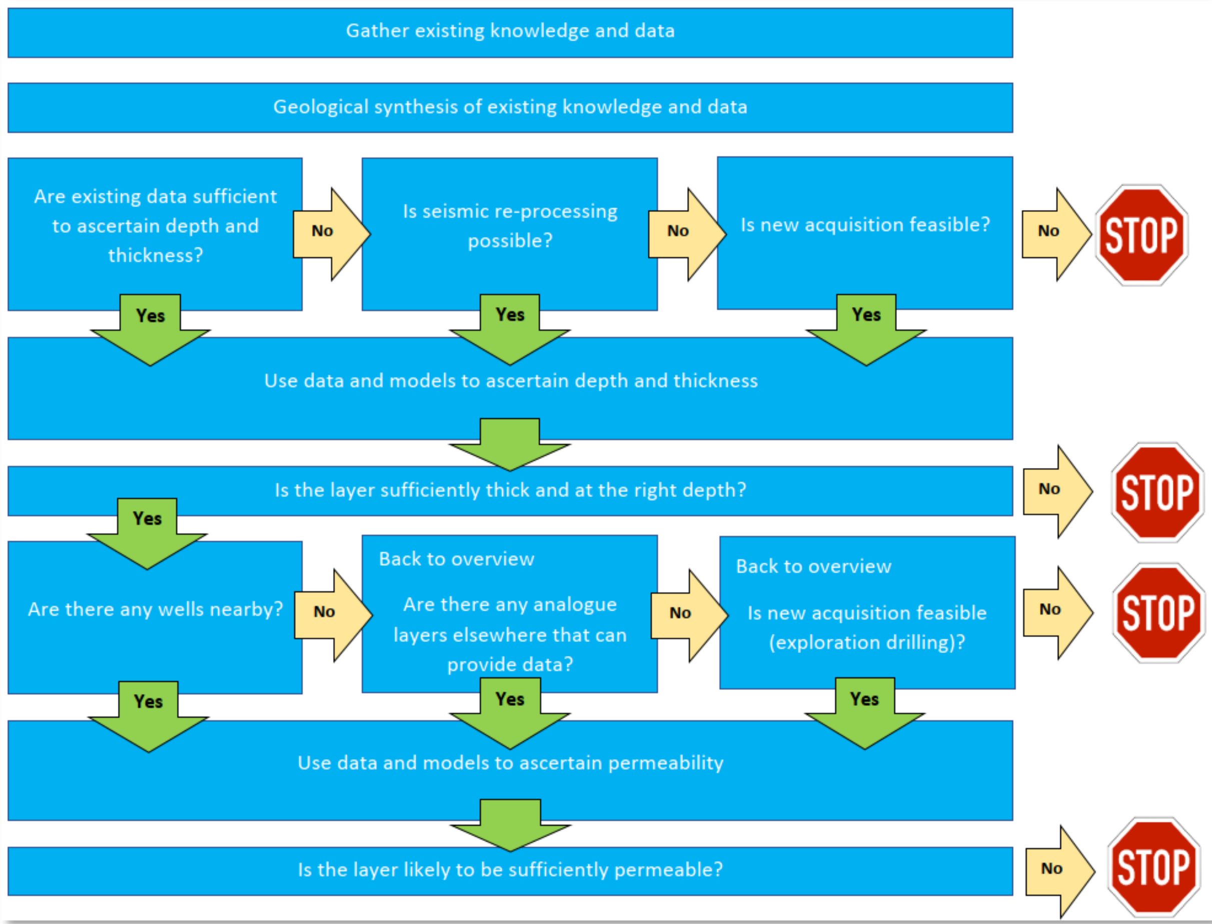


Figure 17: Decision flow chart for DGE projects as compiled in the DGE-ROLLOUT project.

Summary

In this report it is shown how deep geothermal energy (DGE) could be used for the future supply to the district heating network (DHN) of the city of Aachen. Currently, this DHN is feed by the lignite fired power plant of Weisweiler. With the phase out of lignite combustion in 2029 DGE could contribute to a solution at the Weisweiler site. Therefore, a geothermal site is foreseen for the use of DGE, where a doublet is going to be installed to deliver a heat amount of 10-30 MWth., depending on the depth and temperature of the reservoir (1.500 – 4000 m, 50-130°C). Due to the proximity of this DGE area to the DHN, no complex pipeline constructions are required. The design of the integration is shown for 3 different cases, which can be differentiated by the different temperature levels of the production well and the flow an return of the DHN. The cost calculation arrives at costs of 40-60 M€ for the doublet. Economic operation is dependent on the flow rates and temperature profiles. However, in case flow rates and temperature profiles are lower as expected, the doublet might be economically inefficient. In order to substantiate the current estimates, the next step is to advance the exploration by means of a seismic survey and deep drilling.

List of referenced reports

- Investors Profiling (T1.2.2)
- DGE communication strategy report (LT.4.2)
- Examination of regulatory framework and financial risk management of DGE (T1.3.3)
- Financial Risk Management (T1.3.2)
- Economic and environmental assessment of deep geothermal energy projects (T2.2.2)
- Socio-economic potential mapping for DGE (T1.2.3)
- List of existing and planned DGE sites (T1.1.7)
- Depth and thickness maps of deep geothermal limestone reservoir in NWE (T1.1.1-3)
- Exploration Toolbox (T2.2.1)
- Subsurface model DGE aquifers Weisweiler (T3.4.1)
- Fritschle et al. (2021): Deep Geothermal Energy Potential at Weisweiler - Exploring Subsurface Mid-Palaeozoic Carbonate Reservoir Rocks; Z. Dt. Ges. Geowiss. 172 (3), p. 325-338

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