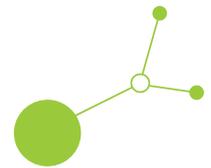


# Feasibility study for the pilot site

## Ampfing, Germany (Molasse Basin)

TRANSGEO Deliverable 2.3.1



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# D.2.3.1 - FEASIBILITY STUDY FOR THE PILOT SITE AMPFING, GERMANY (MOLASSE BASIN)

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## 1. Introduction

This document summarizes the detailed feasibility study on the geothermal potential in the Ampfing area, Bavaria (Germany), which was recently carried out by the company Ing-Kess GmbH. It is a general overview with the key findings of the entire study, which is summarized and made publicly available as part of the TRANSGEO project<sup>1</sup>. This deliverable report reflects the views of the authors.

In cooperation with the municipality of Ampfing, ONEO is planning to develop a dry oil well in Ampfing into a geothermal energy project. Considering the German government's objective of achieving a greenhouse gas-neutral energy and heat supply in Germany by 2045, the project represents the next step towards a greenhouse gas-neutral heat supply for the municipality of Ampfing in the form of an efficient geothermal heating network.

The first study on Ampfing by the Institut für Systemische Energieberatung GmbH on geothermal potential in 2021 already showed that the geothermal potential significantly exceeds the heating requirements of the entire municipality of Ampfing. For this reason, further scenarios were also analysed, in order to make the best possible use of the potential and achieve heat generation prices which are competitive and acceptable to the consumer of the heat.

## 2. Geographic location and analysis of heat demand

The municipality of Ampfing is located in the south-east of Bavaria in the Isental valley approximately 70 km east of Munich, 5 km north of Waldkraiburg and 10 km west of Mühldorf am Inn (see Figure 1). Ampfing benefits from good transport infrastructure due to the A94 highway and the Munich East-Simbach (Inn) railway line to the south. A total of 7,161 people live in the municipality, which consists of the main town of Ampfing and a few smaller settlements (Gemeinde Ampfing, n.d.).

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<sup>1</sup> The TRANSGEO project (<https://www.interreg-central.eu/projects/transgeo/>) is co-funded by the European Regional Development Fund through the Interreg Central Europe program. The overall objective of TRANSGEO is to investigate the potential to transform abandoned hydrocarbon wells into new sources of green geothermal energy. To reach this goal, the TRANSGEO team is providing new tools and knowledge to support communities and industries in the energy transition and to break down economic and technical barriers to well reuse.

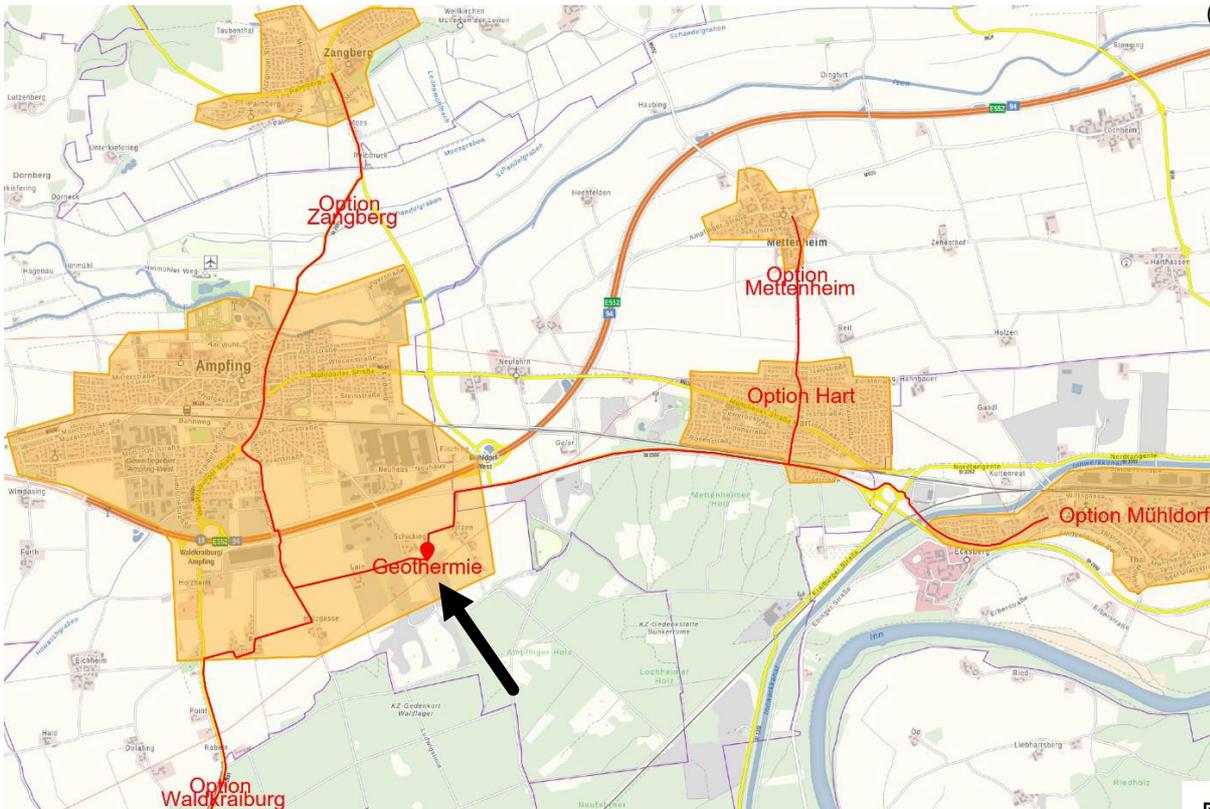


Figure 1: Ampfing well site location (marked with red dot and black arrow) with geothermal expansion options.

In addition, the building layout in Ampfing consists mainly of residential buildings. The Ampfing-West, Ampfing-Ost, Holzheim and Neuhaus industrial areas are in the south. In the future, more business, trade and services as well as industry are to be located in Ampfing-Ost. In addition, Figure 1 shows a site plan with expansion options. The area marked in orange is the one that could be heated with geothermal energy.

Due to the predominantly residential use of the buildings, a maximum flow temperature to the buildings of approximately 70 °C in winter and a return flow temperature of 55 °C can be assumed. In the industrial sector, temperature requirements up to a maximum of 80 °C on the secondary side are known to date.

Furthermore, regarding the required temperature level, no special requirement is known for the flow temperature in the commercial/industrial sector that could not be met with the target flow temperature of approximately 85 °C. Regarding the return temperatures, it is pointed out that an increase in the temperature spread leads to better utilization of the well. Individual discussions and agreements are necessary here in order to achieve the lowest possible return temperature.

The current heat supply structure in existing buildings (residential as well as industrial) was determined on the basis of questionnaires. The analysis of the data revealed that over 90 % of heat is currently generated from fossil fuels such as natural gas and oil (Figure 2). Potential customers with fossil fuel heat generators are increasingly looking for renewable alternatives for various reasons. When focusing on CO<sub>2</sub> abatement and primary energy saving potential, customers who currently generate heat using fossil fuels should be considered first and foremost.

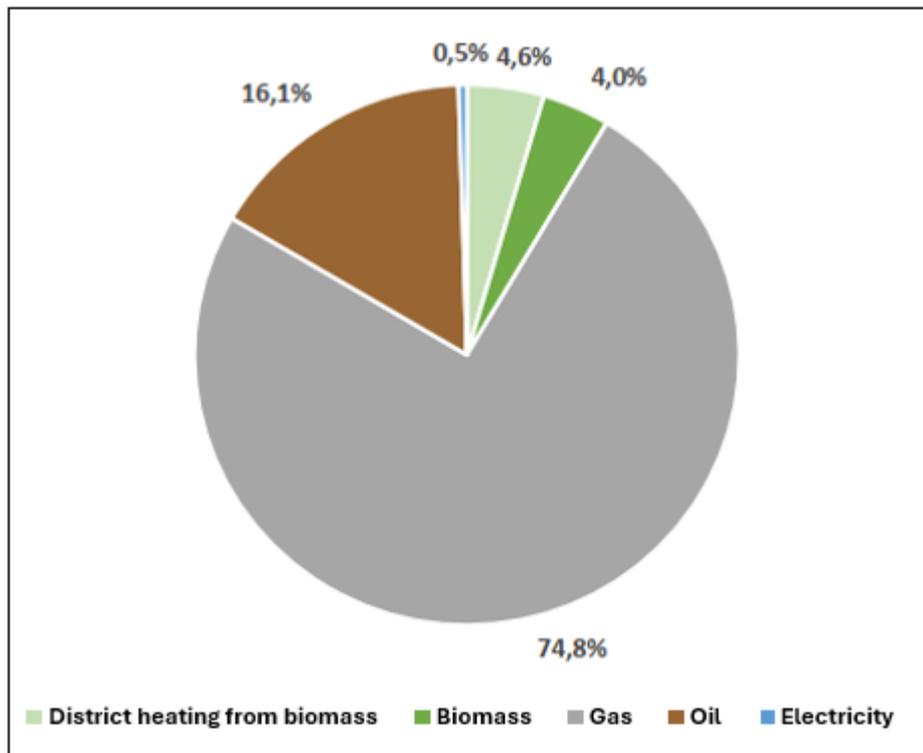


Figure 2: Current type of heat supply based on data from questionnaires.

### 3. Identification of renewables potential using deep geothermal energy

Deep geothermal energy is the use of geothermal energy from a depth of more than 400 meters. In comparison to near-surface geothermal energy, the temperatures are significantly higher and reach values from 20 °C to more than 100 °C (Bundesverband Geothermie, n.d.) A major advantage of deep geothermal energy is that the heat is available 365 days a year. The use of deep geothermal energy is not yet widespread in Germany and can only be realised in areas with thermal water sources. Between the Danube and the Alps is such an area, the South German Molasse Basin, through which the Malmkarst runs as a layer containing thermal water. The municipality of Ampfing is located in this area and, according to the Bavarian Energy Atlas, a temperature of 90 °C can be expected at a depth of approximately 2000 meters. As there is already an unused ONEO well in the Schicking district of Ampfing (Figure 3) initially planned for oil production, a possible deepening of the well to the thermal water-bearing layer was investigated. The wellsite is located around 3.5 km by car from the Ampfing town center. According to the analysis, the thermal water is expected at a vertical depth of 2370 meters. When planning a second well, a distance of at least 1.2 kilometers is recommended in the target reservoir. This is to rule out the risk of a thermal breakthrough. The temperature in the target reservoir is expected to average 107.5 °C. After subtracting the expected temperature losses, a flow temperature of 104.5 to 105.5 °C can be expected. According to the Productivity of the Malm in the area, the achievable flow rate is assumed to be 80 - 100 l/s. Depending on the production rate, a gross output of around 16 MW<sub>th</sub> to 20 MW<sub>th</sub> can be expected for the heat utilisation potential of deep geothermal energy at the Ampfing site. This results in an expected technical expansion potential in the order of 140.2 GWh<sub>th</sub>/year to 175.2 GWh<sub>th</sub>/year. The potential for utilising deep geothermal energy in the municipality of Ampfing by means of district heating results from the above-mentioned production temperatures and the expected output.



Figure 3: Location of the existing SCK-002B well, southeast of Ampfing (satellite image).

### 3.1 Seismic and geological interpretation

Figure 4 shows a schematic cross-section through the Bavarian Eastern Molasse including its stratigraphy. The black arrow marks the approximate location of Ampfing. The light blue horizon (Jura) essentially corresponds to the Malm limestone (target reservoir), which is beneath Ampfing around 2776 m deep.

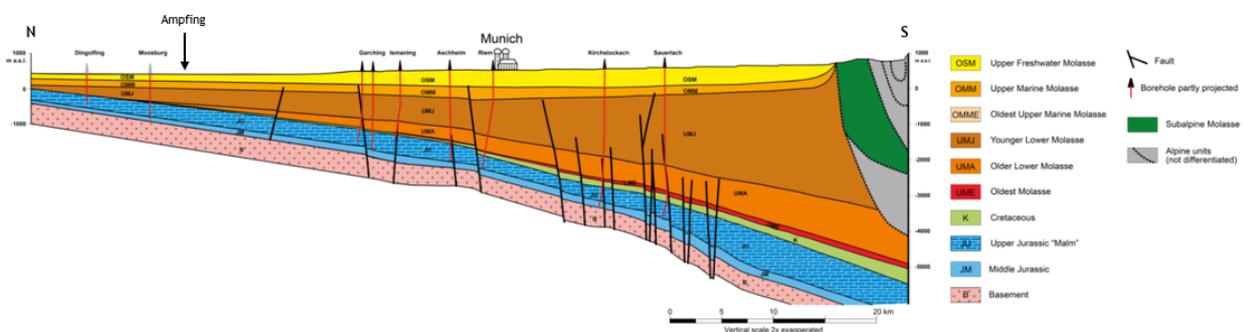


Figure 4: North-south oriented profile section through the Molasse Basin in eastern Bavaria (adapted from Bohnsack, 2023).

In addition to the development of the well, the productivity of geothermal wells in the Malm is controlled by a complex interplay of various geological factors such as karstification, sedimentary facies and diagenesis (dolomitisation). Accordingly, the thickness of the mass facies and karstification are the main factors to be considered (cf. Bohnsack et al. 2020). Mass facies rocks are often dolomitised and therefore karstify more easily than layer facies rocks (see, e.g. Böhm et al. 2013; STMWi 2019, and references



therein). As the Malm thickness is subject to only minor fluctuations within the seismic record, this criterion is not of great importance here. Furthermore, as the evaluation of pumping tests of existing geothermal projects in the Malm shows, the inflow via fractures does not play a significant role in the wells. Only in commercially dry wells, i.e., those with unfavorable lithology (e.g. stratified facies) and without karstification, inflows via fractures can be measured in the range of only a few liters per second.

In addition, the approximate thickness of the mass facies can be calculated from the difference between the Top Mass facies and Top Dogger horizons. This approach is not entirely correct, as stratified facies also occur in the deeper Malm. However, it is completely sufficient, as it is not about absolute values, but only about the (relative) comparison of different areas.

In general, a high proportion of bulk facies in the Malm has a favorable effect on the porosity and permeability of the reservoir (STMWi 2019). As this influences the productivity of geothermal wells, such areas should be favored as drilling targets. The thickness of the interpreted mass facies varies between 250 and 450 m (mean value around 350 m, standard deviation 35 m).

Furthermore, the Top Malm dips towards the south. The geological model shows a grid pattern of predominantly west-northwest-east-southeast-striking with west-east-directed faults.

However, drilling targets appear to be particularly suitable if they are located in areas with a large thickness of the interpreted mass facies. Targets for reinjection wells should also be sufficiently distant from faults, at least until more detailed studies on induced seismicity have been carried out.

In the most likely development scenario, the existing Schicking SCK-002B well is deepened and serves as an injection well. The Schicking Th1 production well is newly drilled, whereby a balance must be found between centralised development of the target and the avoidance of fault areas.

Newly drilled wells can access the reservoir with a drilling diameter of 8.1/2". For the SCK-002B well, the final diameter is limited to 6.1/8" because the 8.1/2" section (with 7" liner) is required for the distance from the current final depth in the Upper Cretaceous to top reservoir.

The following types of pump systems are available for the requirements described above: Electrical Submersible Pumps (ESP) and Line Shaft Pumps (LSP).

Depending on the hydraulics of the reservoir in and around the injection well, it may also be necessary to use a reinjection pump to increase the pressure. A reinjection pump that may be required to increase the pressure is installed above ground as a conventional booster pump at the wellhead of the injection well.



## 4. Different options for geothermal heat generation & supply

A brief overview of the different options available is summarized in the following.

### 4.1 Heat generation

#### 4.1.1 Option 1

ONEO's existing oil well will be deepened, upgraded and used as a reinjection well (including a reinjection pump). A new well will be drilled for production purposes. The ESP will be designed for a peak demand of 20.6 MW in order to utilize the full potential of the well. By reusing the existing well, savings of around 50% can be achieved compared to drilling a new well.

#### 4.1.2 Option 1.1

ONEO's existing oil well will be deepened, upgraded and used as a reinjection well (including a reinjection pump). A new well will be drilled for production purposes. The ESP is dimensioned for the peak load of Ampfing, around 11.9 MW, in the event that only Ampfing is supplied from the well. The optimization reduces the investment costs for the smaller ESP on the one hand and the operating costs due to the pump's lower energy requirements on the other.

### 4.2 Heat supply

#### 4.2.1 Scenario 1: Heat supply Ampfing

In this scenario, the heat supply of Ampfing alone is considered. With a target connection density of 70 %, this results in an annual heat requirement of 37 GWh/a with grid losses of 6 MWh/a. Considering simultaneity effects in the heating network, this results in a total power requirement of 11.9 MW (11.2 MW power requirement with 0.7 MW network losses). Figure 5 shows the underlying expansion parameters. The total output of 11.9 MW and the heat quantity of 43 GWh correspond to the supply of 1,087 connected customers and a network length of 35.9 km. With an average annual increase of 120 customers and an annual pipeline construction of 4 km, the heat network expansion will be completed after 9 years. The gradual reduction in heat demand results from an assumed renovation rate of 2%. Using option 1, the demand data of the municipality of Ampfing is compared with a geothermal heat supply of approximately 20.6 MW. This results in a free heat potential of up to 19.5 MW in summer. The low heat consumption compared to the electricity requirement for the ESP and the reinjection pump leads to higher heat generation costs.

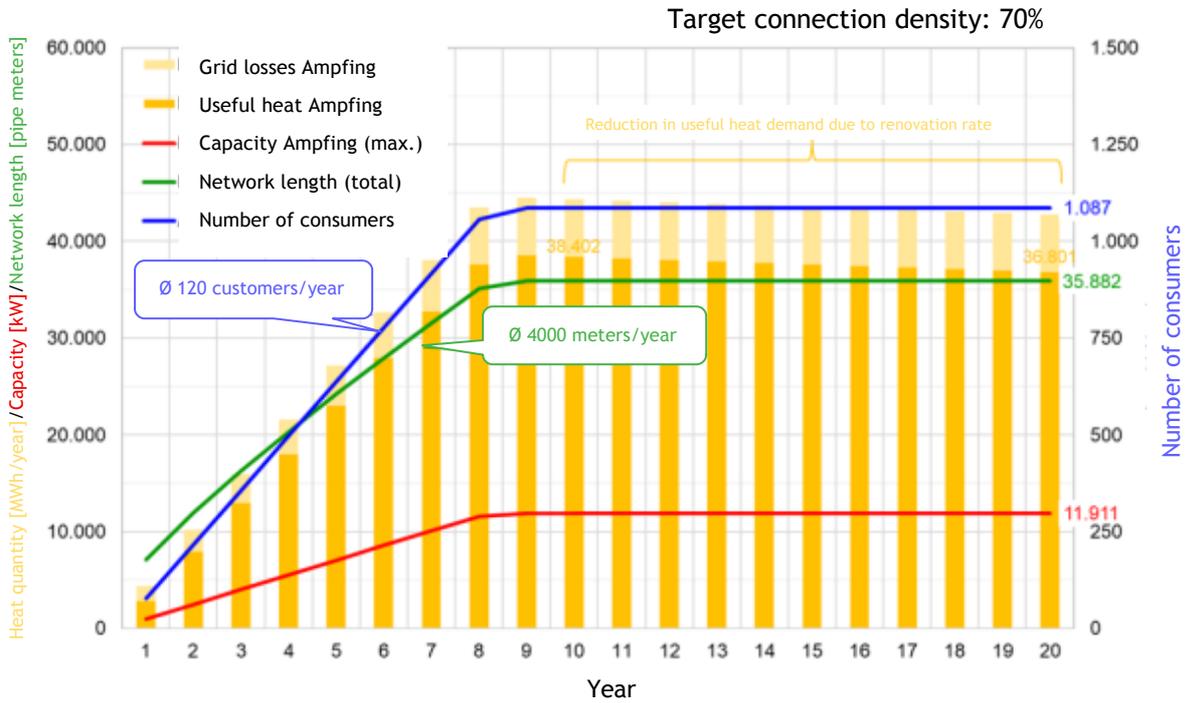


Figure 5: Development of capacity/heat demand in Ampfing (Scenario 1).

To counteract the issues from Option 1, the effect of an ESP and reinjection pump adapted to Ampfing’s heat consumption was investigated (Figure 6). A decrease in heat demand is expected due to building renovations (including thermal insulation). Nevertheless, an improved COP (Coefficient of Performance) and therefore lower heat generation costs are expected.

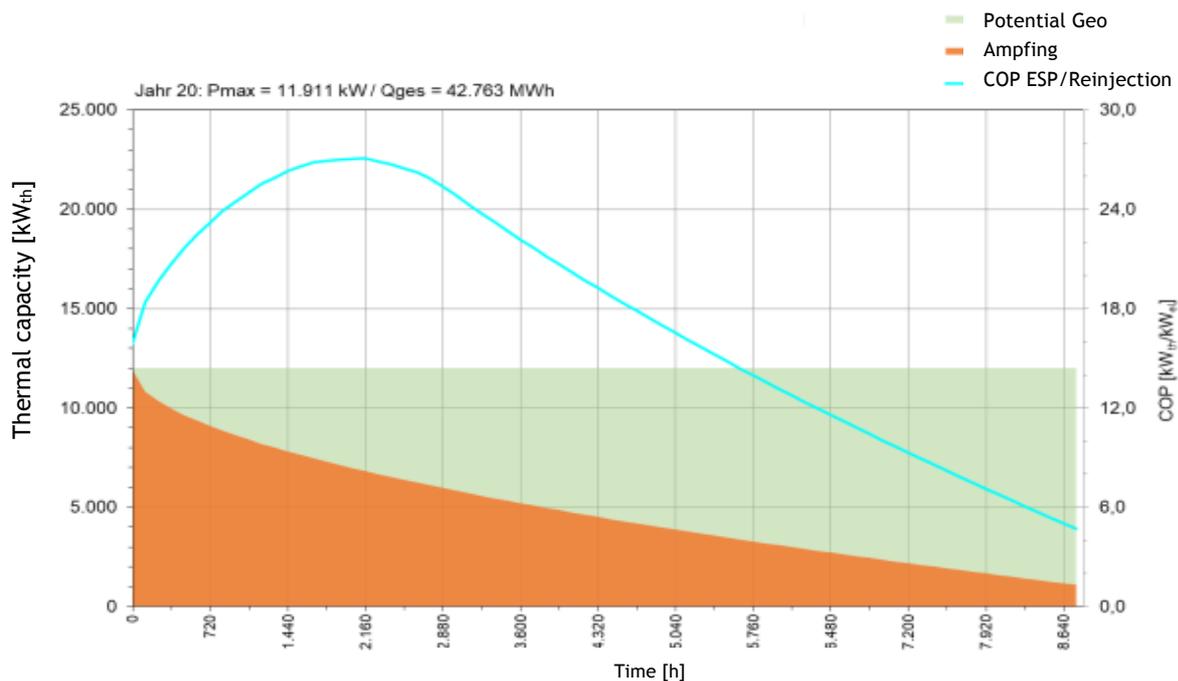


Figure 6: Scenario 1 + potential geothermal energy Option 1.1.



### 4.2.2 Scenario 2: Heat supply Ampfing + third parties

As part of this analysis, the heat supply of Ampfing and third parties (other municipalities) was considered. A fictitious annual duration curve was created for the third parties, in which geothermal energy from Ampfing covers 90 % of the heat demand and only the remaining 10 % peak load is generated by fossil fuel producers. Figure 7 shows the potential geothermal supply capacity for Option 1 depending on the expansion of the heating network in Ampfing. While 19.6 MW of geothermal capacity is still freely available at the start of the expansion in Ampfing, only 8.6 MW of geothermal potential remains available for supplying third parties by the time the heating network expansion in Ampfing is completed.

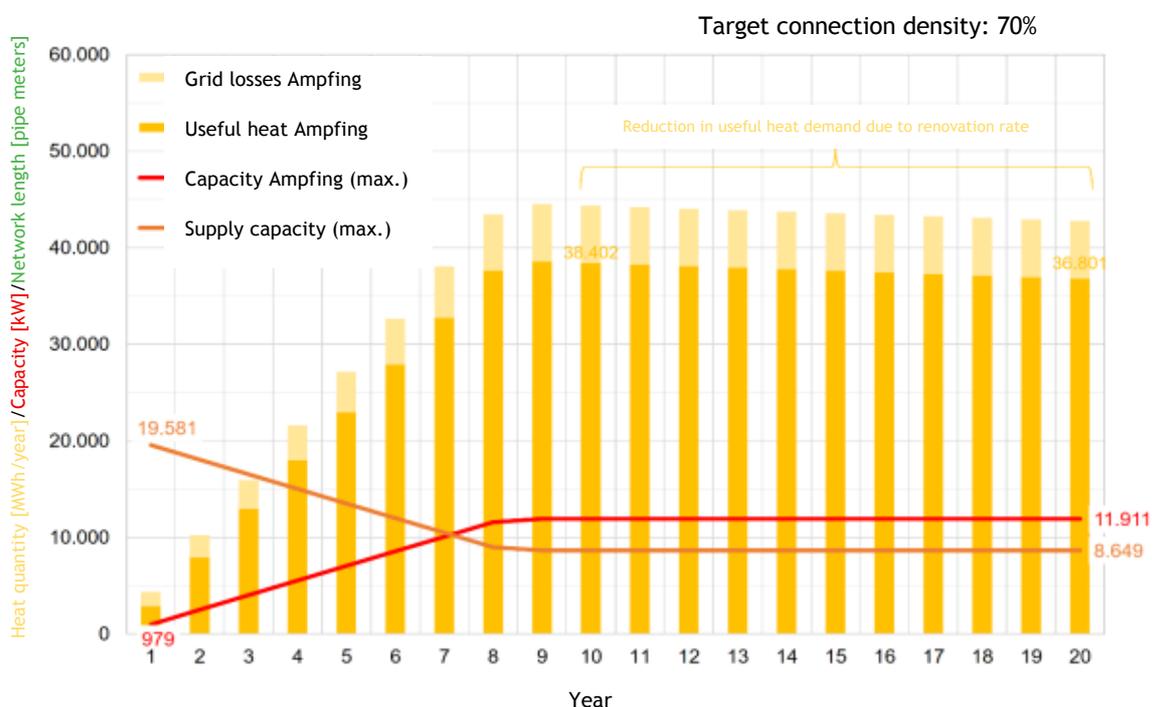


Figure 7: Development of power/heat demand and supply potential for third parties (Scenario 2).

The annual load curve for Ampfing and the available geothermal energy for third parties derived from it, as well as the limitation of the fossil heat generation share to a maximum of 10% by BEW (Bundesförderung für effiziente Wärmenetze), since subsidies are only granted if no more than 10% of the total heat demand is covered by fossil fuels, result in a possible annual load curve for fictitious third parties (Figure 8).

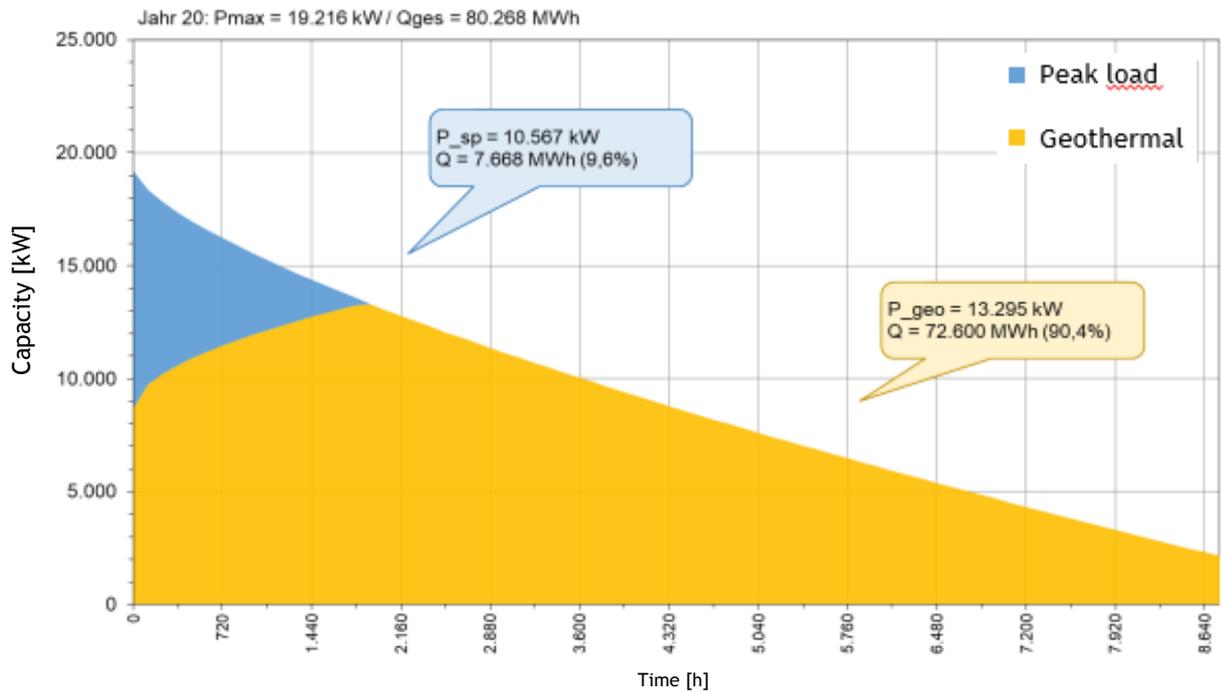


Figure 8: Annual timeline of fictitious third parties (Scenario 2).

The overlay of the annual load curve of Ampfing and the annual load curve of fictitious third parties leads to better utilization of the geothermal doublet, which results in an overall improvement in the overall COP (Figure 9). This increases heat sales while at the same time reducing the heat production costs.

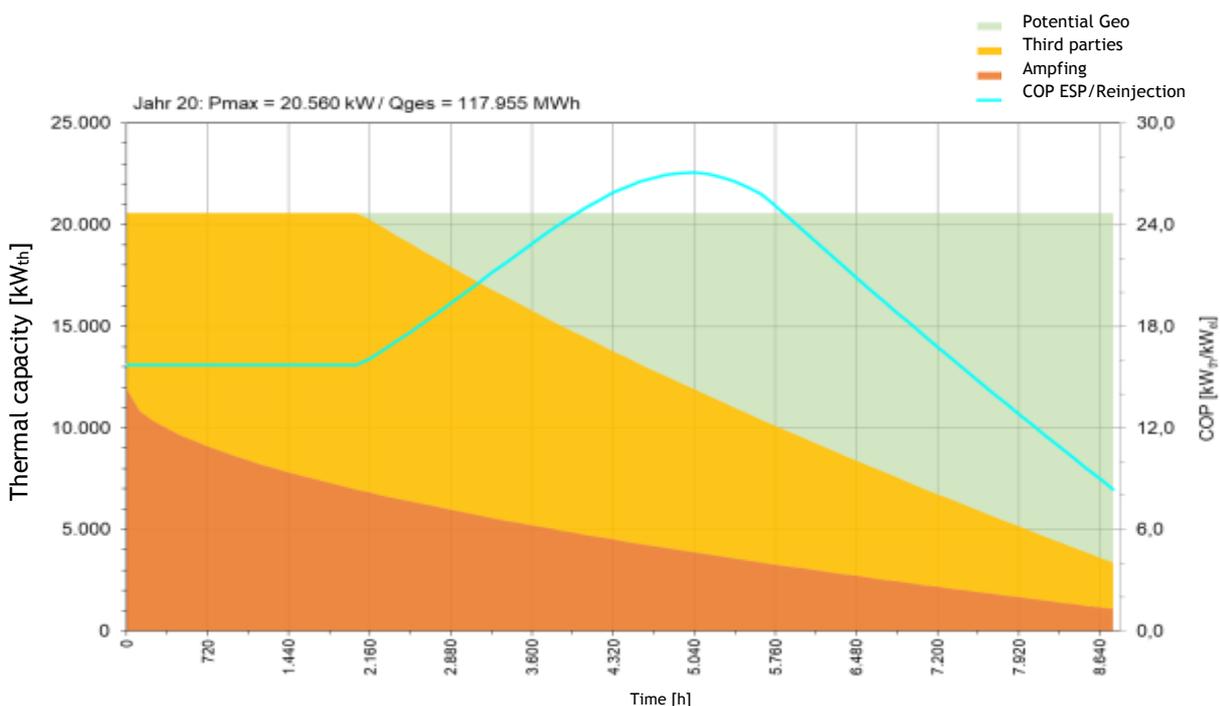


Figure 9: Scenario 2 + Potential geothermal energy Option 1 (Heat supply Ampfing + third parties).



### 4.2.3 Scenario 3: Ampfing + Waldkraiburg

Supplying Waldkraiburg from the Ampfing geothermal plant could also be considered. As Stadtwerke Waldkraiburg already operates a heating network and their existing geothermal doublet is no longer sufficient, a second geothermal doublet is currently being planned. As a hypothetical heat supply from Ampfing on top of two doublets in Waldkraiburg is clearly economically unattractive, it was assumed that Waldkraiburg would not drill the second doublet and therefore the entire heat demand, which exceeds the existing doublet, would be covered by the Ampfing geothermal plant. In that scenario Waldkraiburg has the major advantages of not having to drill a second doublet and secondly a better utilisation of its existing doublet when their heat network is expanding. The amount of heat delivered from Ampfing can be adjusted to the evolving heat demand during heat network expansion.

### 4.2.4 Scenario 4: Ampfing + Mühldorf

Another consideration is the supply of Mühldorf am Inn by the Ampfing geothermal power plant. In order to realistically include Mühldorf in the calculations despite the lack of a heating network, a hypothetical expansion for a future heating network in Mühldorf was assumed. Compared to Waldkraiburg the use of the geothermal potential is higher during summer times as also a base load would be required. Other results are similar to the Waldkraiburg scenario.

## 5. Cost framework and economic analysis

For a district heating network to achieve the connection density required for economical operation, the connection must be financially attractive for potential heat customers. In addition, other benefits such as space savings in the boiler room, convenience and environmental friendliness must be communicated to potential customers.

### 5.1 Example for Scenario 1 - Option 1 or Option 1.1

The largest cost items are the heat distribution within the distribution network, house connections and transfer stations. Around € 34.3 million (net) will be incurred for 32.8 km of pipelines and 1,087 stations in Ampfing. Based on the current state of planning and knowledge, the total costs for property, plant and equipment amount to around € 67.4 million (net). The planning costs were calculated separately on the basis of the individual investment items. This results in total ancillary construction costs of around € 6.3 million (net). This means that the investment sum for the overall project, including planning costs, amounts to around € 74 million (net). An interest rate of 5.0% was assumed for the calculation of the resulting capital costs (using the annuity method) and maintenance costs (using factors). The useful lives and maintenance factors are based on the specifications of VDI 2067 (Verein Deutscher Ingenieure), resulting in annual capital costs of around €4.6 million (net) and annual maintenance costs of around € 0.3 million (net). Taking into account the maximum possible subsidy under BEW, the annual capital costs are reduced to around € 2.8 million (net). The subsidy has no influence on the maintenance costs.

#### 5.1.2 Heat price Ampfing

In order to estimate a realistic heat price for Ampfing, an expected return of 6% was assumed for the future network operator in Ampfing, with a connection density of max. 70% based on the medium price



rate which has been assumed in comparison with other (neighboring) geothermal heat network prices for end consumers.

## 5.2 Cumulative overall result

The cumulative overall results after 20 years, as shown in Figure 10, reveal that the profitability of the whole project benefits from the additional heat sales to third parties. An end-use connection density of 70% is assumed, as well as a heat price to third parties of 25 €/MWh. Depending on the heat sale price and the scenario, different results are obtained, with the best result achieved by the expansion of the heat supply of Ampfing, including the extension of the existing oil well, with possible third parties.

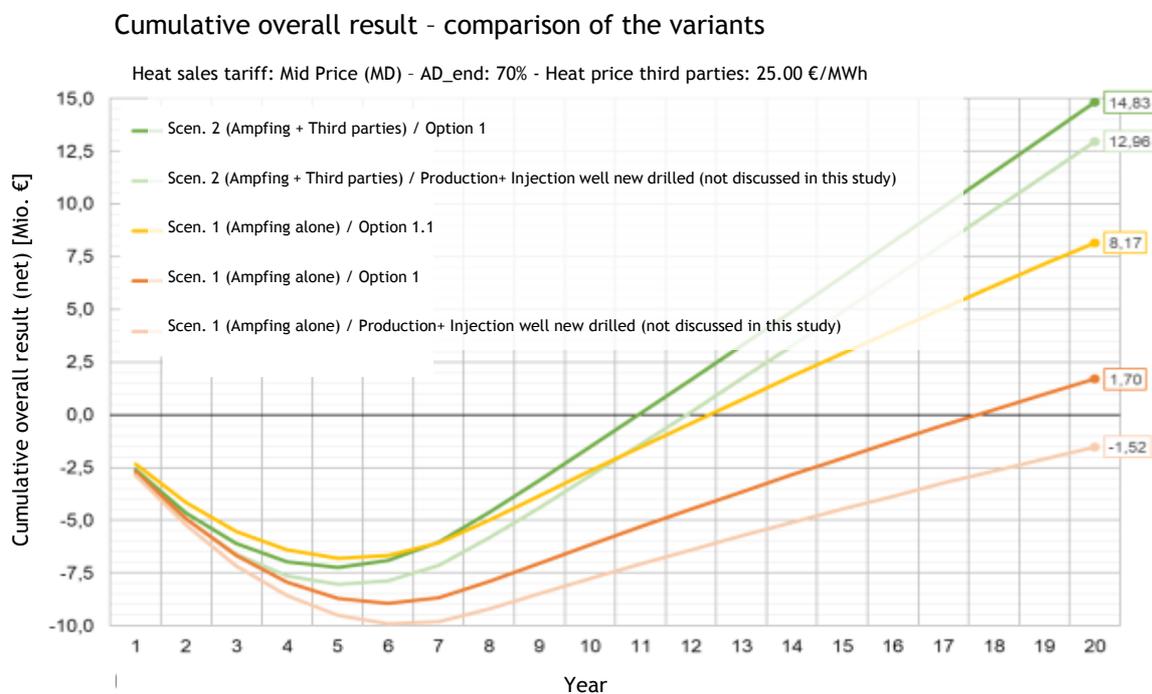


Figure 10: Comparison of variants cumulative overall result.

In addition, as the calculations carried out are based on factors that are sometimes difficult to predict, fluctuate or have not yet been finally clarified, sensitivity analyses were carried out with regard to the individual variants for the expansion of geothermal energy and the municipalities supplied, the connection density, the heat price for third parties, the interest rate and the level of subsidies. The results of the sensitivity analysis show that the individual variants in combination with the different scenarios are economical under certain framework conditions. However, this will not be discussed further, as financial information is confidential to ONEO and is being used exclusively for internal project planning purposes.



## 6. Conclusion

In this study, the use of a geothermal system in Ampfing has been examined in various scenarios. Although this is not explicitly stated in the study (due to confidentiality reasons), it has become evident that, from today's perspective, end customer prices are not attractive enough to be competitive across all scenarios. For this reason, an intermunicipal solution is necessary to create the required synergies. Through collaboration with other municipalities, significant savings can be achieved, bringing both economic and ecological benefits together and enabling the realization of a geothermal heat supply for the Ampfing region by reusing a dry oil exploration well.

## 7. References

This document provides a summary of the detailed feasibility study conducted by Ing-Kess GmbH and should be considered as the primary reference for that study. Some references included in this document have been taken directly from the original feasibility study.

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