ECONOMIC COMPARISON OF SEASONAL HEAT-STORAGE IN COMBINATION WITH A DEEP GEOTHERMAL DOUBLET WITH TWO DOUBLETS, EXAMPLE FROM THE PILOT PROJECT IN BERN, SWITZERLAND

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ABSTRACT

In climate zones with hot summers and cold winters and with geothermal gradients (<= 35°C/km) requiring to drill deep wells (> 3000 m) for district heating at 90-110 °C it may be economically advantageous to construct one well doublet (> 3000 m) together with a seasonal underground heat storage at shallow depth of around 500 m and to operate the system also during summer, instead of constructing two well doublets which operate only in cold months of the year. Of course, such a concept relies on good hydrogeological conditions in the lower deep geothermal reservoir and in the upper storage reservoir. We present the concept and the plans for a pilot project in the city of Bern, being part of HEAT-STORE GEOTHERMICA.

Keywords: Seasonal heat-storage, sandstone layers, economic analysis, combination of geothermal heat production from deep wells and heat storage in shallow formations

1. INTRODUCTION

The city of Bern is considering to replace fossil heat sources largely by renewable energy. Based on the heat demand of the district heating network in Bern, it will be shown as an example that the combination of one geothermal well doublet (> = 3000 m) and an underground heat storage can be economically more advantageous in comparison to heat generation from two geothermal well doublet operations. A schematic drawing of the two systems is shown in Figure 1.

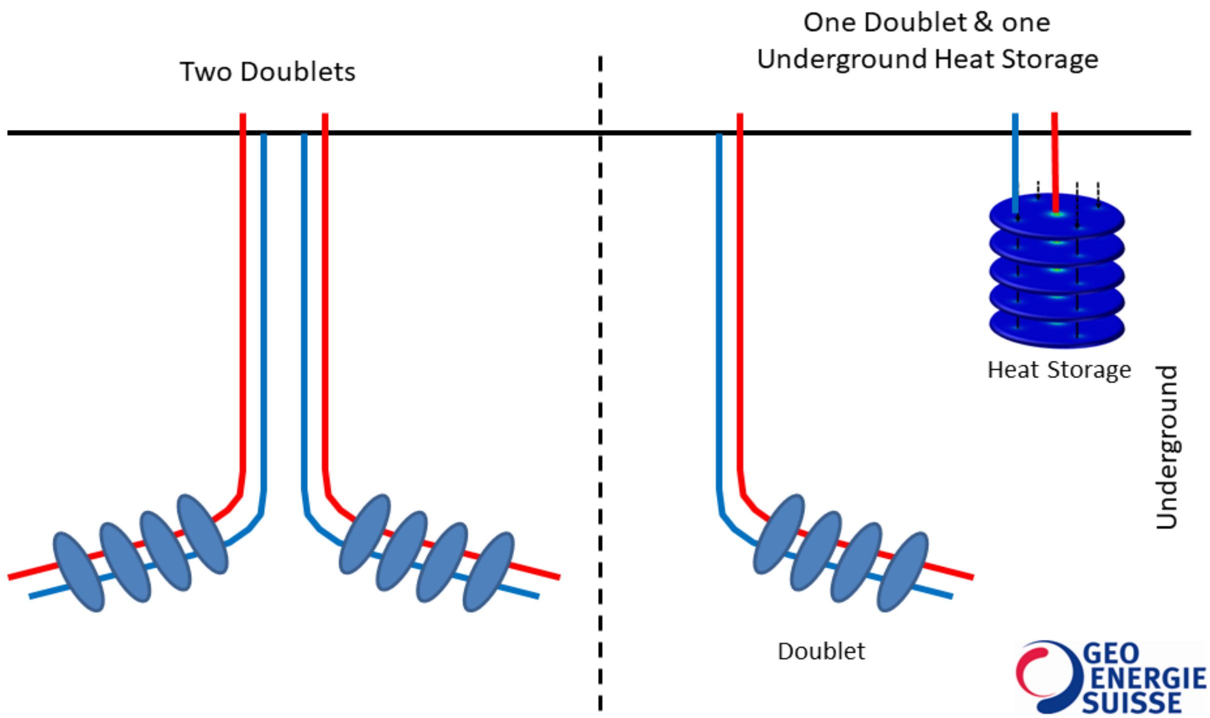

Fig. 1 Schematic drawing showing the two systems (left two doublets, right one doublet and an underground heat storage) which are compared based on economics.

The profitability calculations are based on the annual heat demand data of the district heating network in Berne. Figure 2 shows this heat demand and also the proportions of heat sources. If only the fossil portion of the heat sources is considered, which is to be largely replaced by geothermal energy, the annual characteristic curve for the use of fossil heat can be derived from these data. This characteristic is shown in Figure 3.

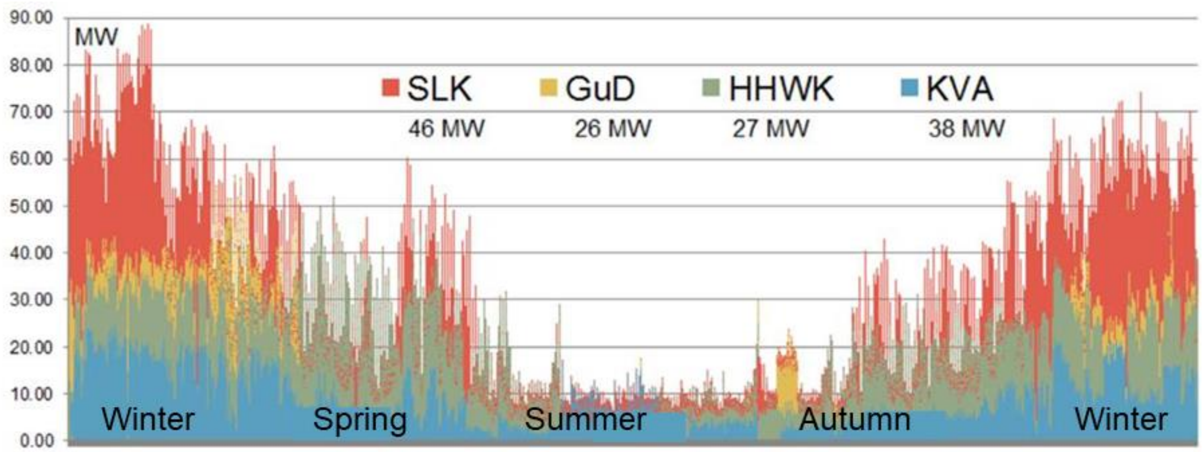

Fig. 2 Heat demand and heat sources (SLK (peak load gas boiler), GuD (waste heat from gas turbine), HHWK (heat from wood fired plant), KVA (heat from waste incineration plant)

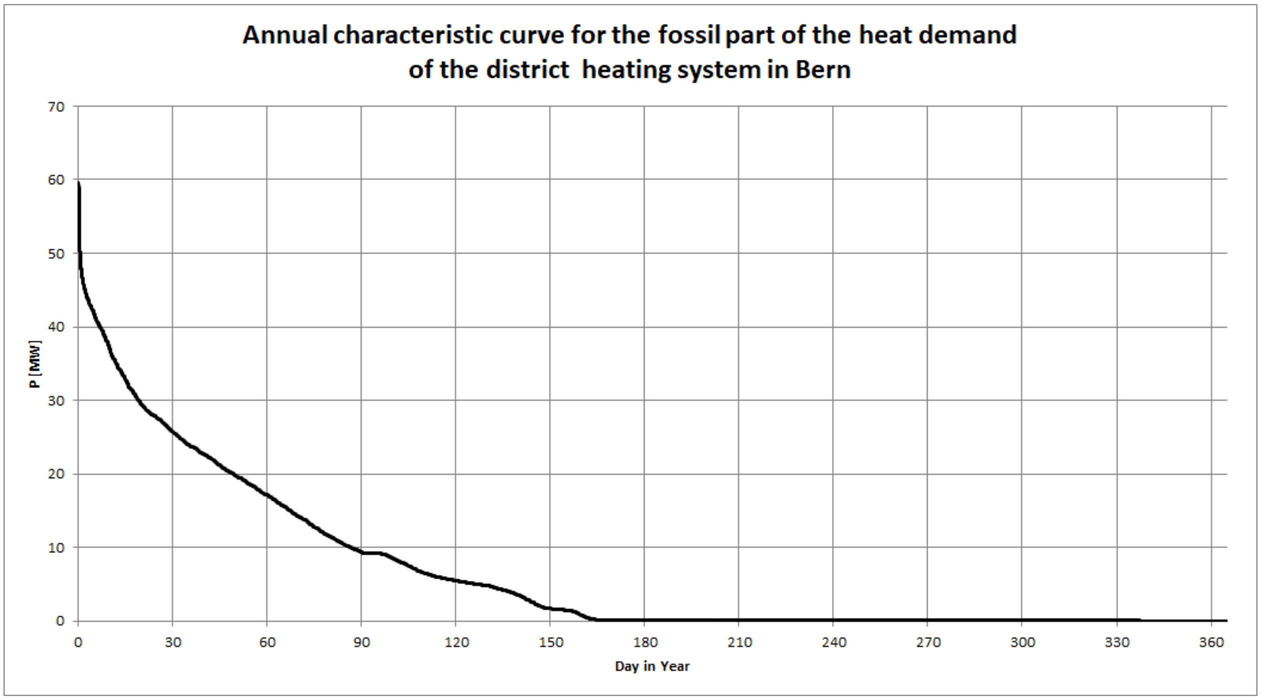

Fig. 3 Annual characteristic curve for the fossil part of the heat demand of the district heating system in Bern

The following assumptions were made for the comparison of the economic efficiency of a geothermal plant with and without heat storage:

- The geothermal plant is intended to replace fossil heat sources to a large extent. These heat sources are the peak load boiler (SLK) and the gas and steam power plant (GuD) (see Figure 1 and Figure 2).
- For reasons of efficiency, the peak load above 30 MW is not to be covered by geothermal energy.
- The capacity of a doublet at 4000 m is assumed to be 15 MW (with conservatively estimated flow rate and temperature).
- A discharge capacity of 15 MW is assumed for the maximum capacity of the storage facility.

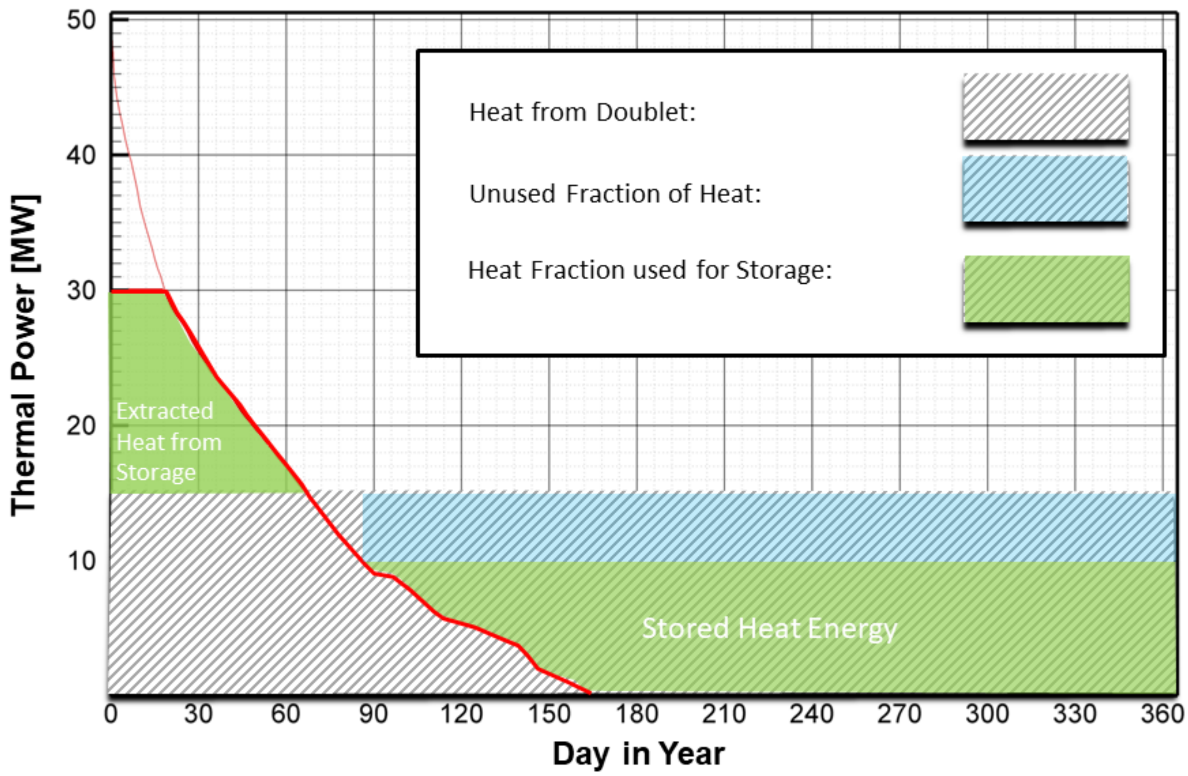

Fig. 4 Annual characteristic curve for the coverage of fossil heat demand by one doublet and the heat storage.

Two doublets are required to cover the heat demand and the maximum required heat output of 30 MW. The following calculation example shows that the heat storage can replace one of the two doublets.
This replacement is only possible if, on the one hand, the heat storage is dimensioned in such a way that it can achieve both the maximum output of 15 MW during withdrawal and can also store the required quantities of heat. On the other hand, the missing amount of heat in winter must be compensated by the stored surplus heat in summer. Here, storage losses must be taken into account with only 60% of the heat stored can be used.

Figure 4 shows the result for a suitable operating configuration of the doublet and storage system. In this configuration, the doublet with its maximum output of 15 MW is fully utilized for the first 90 days of the characteristic curve. The additional heat required is taken from the storage during this period. During the rest of the year, the doublet capacity can be reduced to less than 10 MW. The excess heat available for injection at a capacity of 10 MW exceeds the required heat quantity, so that a buffer is available or the efficiency of the storage can be increased by heating up the storage more quickly.

The following basic assumptions for determining the operating parameters of the doublet geothermal storage system are used: maximum heat output of the doublet 15 MW, maximum withdrawal capacity of the storage 15 MW, temperature doublet 160 °, temperature during storage in the heat storage 90 °C, return flow temperature district heating network 50 °C, fluid density 985 Kg/m3, heat capacity fluid 4180 J/kg/K and heat storage efficiency 60%.

On the basis of these data and the annual characteristic curve, it is possible to determine the amount of heat that the storage must supply during periods of high heat demand (heat output higher than 15 MW) (20.1 GWh. If the capacity of the doublet is reduced to 10 MW in times of excess heat, 56.8 GWh are available for storage and thus considerably more than would be necessary due to the storage efficiency of 60%. The determined parameters for the operation of the geothermal system "doublet and storage" are: heat output of the doublet in winter 15 MW, heat output of the doublet during storage 10 MW, full load days of the duplicate 90 days, flow rate of the doublet at full load 33 l/s, flow rate of the doublet in the injection phase 22 l/s, flow rate storage variable, 0-90 l/s, stored heat 56.8 GWh and produced heat 20.1 GWh.

3. Results of the economic analysis

Net present values of -25 Mio. CHF were calculated for the two-doublet system and +7 Mio. CHF for the combined system of one doublet and heat storage assuming the following values:

- Costs for two doublets: 200 Mio. CHF
- Costs for one doublet and heat storage: 120 Mio. CHF
- Subsidies according new energy law: 60%
- Interest rate 5 %
- Selling price for heat: 0.068 CHF/kWh
- Heat yearly sold: 55 GWh
- Lifetime of project: 30 years

4. CONCLUSIONS

In climate zones with hot summers and cold winters and with geothermal gradients (<= 35°C/km) requiring to drill deep wells (> 3000 m) for district heating at 90-110 °C it may be economically advantageous to construct one well doublet (> 3000 m) together with a seasonal underground heat storage at shallow depth of around 500 m and to operate the system also during summer, instead of constructing two well doublets which operate only in cold months of the year.