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Economic Feasibility of Installing Heat Pumps at "Kanjiza Spa"

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ABSTRACT

A specialized rehabilitation center "Kanjiza Spa" in the northern part of Vojvodina Province in Serbia has used geothermal water for balneology and energy requirements for twenty years. The existent boiler room at the Spa has been redesigned to allow the use of geothermal water for energy requirements, and it now operates at low temperature enthalpy using plate heat exchangers.

A heat exchanging unit for thermal water with two plate exchangers of 1050 kW and 600 kW has been built, to allow the object to replace heating boilers for up to -5°C of external temperature with thermal water from a hydrothermal well at the temperature of 65°C and maximum flow rate of 11,7 l/s.

Since the Spa has expanded its capacities by building new extensions and installing air systems (air chambers), it was necessary to consider the use of heat pumps for both heating and cooling of the object, with thermal water as the main energy source.

This analysis shows the application of modern heat pumps with dry cooling towers and gives comparative costs of electric power, natural gas and geothermal energy in such a complex installation.

1. INTRODUCTION

In 1907, at pastures near a small town of Kanjiza, there were two artesian wells that were used for the cattle watering. As the needs grew, local shepherds asked the town authorities to drill another two wells. In May, 1908, a well was drilled, 274 m deep with the capacity of 1,4 l/s.

Water from this well was warmer than from the existing two and its color was yellowish, but together with the water some flammable gas also flew. Such water characteristics were a good ground for the stories of the water's healing properties, and the local people soon named this well "magic".

The town authorities reacted promptly, and that same summer people could go swimming in the magic well water. During 1909, the water samples were sent to the Royal Chemistry Institute in Budapest, and the analyses were completed in 1910. But in 1909, the local Kanjiza businessman, Grünfeld Herman, initiated and founded a joint stock company that would establish and open a spa. It took Mr. Herman 4 years to convince the local authorities before finally getting their permission for the works in Kanjiza.

The water from the magic well was awarded to the company for the period of 30 years, and the water from the first two wells at the pastures was also brought into the town's People's park (5.750 m off the well), where a new swimming pool/spa was constructed. During 1913, a new artesian bath was opened, with the water from the magic well; the building had 12 rooms and 20 bath tubs. The building was also equiped with steam heating and electric lights. Beside the bath, an open-air swimming pool with thermal water was also built in the park.

Despite the area being struck by two world wars, the Spa worked successfully, healing the wounded and introducing new healing methods – "pearl baths". A new water analysis was conducted in 1954 in Belgrade, when it was suggested that the spa should work as natural thermal spring.

2. THE USE OF THERMAL WATER FOR ENERGY NEEDS AT THE SPA

During all these years the Spa worked with success, and since 1976 it has been an autonomous object under the name Center for rehabilitation and recreation - the Kanjiza Spa. Owing to the increasing requirements and expansion at the "Abella" building, another hydrothermal well was drilled in 1977, named Kz-1/H, which has the following properties:

- well depth: 1,147 m
- maximum capacity (natural flowing): 2.7 l/s
- optimal capacity: 2.1 l/s
- water temperature: 41 °C
- total mineralization: 2.25 g/l

With the construction of hydrothermal system for water treatment (degassing – separation of flammable gas and transportation system), this well was very soon included into the therapeutic program of the Spa.

A new object within the Spa, "Aquamarin", opened in 1980; it provides the quality service of a 3-star hotel with its capacity of 150 beds, therapeutic block, sport hall, restaurant for 300 guests, 2 indoor swimming pools and other contents.

With the development of modern heating and ventilation systems, it was concluded that thermal water could be used for energy requests in the Spa. In 1983, a new well Kz-2/H was drilled at a close distance (800 m from the object), which yielded thermomineral water of the following properties:

- well depth: 1,123 m
- maximum capacity (natural flowing): 11.7 l/s

- optimal capacity: 9.1 l/s
- water temperature: 65 ^oC
- total mineralization: 4.03 g/l
- gas factor: 1.0 m_n^3/m_v^3
- water type: HCO_3 - Na

With the construction of an annex to the "Abella" in 1985, the capacity of the Spa reached 300 beds.

2.1 Energy balance at the Spa

During the construction, it was anticipated that the thermoenergy block in the Spa's objects would work with conventional heating boiler rooms and liquid fuel operated boilers. The heating system was anticipated as a combination of air and radiator heating.

At the moment, the Spa complex consisted of the following objects:

1. Rehabilitation and recreation object "Aquamarin" with accommodation wing built in 1980
2. Annex to the "Abella" for accommodation, built in 1985 when the old Spa was reconstructed

Both objects were equipped with heating energy sources during the construction, and they were liquid fuel operated boilers.

1. Boiler room "Aquamarin" with the following characteristics:

   - Heating boiler 90/70 ^oC with boiler, capacity 1,500 l, and power 1,160 kW 1 pc.
   - Heating boiler 90/70 ^oC with no boiler, and power 1,160 kW 1 pc.
   - Heating boiler 90/70 ^oC with boiler, capacity 1,500 l and power 465 kW 1 pc.
   - Steam boiler for production of 300 kg/h of steam of 10 bar and power 175 kW 2 pcs.

Total installed boiler room power: 3,135 kW

1. Boiler room "Abella" consists of:

   - Heating boiler 90/70 ^oC and power 450 kW 1 pc.

2.2 Installed power of thermotecnical installation

The above boiler rooms have the following installed capacities:

"Aquamarin", rehabilitation/recreation center:

- Radiator and floor heating 502 kW
- Air heating in air handling 1,780 kW

TOTAL 1.: 2,282 kW

2. Annex to the "Abella"

   - Radiator heating 450 kW

TOTAL 2.: 450 kW

By analyzing both thermotechnical installation at the Spa and properties of the geothermal well Kz-2/H, it was concluded that the available heating power of the well could be used for heating the "Aquamarin", with the reconstruction of the thermotechnical installation. After it has been used for energy needs, the thermal water could later be used in balneology for therapeutical needs.

The heat power of the well Kž-2/H is:

$$Q_2 = G_2 \cdot c \cdot \Delta t = 1{,}143 kW \tag{1}$$

where: Q_2 heating power of the well Kz-2/H, G(kg/s) optimal capacity, c(kJ/kgK) water specific heat, Δt(^oC) temperature difference.

To use the available heating power, the ventilation chambers in the "Aquamarin" were reconstructed and pre-heaters were installed (which was allowed for by the previous four-pipe distribution line in the air-conditioning system); a partial replacement of the radiators with fan-coil system was also made.

The thermotechnical installation at the "Aquamarin" was reconstructed in 1988/1989. An exchange thermal water station was built, with two plate power exchangers of 1050 kW and 600 kW, respectfully; this way, when the outside temperature is up to cca -5^oC, the object is allowed to replace the heating boilers with the Kz-2/H thermal water, which temperature is 65 ^oC and optimal flow rate 9,1 l/s.

When the outside temperature is below -5^oC, the heating boilers should operate only the radiator heating of those objects that have no air heating, and that include mainly the accommodation (rooms). Installation at the exchange station is shown in Fig. 2.

This use of thermal water at the Spa allows the utilization of total energy potential of the thermomineral water, as well as its balneological properties. Today, the thermomineral water is used for heating the "Aquamarin", for water therapy in to indoor swimming pools, therapy at the medical block, and as warm water in all the rooms.

The temperature of the thermal water from the object is nearly 35 ^oC and can also be used for fish farming. The Spa has made an elaborate design and acquired the technology for intensive farming of the African cat fish from the Institute in Sarvas, Hungary, which has been in the business for 12 years.

2.3 Present status of the thermal water use at the Spa

Following the development of the Spa's capacity utilization of 90% in the last 10 years, it was concluded that another thermal well should be drilled, which would secure the supply of thermomineral water and realization of the plans for the Spa's expansion. To that purpose, NIS-Naftagas, a part of the National Petroleum Industry of Serbia, that has drilled and equipped the previous two wells, drilled and equipped a new hydrothermal well Kz-3/H in 1996. The well has the following properties:

- well depth: 1,140 m
- maximum capacity (natural flowing): 17.5 l/s
- optimal capacity: 16.7 l/s
- water temperature: 69 ^oC

- total mineralization: 4.08 g/l
- gas factor: 1.52 m_n^3/m_v^3
- water type: HCO_3 - Na

The heating power of the well Kz-3/H is:

$$Q_3 = G_3 \cdot c \cdot \Delta t = 2{,}377 kW \qquad (2)$$

where: Q_2 heating power of the well Kz-3/H, G(kg/s) optimal capacity, c(kJ/kgK) water specific heat, Δt(°C) temperature difference.

By introducing the well Kz-3/H into production, the hydrothermal system for thermal water treatment was reconstructed, which allowed the supply of the Spa with thermal water from each individual well (of the three available), or mixing thermal waters of different temperatures, depending on the immediate needs or the season. Fig. 1 shows a scheme of this installation.

3. PLANS FOR FUTURE USE OF THERMOMINERAL WATER AT THE SPA

Future use of thermomineral water at the Spa is based on the expansion of accommodation capacities, which has partly been realized in 2003 through connecting a newly built apartment building "Ana" to the Spa's power station and through plans for building the 3rd floor of the "Aquamarin". To improve the accommodation, the equipment was installed that would allow air-conditioning of the object (heating in winter, and cooling in summer), which resulted in overall service quality improvement – from 3 to 4-stars.

Total requirements for the heating energy of the Kanjiza Spa with expansions are:

"Aquamarin"	2,282 kW
"Abella"	450 kW
"Ana"	245 kW
3rd floor construction	250 kW
TOTAL:	3,227 kW

With the synchronicity factor φ=0,8, the Spa's energy station should have the heating capacity of nearly **2,600 kW**.

Today, the hydrothermal system that can use three geothermal wells, which thermal water ranges between 41–69 °C, is available to all the Spa's objects.

To make a better use of these natural resources, an analysis and project design have been made, which include the installation of two modern reversible heat pumps (RHT) with dry cooling towers (DCT). They use disposed thermal water over 35°C, which is let out at the existing installation.

4. ECONOMIC ANALYSIS OF THE HEAT PUMPS USE

A design has been made to predict the Spa's energy station reconstruction and necessary equipment installation, in order to use the heat pumps which work would be based on the use of disposed thermal water.

These designs include installation of two reversible heat pumps, dry cooling towers, plate heat exchanger, pumps and pipe network, and automatic regulation system. Construction of this installation would supply the Spa's energy system with additional **725 kW** of heating energy for the system 50/45°C, and **540 kW** of cooling energy for the system 7/12°C. Technology scheme of the new installation is shown in Fig. 3.

Total investments for the new installation and the Spa's energy station reconstruction are **220,000 €**, of which the dry cooling tower (DCT) is **80,000 €.**

The required electric power for the heat and circulation pumps in the system is 200 kW.

With regard to the estimated power requirement for the Spa's energy source of 2,600 kW, the annual energy consumption for heating is:

$$E_G = Q_{gr} \cdot H_G \cdot d \cdot \varepsilon \qquad (3)$$

where: Q_{gr} estimated source heating power (kW), H_G number of days per year (day/yr), d number of hours per day (h/day), ε load factor.

E_G = 2,600 x 200 x 16 x 0.5 = 4,160,000 kWh

which equals the consumption of:

495,240 m_n^3/yr of natural gas, or

363,180 kg/yr of liquid natural gas (LNG)

The use of heat pumps can yield maximum utilization of the heat source, i.e. geothermal wells potential. Temperature of the disposed thermal water without the use of heat pumps is min. 35°C, and the operation of heat pumps in the installation can allow the disposed thermal water temperature drop to max. 20°C.

A combined use of the heat source with heat pumps can yield:

Δt_{max} = 69-20 = 49 °C

In theory, the required thermal water quantity for heating is 85,880 m^3/yr.

The heat pumps will have the following annual consumption:

E_{el} = 200 x 200 x 16 x 0,5 = 320,000 kWh, of electric power.

4.1 Cost analysis

A comparison of power costs for different types of fuels shows:

Costs of natural gas:

C_g = 495,240 x 0.095 = 47,000 €/yr

Costs of LNG:

C_{LNG} = 363,180 x 0.21 = 76,160 €/yr

Costs of thermal water and electric power:

C_{tve} = (85,880 x 0.15) + (320,000 x 0.036) = 24,400 €/yr

The above comparison shows that power costs are lowest when thermal water and electric power are used for the heat pumps.

When we compare supply of the Spa's reconstructed objects with heat power using natural gas fueled boiler rooms and a combined use of thermal water and electric power, we can present the time of investment return for the heating system expansion with RHT with the following relation:

$$\tau = \frac{\Sigma I_T - \Sigma I_{DCT}}{C_g - C_{tve}} [year] \tag{4}$$

where: τ (year) time of return, ΣI_T (€) total investment for reconstruction, ΣI_{DCT} (€) DCT investments, C_g (€/yr) power costs of natural gas, C_{tve} (€/yr) power costs of the reconstructed power station at the Spa.

$$\tau = \frac{220.000 - 80.000}{47.000 - 24.400} = 6{,}2\, years$$

The time of investment return is obviously within the lifetime of the project.

5. CONCLUSION

Thermal water in the vicinity of Kanjiza has been used in balneology for almost 100 years.

The specialized center for medical rehabilitation, the Kanjiza Spa, has used thermal water from three geothermal wells not only for balneology, but also for heating the Spa's object for 20 years.

Reconstruction of the Spa's energy station allows connection of two reversible heat pumps into the system, which results in maximum utilization of energy potential of the geothermal wells, as well as in advancement of accommodation quality at the Spa (air-conditioning).

The connection of the apartment building "Ana" to the Spa's energy station and construction of the 3rd floor of the "Aquamarin" results in bed number increase to 420 and in service quality advancement to that of the 4-star hotel.

With regard to the present status of the Spa and the future increase of bed numbers, and with regard to the installation of heat pumps into the Spa's energy station, it would be realistic to expect the increase of total revenue that would result in a shorter time period for investment return.

The installation of reversible heat pumps at the Spa results in new cooling air-conditioning units for the summer season, for which the user would otherwise have to make additional investments.

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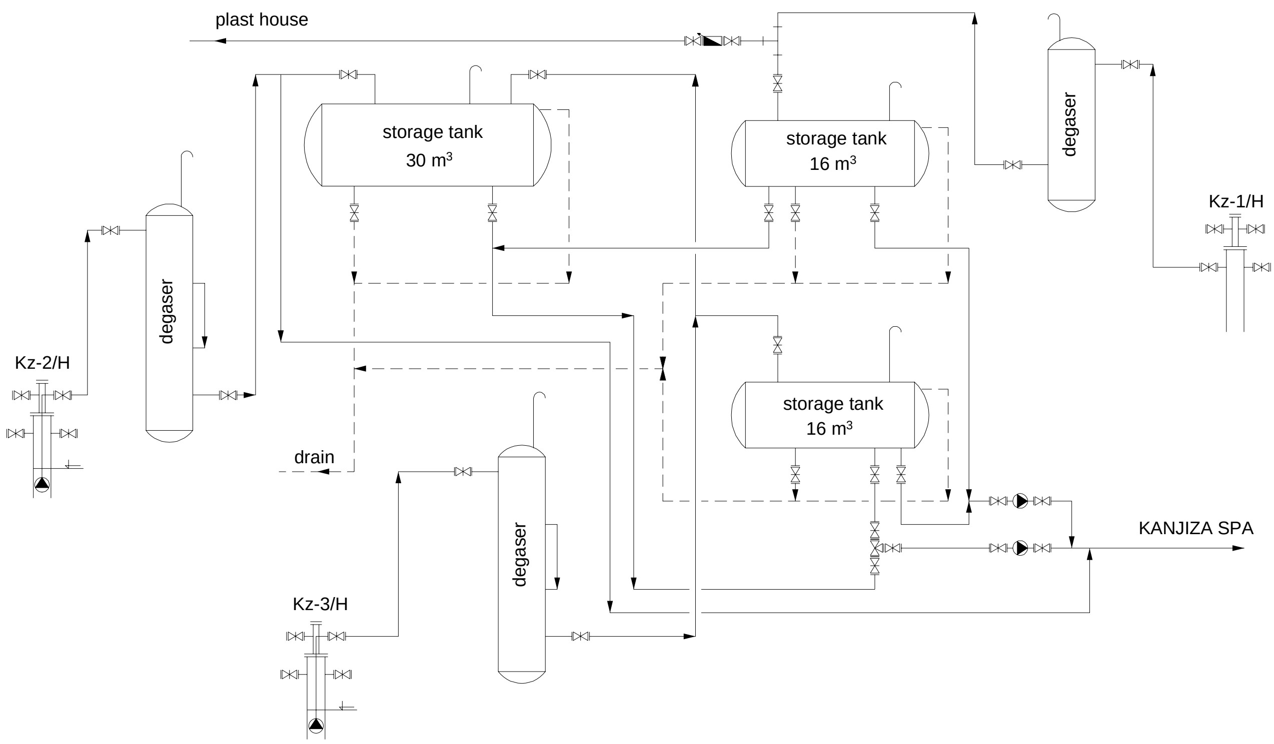

Fig 1: Hydrothermal system for thermal water treatment at the Kanjiza Spa

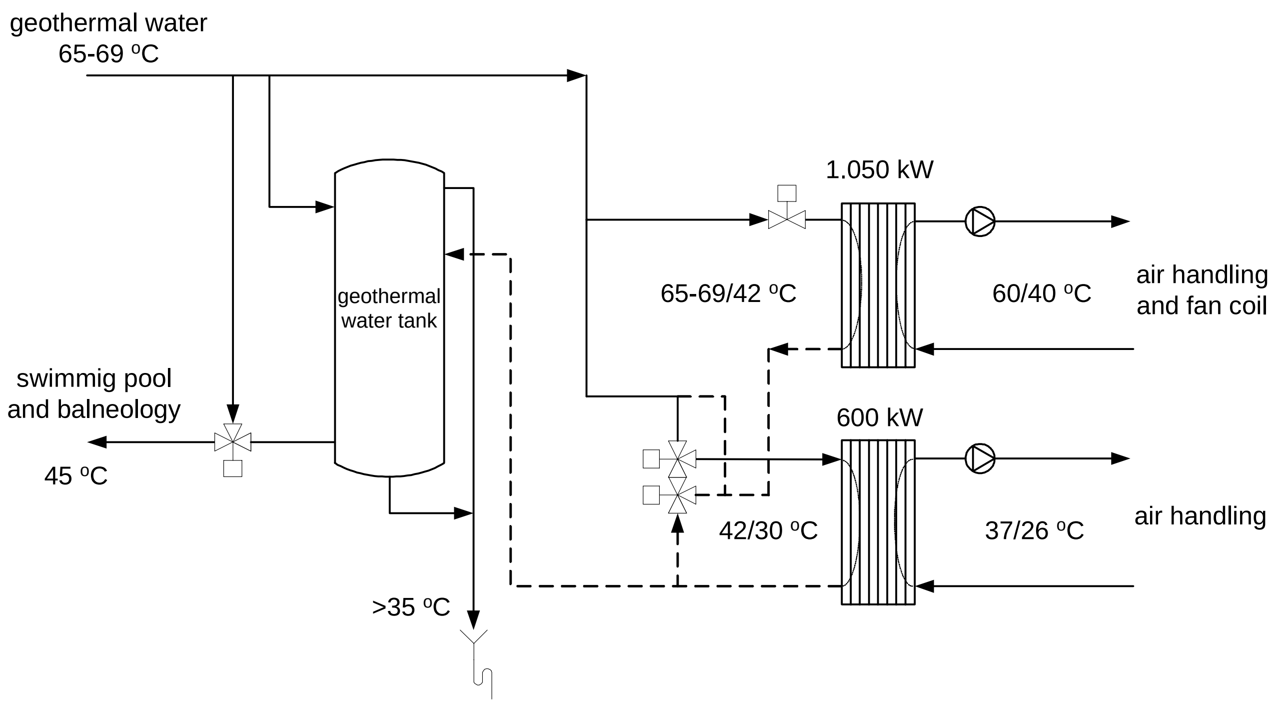

Fig 2: The present state of geothermal water utilization at the Kanjiza Spa

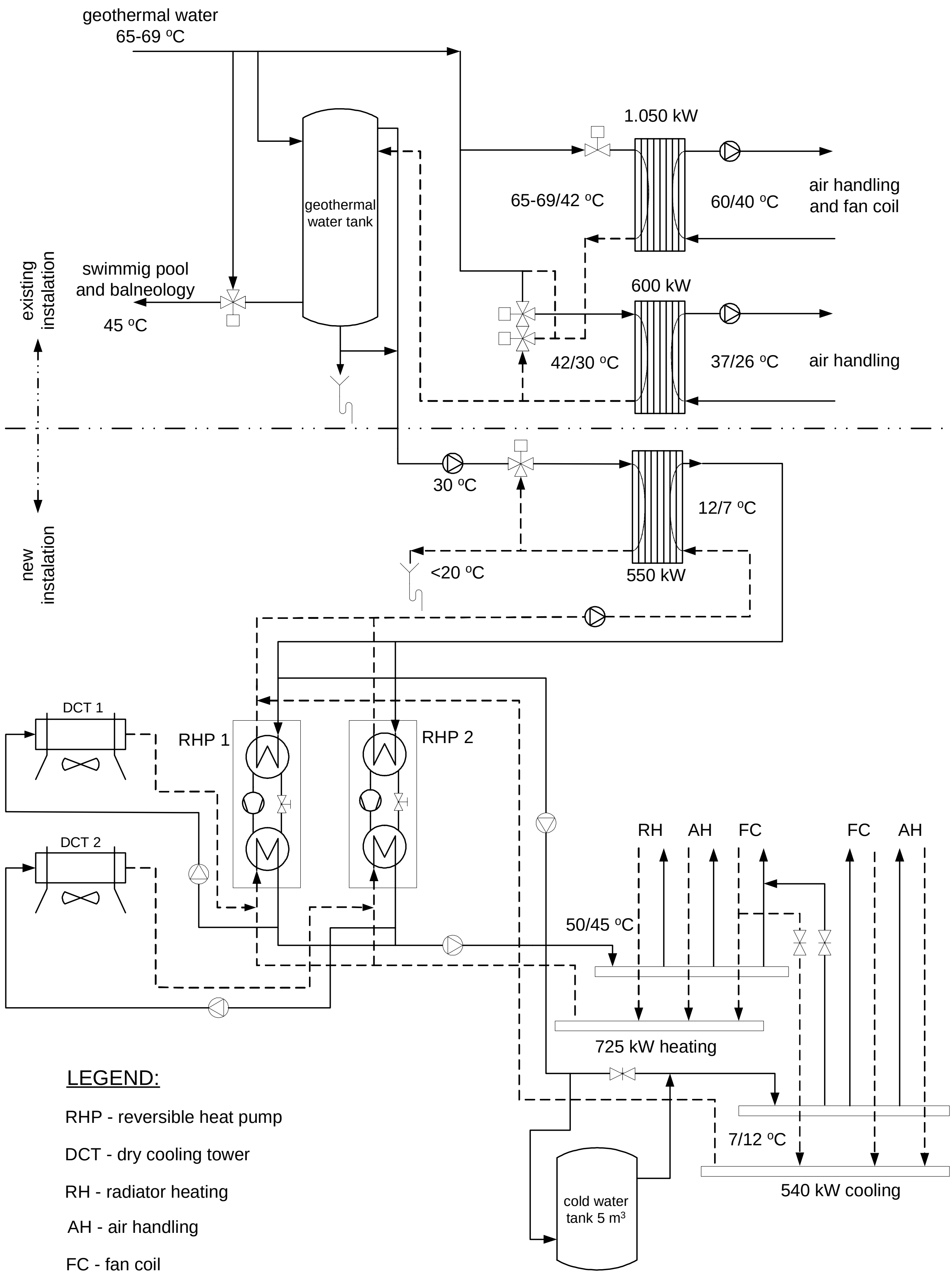

Fig 3: Heat pumps installation into the Spa's power station