

Experience Gained on Direct Use of Low Enthalpy Energy in Hotel do Parque, S. Pedro do Sul, Portugal

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Abstract. Despite the high number of thermal flowing springs in Portugal mainland (up to 52 hot springs), ranging temperatures from 20 °C to 77 °C, and with significant water flow rate, few district heating system were implemented in Portugal. Here we present the São Pedro do Sul district heating system, located northern of Portugal. The thermal power plant was designed, completed, and commissioned in 2001 allowing the utilization of the geothermal heat by local users, as Hotel do Parque. The district heating system sums about 15 years of utilization without interruption and with minor drawbacks. On this paper we present the project overview along with thermal power plant specifications and data numbers. Heat comes from a 16.9 L/s of thermal water supplied by a natural spring and a nearby well. Heat from the spring and well sources is transferred to a secondary low mineralized water system by a plate heat exchanger, allowing the heating of space and domestic waters of hotel areas. Based on a theoretically cascade direct use of heat from a 67 °C to a 20 °C water temperature range, available heat totals $29.1 \cdot 10^6$ kWh yearly. However, past and actual use of heat only reaches around 1.6% of that figure. By comparing with fossil heat sources, actual use of a natural heat source reduces a theoretically amount of 117.9 ton of CO₂ emissions by year. The successful use of this district heating system can promote local expansion of new users and other possible heat uses of this renewable energy, giving chance for the district heating system saturation.

1. Introduction

Despite the high number of thermal flowing springs in Portugal mainland (up to 52 hot springs), ranging temperatures from 20 °C to 77 °C [1], and with significant water flow rate, few district heating systems have been implemented in Portugal so far. Due to an excess flow rate and heat from natural spring (here called as traditional spring) and nearby 500 meters well (AC1), design was made to use the additional heat for district heat system in a cascade use fashion. In this paper we present the São Pedro do Sul district heating system, namely the Hotel do Parque user, located northern of Portugal, finance supported by the Thermie Program [2, 3].



The geothermal resource under study, here called the São Pedro do Sul Hydromineral and Geothermal Field (SPSHGF), is part of the concession known as "Termas de São Pedro do Sul", which was concessionary to the São Pedro do Sul Municipality. The concession licenses the resource for two utilizations: as hot mineral water resource, in the thermal baths, and for the heat utilization, as a direct use of geothermal energy. In the SPSHGF two zones (or poles) were identified as targets for the resource exploitation (Figure 1): the TERMAS Pole (TP) and the VAU Pole (VP).

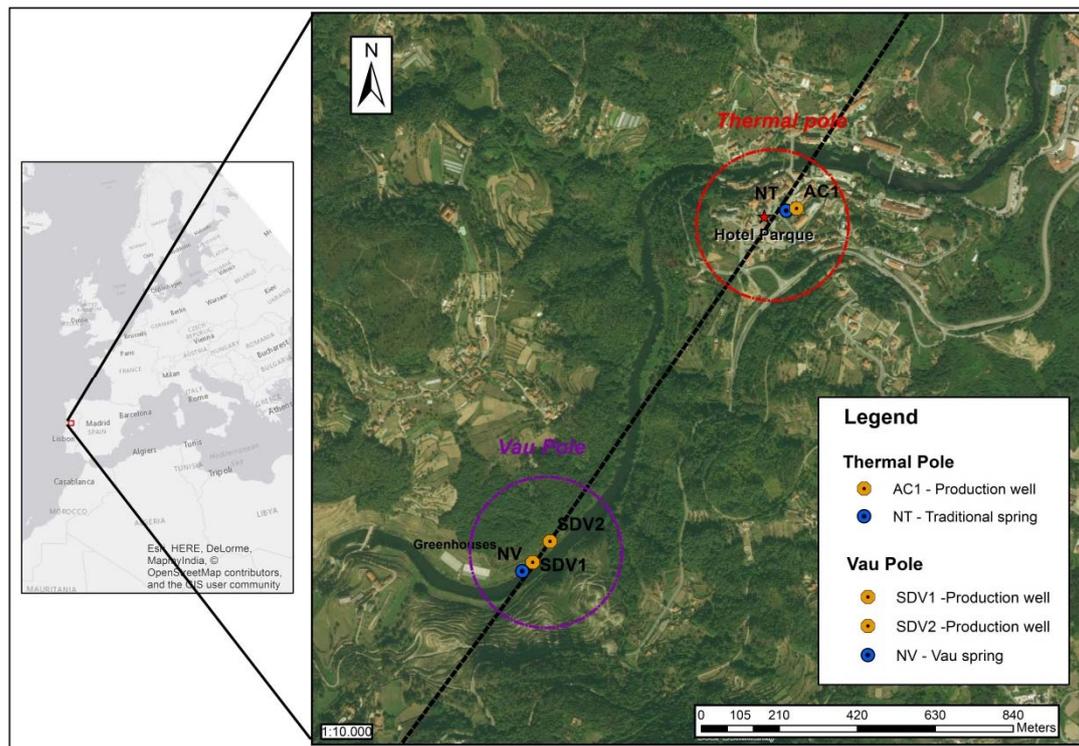


Figure 1. Vau and Termas Poles, including location of Hotel do Parque

In the TP the hot water production comes from both the traditional mineral hot spring (TMHS) and the AC1 well with a sum flow rate of about 16.9 L/s with an average temperature of 67 °C. Due to the small distance between well and spring, the hydraulics circuits of the spring and well interfere each other under well production. Under well AC1 shut in conditions, the spring flow rate output reaches 10 L/s, whereas under well artesian maximum production (12.2 L/s) the spring output reduces to 4.7 L/s. There is no substantial temperature change under spring and well production rates. Maximum temperature spring record was 69°C [1]. In order to maintain stability in the water quality, the recommended flow rate is as follow: 6.9 L/s from well AC1 and 10.0 L/s from TMHS. Bathers reached about 25000 on year 2015. Two main bathing resorts use directly the mineral hot water: the Balneário Rei D. Afonso Henriques and the Balneário Rainha Dona Amélia. After heat exchange from the production hot water sources (AC1 and TMHS) to water closed secondary circuit, part of the geothermal heat is being used for district heating system on the São Pedro do Sul village. Here we describe the case of Hotel do Parque, one of the users of this geothermal heat source.

In the VP, distanced about 1.3 km south to the TP (Figure 1), two exploration wells were executed: SDV1 and SV2. SV1, a producer well, is supplying about 1.5 L/s of water at 67 °C for greenhouse heating, where bananas and pineapples are being cultivated. SVD2 well is being used for monitoring purposes. Research made on the VP [3] gave indications of reservoir exploitation capacity of around 10 L/s to 15 L/s of fluid of expected temperature up to 75°C.

The SPSHGF has been investigated since the beginning of XIX century. Detailed geological, hydrogeological, and chemistry data source can be found on several published papers [4, 5, 6, 7].

2. The thermal power plant layout

The use of heat from the hot sources (well AC1 and spring), a geothermal utilization, was designed in order to augment to the maximum the heat source potential. Direct use of the water is only possible in thermal balneary, as a medical use. So, in order to use the geothermal heat for other users than balneary, one must use a heat exchanger and a secondary fluid, in order to transport the heat to the final users. In fact, the system layout, here called the District Heating System (DHS), is a little bit more complex. It includes (Figure 2): the Thermal Power Plant (TPP); the Pipeline Circuit; the Final User Facilities.

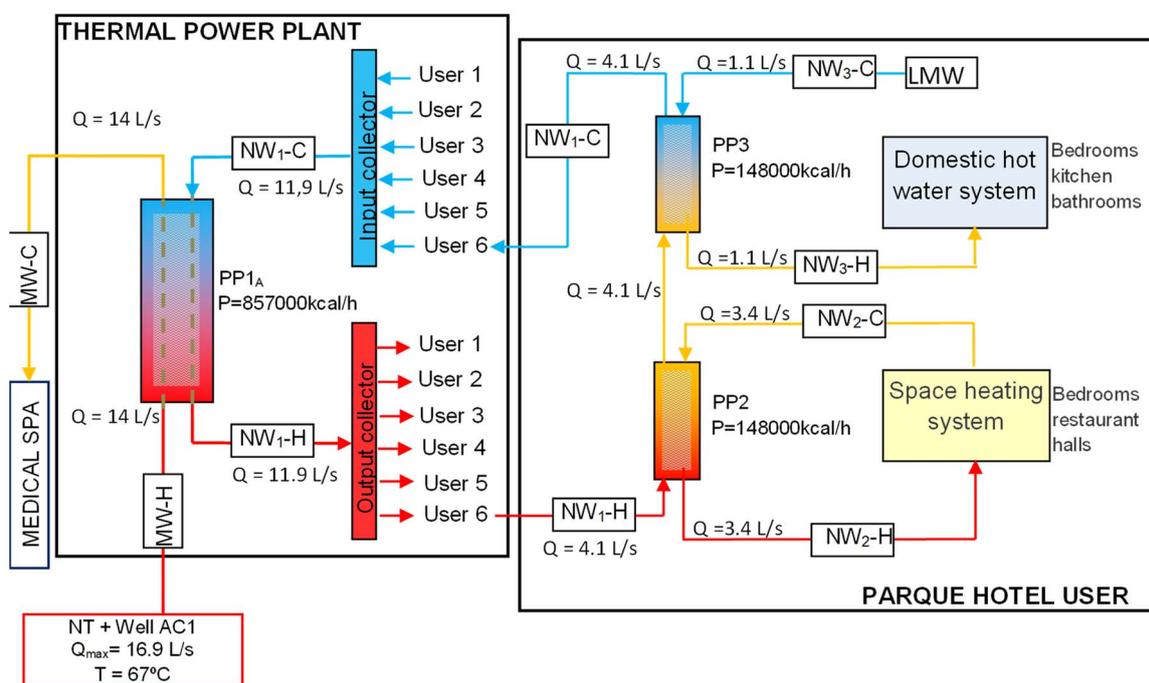


Figure 2. Layout of the District Heating System which include the Thermal Power Plant; Pipeline System; Hotel do Parque user [7]

The TPP (Figure 2) receives the geothermal fluid (the mineral hot water) from the well AC1 and MTS (on Figure 2 named NT) (MW-H: flow rate 14 l/s; 67°C). By means of a plate heat exchanger (PP1_A), the main heat exchanger of the system, the heat is transferred to a secondary low mineralized water (NW₁-H) pipeline circuit. The cooled mineral water leaves the NW₁-H at a temperature of 50 °C for balneary utilization. The NW₁-H, pumped at a flow rate of 11.9 L/s, is heated from a temperature of around 40 °C to 60 °C, and sent to the final users. For each end user there is an independent circuit (NW_{1, 2, 3 ...}-H). Afterwards the utilization of the water by the final users, the cooled water will return back to the TPP (NW₁-C). Those mentioned data (flow rates and temperatures) are nominal project design values. Real operation numbers will be presented here for the case of Hotel do Parque, an end user of the DHS. The system was designed for 6 end users of geothermal energy. In order to heat the several rooms inside end users buildings, two additional heat exchangers and circuits were designed for the Hotel do Parque case (Figure 2): PP2 heat exchanger heats the air, whereas PP3 heats the domestic waters. NW₂, for space heating purpose, is a closed circuit whereas the NW₃, for the sake of domestic waters use, is an open circuit. On figure 2 the design values of the system are shown.

The geothermal energy obtained from the hot mineral water, in cold days, contributes for the space heating of several rooms of three installations: The Hotel do Parque (128 bedrooms); Pousada da Juventude (128 bedrooms), and the Exhibition Room. The Exploitation Plan, a legal request, was implemented in 2001 [8].

From the DHS commissioning, a system was installed to control and monitor all the Thermal Power Plant devices. Due to maintenance issues the system experimented problems and data recording interruptions over the time length of functioning.

3. Energy balance and project design

The thermal available power by TMSH and Well AC1 can be calculated according:

$$P = mC_p(T_f - T_i) \quad (1)$$

, where P is the available power (kW), m the mass flow (kg/s), T_f and T_i the final (or abandoned) and initial temperatures, respectively, and C_p the water specific heat ($\text{kWkg}^{-1}\text{C}^{-1}$). Based on an initial temperature of 67°C for a volume flow rate of 16.9 L/s, and assuming a full year use of that energy, we calculate and yearly theoretical potential energy of $29.1 \cdot 10^6$ kWh. Taking into consideration the energy balance at PP1 (flow rate of 14 kg/s and T_f and T_i of 50°C and 67°C , respectively), the potential energy utilization on an annual basis is $8.7 \cdot 10^6$ kWh, about 30% of the available energy.

The preliminary design for the Hotel do Parque building (120 bedrooms) estimated a total yearly energy demand of about $3.55 \cdot 10^5$ kWh [2]. Those calculations were based on a utilization of $1.50 \cdot 10^5$ kWh for domestic heating and $2.05 \cdot 10^5$ kWh for space heating. The input design for domestic waters (open circuit) heating system (PP3), from 15°C to 50°C temperature water increment, considered a hotel usage of 70% (two persons by bedroom) and a domestic water consumption of 60 L/day. In the space heating case (PP2), the design assumptions took onto consideration an average demand of 11.6 kWh/bedroom/day for 7 months with average hotel use of 70%.

The district heating system of Hotel do Parque was commissioned in 2001. Here we present some data recorded by the monitoring system for the year 2003 (Tables 1 and 2). As we can outline from the data, the energy consumption reaches the maximum in winter times whereas the minimum consumption corresponds to the summer period, where there is no need for space heating, by the contrary, cooling is needed.

The operation data exposed on Table 1 is somewhat different from the design. The average production temperature of well AC1 is lower (65.7°C) than temperature design (67°C), probably due to pipeline heat loss and or changes in the source temperature. The mineral water temperature after leaving PP1 heat exchanger (58.6°C) is higher than designed (50°C) because Pousada da Juventude user was not connected to the system at the time of data recording; moreover, for the same reason, the recorded temperature difference between T_o and T_f (in average 7.1°C) was lower than designed (17°C). The same justification applies for the returning water temperature (PP1): designed, 40°C ; real data, 52.0°C . Due to the short distance (around 100 m) and pipe insulation, there is a small temperature gap (0.53°C) between TPP and end user Hotel do Parque facilities (Figures 1 and 2).

Table 2 presents the statistics of daily Energy use of Hotel do Parque for the year 2003. The differential use of energy for space heating in hotter days is opposite to colder days (winter and summer), explains mostly the differences between minimum and maximum consumptions. No heat is used in the hotel for air heating in the hotter days. Some data gaps on January and September results on biased statistics for those months.

Table 1. Recorded data and statistics for the year 2003 for the user Hotel do Parque.

Month	To AMQ	Tf AMF	To-Tf	T1 ANM1	T2 ANM1	T6 -ANM1F	T1-T2	T1-T6	T3 ANM2 F	Energy (kWh)
Jan	65.4	56.7	8.7	59.5	58.8	41.3	0.7	18.2	20.4	20730
Feb	65.5	56.3	9.2	59.2	58.4	50.2	0.8	9.0	31.0	34080
Mar	65.6	56.4	9.2	59.2	58.5	50.2	0.7	9.0	48.8	45050
Apr	65.6	58.2	7.4	59.2	59.7	49.0	0.7	11.4	52.2	35920
May	65.7	60.4	5.3	60.4	61.7	55.0	0.4	7.1	37.2	34360
Jun	65.8	61.8	4.0	62.1	62.9	57.3	0.3	5.9	25.7	15360
Jul	65.8	61.8	4.0	63.2	62.8	57.1	0.3	6.0	26.1	13290
Aug	65.9	61.6	4.3	63.1	62.7	56.6	0.2	6.3	28.5	15860
Sep	65.9	61.3	4.6	62.9	61.6	55.2	1.1	7.5	27.3	17090
Oct	65.7	58.9	6.8	62.7	60.5	53.4	0.4	7.5	32.0	31460
Nov	65.7	56.2	9.5	60.9	58.7	50.4	0.3	8.6	50.2	43510
Dec	65.6	53.7	11.9	57.2	56.8	48.1	0.4	9.1	46.5	41570
Min	65.4	53.7	4.0	57.2	56.8	41.3	0.2	5.9	20.4	13290
Med	65.68	58.61	7.08	60.78	60.26	51.98	0.53	8.8	35.49	29023
Max	65.9	61.8	11.9	63.2	62.9	57.9	1.1	18.2	52.2	45050
Stand Dev	0.15	2.76	2.64	2.00	2.06	4.71	0.27	3.36	11.11	11872.97

AM: mineral water; Q: hot; F: cold; T: temperature (f, final, o, initial); ANM: low mineralized water. 1 and 2 are circuit numbers.

Table 2. Statistical information of recorded energy use (kWh) on Hotel do Parque for the year 2003.

Month	Daily			Monthly	
	Minimum	Medium	Maximum	Month value	Statistics accumulated
Jan	0	401	1080	12430	12430
Feb	160	650	1070	18190	30620
Mar	730	1259	1580	39050	69670
Apr	390	1116	1490	33500	103170
May	360	755	1350	23440	126610
Jun	350	466	630	13980	140590
Jul	370	477	640	14790	155380
Aug	350	538	790	16700	min=12430 172080
Sep	60	611	810	18390	med=24721 190470
Oct	640	923	1840	28650	max=41710 219120
Nov	620	1193	1920	35820	254940
Dec	1050	1345	2000	41710	296650

On Table 3 we present the thermal energy consumed for the years 2002, 2004, 2005, and 2008. The data for years 2006, 2007, and 2009 display some gaps due to malfunction monitoring system and for that reason are not shown.

The geothermal energy used on the Hotel do Parque for the years displayed on table 3 are in line with project design figures but distant from the available geothermal power of de DHS (4.1%) and from the spring and well production energy potential (1.2% - 1.6%). Due to improvements on space heating system on Hotel do Parque the heat consumption increased 2005 onwards.

Table 3. Energy comparison of DHS and Hotel do Parque Project (design and operation).

Energy (year base)	ID	10 ⁶ kWh/year	Percentage by ECD	Percentage by ECP	Percentage by designed	Comments	
Potential thermal energy available in Termas	ECD	29.1				Ti=67°C; Tf=20°C; Q=16.9 L/s	
Potential thermal energy available DHS	ECP	8.73	30,0%			Ti=67°C; Tf=50°C; Q=14.0 L/s	
Hotel do Parque energy demand (designed)	ECD	0.355	1.2%	4.1%		Space heating : 205134 kWh Domestic waters: 149820 kWh	
Energy used on Hotel do Parque	2002	ECD	0.348	1.2%	4,0%	98%	On year 2005 the space heating system on Hotel do Parque was improved
	2003	ECD	0.297	1.0%	3.4%	84%	
	2004	ECD	0.351	1.2%	4.0%	99%	
	2005	ECD	0.441	1.5%	5.1%	124%	
	2008	ECD	0.457	1.6%	5.2%	129%	

4. Economic and environmental system balance

The district heating system of São Pedro do Sul is far from saturation. The Hotel do Parque is the sole complete nonstop running system. Nevertheless, after 15 years of commissioning, the Hotel do Parque system is in full operation, turning possible the use of a renewable energy source, reducing the fossil fuels utilization. Without this energy use (assuming the energy consumption of 456950 kWh, as 2008 figure), and taking into consideration an actual price of 2.16 euros by kg of propane gas (specific energy of 12.9 kWh/kg with 90% of efficiency on heat transfer) we reach a total year price of 85014 euros. In case of electrical power use (0.236 euros/kWh) the figure will increase to a theoretical cost of 107840 euros. The geothermal energy runs without CO₂ emissions in comparison with gas power and most electrical power units, thus making geothermal energy a clean and friendly energy source. By considering the theoretical CO₂ emission from the propane gas burning process (2.995 kg of CO₂ emission by 1 kg of burning gas), the annual emission reduction is estimated as 117.9 ton of CO₂.

According to Cardoso [9], taking into consideration 50% of investment (50% of the project investment was ECC financed), the maintenance costs and the energy used on both Hotel do Parque and Pousada da Juventude, the payback period was calculated on 25 years (income used was 3%). Additional users must be incorporated in the district heating system in order to reduce the payback period. If all the theoretical available energy (29.1*10⁶ kWh) was used, and considering an actual cost of 0.236 euros/kWh, the yearly income would be 6.87*10⁶ euros, with a potential reduction of 7507 ton of CO₂ emissions by year. The actual results are interesting, promoting use of clean renewable energy on a beautiful and amazing natural region, thus contributing for healthy life style.

The District Heating System makes uses of small room space and most of the devices are buried, almost without environmental impact. Moreover, most of fluid is done in a closed pipeline circuit. Additionally, the temperature falling on the mineral water reduces water disposal impacts on rivers [7].

5. Conclusions

On this paper we presented the geothermal direct use energy of Hotel do Parque, including project design and real data of the thermal power plant specifications and end users. Heat comes from a 16.9 L/s flow of water at a temperature around 67 °C, supplied by a natural spring and a nearby production well, used for Balneology on Termas buildings, which receives about 25000 bathers every year. By means of a heat exchanger, heat powers space and domestic waters in Hotel do Parque and Pousada da

Juventude. The District Heating System only uses a small portion (1.2% to 1.6%) of the potential of the system calculated as $29.1 \cdot 10^6$ kWh yearly.

One of the main users is the Hotel do Parque, a 120-bedroom capacity unit, who utilizes the heat for both space and domestic water heating. After commissioning in 2001, the design figures are close by to the real data collected by the monitoring system. The geothermal energy used on the Hotel do Parque are in line with project design figures but distant from the available geothermal power of the DHS (4.1%).

By consideration the theoretical CO₂ emission from the propane gas burning process the annual reduction is estimated as 117.9 ton of CO₂. If all the theoretical available energy, $29.1 \cdot 10^6$ kWh, was used, and considering an actual cost of 0.236 euros/kWh, the yearly income would be $6.87 \cdot 10^6$ euros, with a potential reduction of 7507 ton of CO₂ emissions by year. The successful use of this district heating system can promote local expansion of new users and other possible heat uses of this renewable energy, giving chance for the District Heating System saturation.

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