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INTRODUCING GEOTHERMAL ENERGY INTO EXISTING DISTRICT HEATING SYSTEMS – SUCCESSFUL EXAMPLES FROM SLOVAKIA

ABSTRACT

In the case of Slovakia, an abundance of geothermal water reservoirs and the existence of many district heating systems present optimal conditions for introducing geothermal energy and enhancing geothermal project development. During the last three years, two such projects were implemented in Slovakia which focused on incorporating geothermal energy into existing district heating systems. The projects are located in the towns of Sala and Sered in the Danube basin, and are very similar to each other ? old natural gas burned central boiler plants with a wide distribution network were present in both towns. New production geothermal wells were drilled in both locations, and piping and heat exchanger stations were built and connected to the existing boiler plants' circuits. Heating water and hot tap water is now prepared using geothermal energy, achieving significant natural gas savings and CO_2 emissions reduction. Good project design and conception has been confirmed after several months of operation, and geothermal energy has proven to be the optimal RES in particular localities. These projects create good examples how old fossil fuel based district heating systems can be modernised and optimised by adding a geothermal heat source. They constitute good examples to be studied in other CEE countries possessing many centralised heating systems which require modernisation, optimisation, and ecological improvement. These factors can be achieved by incorporating geothermal energy as one of the applied energy sources.

KEY WORDS

Geothermal district heating, direct geothermal energy uses, natural gas saving, CO_2 emission reduction, Slovakia

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INTRODUCTION

In Europe, Slovakia belongs to the group of countries with above-average geothermal carditions. A great deal is already known thanks to extensive surveying of geothermal structures and areas due to many hydrogeologic and also hydrocarbon exploration wells completed within survey works directed by the state. This knowledge and effort resulted in the completion of the "Atlas of Geothermal Energy of Slovakia" (Franko et al. 1995) where the prospective areas are selected and described. Most of the geothermal reservoirs in the country are low-enthalpy reservoirs and provide geothermal water with a temperature lower than 100°C. This is insufficient for efficient power generation but optimal for district heating purposes (Halás 2009).

Mass housing development which took place in the 1970´s and 80´s typically employed centralized heating systems. Therefore, there is a district heating system in almost every town in Slovakia. Presently the efficiency of many of them is on the edge of acceptable limits, and it is necessary to begin renovating this infrastructure. Within the framework of district heating renovation, the local possibilities for adopting renewable energy resources must be taken into account. In selected areas, geothermal energy appears to be one of the most convenient alternative energy resources. Using available geothermal energy in a district heating system represents a stable, economical, and ecological renewable energy resource. The aim of this paper is to provide an overview of the newly implemented geothermal district heating projects in the towns of Sala and Sered.

Sala and Sered are both located in the southwest part of Slovakia (fig. 1), in the warmest and most fertile area with the longest period of sunshine during the year. These localities belong to the central depression of the Danube basin from the geological point of view. The Vah River, the largest Slovak river, flows through both of the towns. In 2012, the population of Sala and Sered was 23,440 and 16,214 inhabitants respectively. Several district heating systems owned and operated by the municipalities were built in these towns. The annual heating period lasts approximately 210 days.

Fig. 1. Location of the towns of Sala and Sered in Slovakia (map source: www.tatry-ubytovanie.com)

Rys. 1. Położenie miast Sala i Sered na Słowacji (mapa: www.tatry-ubytovanie.com)

1. EXPLOITATION AND TECHNICAL CONDITIONS OF GEOTHERMAL WATER USED IN NEW DISTRICT HEATING SYSTEMS IN THE TOWNS OF SALA AND SERED

New, 1,800 m deep geothermal production wells have been drilled in both towns. Collectors for geothermal brine are created by sandstones. Reservoirs are semi-open, i.e. recovery of the reservoir is provided by natural water inflow. Submersible electric pumps are installed in order to provide sufficient pressure of the geothermal water in the whole system. Basic parameters of the wells are outlined in table 1.

Table 1

Sala and Sered: parameters of geothermal water discharged by production wells (TDS – total dissolved solids)

Tabela 1

Sala i Sered: parametry wód geotermalnych ujętych otworami produkcyjnymi (TDS – zawartość substancji rozpuszczonych w wodzie)

Town	Well name	Temperature on well head	Flow rate by pumping	TDS
		[°C]	[m^3/h] ([l/s])	[g/m^3]
Sala	GTS-1	73	54.0 (15)	5,200
Sered	SEG-1	66	28.8 (8)	5,100

Discharged geothermal brine has corrosive properties, while a scaling effect does not appear under the conditions maintained in these systems. Therefore, geothermal systems in both towns are equipped with corrosion resistant materials (piping and valves of stainless steel and plastic, heat exchangers of titanium) in order to avoid corrosion problems.

In the town of Sala, geothermal energy is being used in the large boiler plant CK31, where four natural gas boilers of 20.7 MW of total thermal output are installed. The installed capacity is strongly over-designed in relation to recent heat consumption (extensive installation of external thermal insulation on apartment houses has taken place), and significantly lower heat production is needed even during an extremely cold period. The designed temperature gradient of heating water is 100/50°C; but most of the year, lower return heating water temperature is being achieved. The distribution network supplies 82 pressure independent heat exchanger stations situated in apartments and public service buildings. Annual heat production of the CK31 boiler plant averages 75,000 GJ (20,833 MWh). The geothermal well GTS-1 is located approximately 200 m west of the boiler plant. Geothermal brine is transported via a pre-insulated pipeline to a heat exchanger station placed at the boiler plant site (fig. 2). Two stages of direct geothermal water uses are employed: in the first stage, return heating water is being warmed; in the second stage, the water from the heat pump evaporator loop is being warmed while the heat pump warms the return heating water. Parameters of the mentioned devices are outlined in Table 2. Geothermal energy combined with the heat pump provides the base load heat source, while natural gas boilers are used

Fig. 2. Geothermal heat exchanger station in CK31 boiler plant in Sala (photo O. Halas)

Rys. 2. Stacja geotermalnych wymienników ciepła w kotłowni CK 31 w miejscowości Sala (fot. O. Halas)

during peak demand or as a back up source. Thermally used geothermal brine is drained via an 800 m long plastic pipeline into the Vah river.

In the town of Sered, the advantage of geothermal energy is realized in the medium size boiler plant K5, where four natural gas boilers of 8.7 MW of total thermal output are installed. The installed capacity is, as in Sala, over-designed since substantially lower heat production is needed throughout the whole year. The designed temperature gradient of heating water is 65/45°C. The distribution network supplies 20 pressure dependent heat exchanger stations situated in apartments and public service buildings, totalling more than 960 apartments. Annual heat production of the K5 boiler plant averages 25,000 GJ (6,944 MWh). The geothermal well SEG-1 (fig. 3) is located approximately 300 m south of the boiler plant. Geothermal brine is transported via a pre-insulated pipeline to the heat exchanger station placed at the boiler plant site (fig. 4). Two stages of direct geothermal water utilization are employed: in the first stage, return heating water is being warmed; in the second stage, the water of the heat pump evaporator loop is being warmed while the heat pump warms the return heating water. In addition, a natural gas fired cogeneration unit producing heat for the network and electricity mainly for own consumption is installed. Parameters of the mentioned devices are outlined in table 2. Altogether four types of heat sources are installed where geothermal water, a heat pump, and a cogeneration unit provide the base load heat source, while natural gas boilers are used during peak demand or as a back

Fig. 3. Well head of SEG-1 geothermal well and accumulation/degassing tank in Sered (photo O. Halas)

Rys. 3. Głowica otworu geotermalnego SEG-1 i zbiornik akumulacyjno-odgazowujący w miejscowości Sered (fot. O. Halas)

Fig. 4. Geothermal heat exchanger station in K5 boiler plant in Sered (photo O. Halas)

Rys. 4. Stacja geotermalnych wymienników ciepła w kotłowni K5 w miejscowości Sered (fot. O. Halas)

Table 2

Thermal outputs of installed geothermal heat exchangers and other heat sources in Sala and Sered boiler plants (HX – heat exchanger)

Tabela 2

Moc cieplna wymienników geotermalnych i innych źródeł ciepła zainstalowanych w kotłowniach w miejscowościach Sala i Sered (HX – wymiennik ciepła)

Device/Locality	Sala – CK31 boiler plant	Sered – K5 boiler plant
I. stage geothermal HX [MW]	1.3	0.6
II. stage geothermal HX [MW]	0.5	0.5
Heat pump [MW]	0.6	0.6
Cogeneration unit [MW]	–	0.25

up source. Thermally used geothermal brine is drained via a 400 m long plastic pipeline into the Vah river.

2. ENERGY BALANCE

Overall thermal energy production in the Sala and Sered plants for the year 2012, including the contributions of newly installed devices, is summarized in table 3. A graph with relative contributions expressed in percents is shown in figure 5.

Table 3

Overall thermal energy production in Sala and Sered plants (including geothermal) in 2012

Tabela 3

Całkowita produkcja energii cieplnej (w tym geotermalnej) w ciepłowniach w miejscowościach Sala i Sered w 2012 r.

Locality	Sala – CK31 boiler plant		Sered – K5 boiler plant	
	[GJ]	[MWh]	[GJ]	[MWh]
Geothermal	21,810	6,058	10,177	2,827
Heat pump	5,876	1,632	6,736	1,871
Boiler	46,102	12,806	7,294	2,026
Total	73,788	20,497	24,207	6,724

With respect to the parameters of given district heating systems and geothermal conditions of the localities, it is unfeasible to completely replace natural gas boilers with geothermal energy. However, the above described rate of geothermal energy use led to natural gas savings of 860,000 m^3 in Sala and 530,000 m^3 in Sered per year, 2012. These

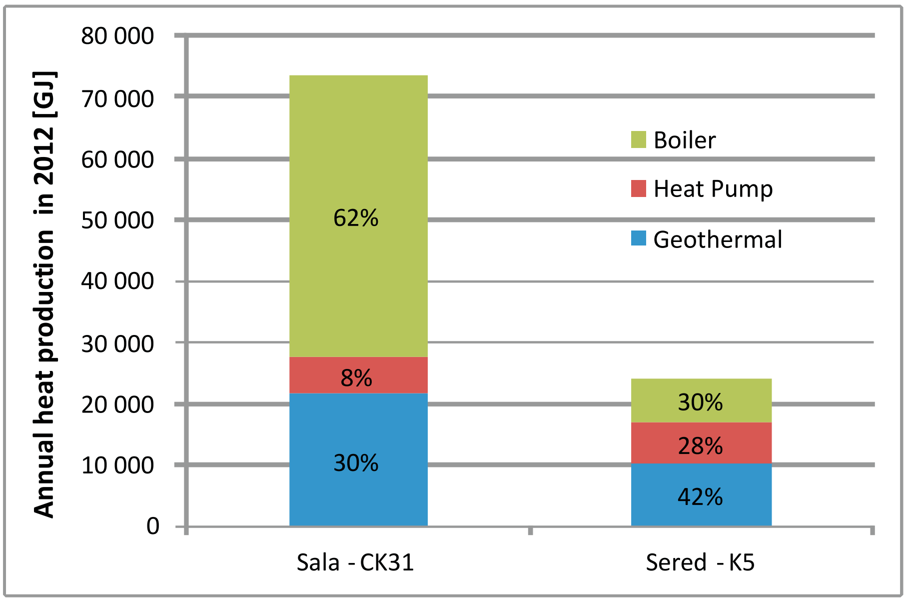

Fig. 5. Overall thermal energy production in Sala and Sered boiler plants in 2012. Contribution of each heat source installed is depicted

Rys. 5. Całkowita produkcja energii cieplnej w kotłowniach w miejscowościach Sala i Sered w 2012 r. Pokazano udział każdego z zainstalowanych źródeł ciepła (boiler – kotły gazowe, heat pump – pompy ciepła, geothermal – energia geotermalna)

figures therefore indicate a valuable asset from a technical, economical, and also ecological point of view.

3. ENVIRONMENTAL AND ECONOMIC ASPECTS

Replacing natural gas consumption with geothermal energy resulted in a reduction in CO_2 emissions of 1,837 tons in Sala and 1,122 tons in Sered in 2012.

Considering the economic aspects, one of the very few weak points of geothermal energy use is the relatively high initial investment cost in comparison with other renewables. This inconvenience was also faced in the projects described in Sala and Sered. Thanks to extensive efforts on the part of all involved parties, a commercial loan was obtained covering 90% of the investment costs for both projects following lengthy negotiations. Structural funds or other non-refundable subsidies were unavailable due to several mainly administrative obstructions in the subsidy system. The investment return period for the projects was calculated to be approximately 10 years.

The heating costs for the final customers – after implementation of the geothermal projects – do not change in the initial years. This is because the savings on natural gas approximately cover the loan repayments and interest. However, as soon as the loan is paid, the heating costs will decrease significantly. The reduction in the dependence on natural gas also results in higher stability of the heating costs.

4. CLOSING REMARKS

The above average occurrence of geothermal resources in Slovakia, their thorough exploration, and the existence of extensive district heating networks constitute good conditions for the implementation of new geothermal projects focused on space heating in the towns. Geothermal energy is an environmentally friendly, local, and stable renewable resource which is independent of climatic and market conditions. It is worth pointing out that rising natural gas prices are a strong motivation for heat producers and municipalities to support and develop geothermal projects. Moreover, newly launched geothermal projects in Sala and Sered confirm that well designed and implemented projects are economically feasible without any subsidy. Currently, the preparation of further geothermal projects of a similar scale and conceptualization (i.e. introducing geothermal energy into existing heating systems) are presently at various stages of realisation in Slovakia. Hopefully, after the good experience with the presented projects, the other planned implementations will soon be effectual.

The projects in Sala and Sered represent examples to follow in other countries, especially those in Central and Eastern Europe. Such locations also possess many centralised heating systems which require modernisation, optimisation, and ecological improvement. These factors can be achieved by incorporating geothermal energy as one of the applied energy sources. Recently, such possibilities and solutions have been considered by, among others, two European projects involving several countries, namely GEOCOM (www.geothermal-communities.eu) and GeoDH (www.geodh.eu).

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WPROWADZENIE ENERGII GEOTERMALNEJ DO ISTNIEJĄCYCH SYSTEMÓW CENTRALNEGO OGRZEWANIA – UDANE PRZYKŁADY ZE SŁOWACJI

STRESZCZENIE

Słowacja, która charakteryzuje się występowaniem licznych zbiorników wód geotermalnych oraz – jednocześnie – istnieniem wielu pracujących sieci centralnego ogrzewania (c.o.), posiada optymalne warunki dla wprowadzania energii geotermalnej do takich sieci. Będzie to skutkować redukcją zużycia paliw kopalnych, a także zachęcać do realizacji projektów geotermalnych. W ostatnich trzech latach zrealizowano na Słowacji dwa projekty dotyczące włączenia energii geotermalnej do istniejących systemów c.o. W każdej miejscowości wykonano nowe otwory geotermalne, wybudowano rurociągi wody geotermalnej i stacje wymienników geotermalnych, które podłączono do układów istniejących kotłowni. Ogrzewanie i ciepła woda użytkowa pochodzą obecnie z geotermii, dzięki czemu znacząco zredukowano również emisję CO_2. Słuszność koncepcji i dobre zaprojektowanie prac znalazły potwierdzenie po kilku miesiącach funkcjonowania instalacji, a energia geotermalna sprawdziła się jako optymalne odnawialne źródło energii. Projekty te są dobrymi przykładami, a jaki sposób stare, oparte na paliwach kopalnych sieci centralnego ogrzewania mogą być zmodernizowane i zoptymalizowanie przez dodanie geotermalnego źródła ciepła. Stanowią one przypadki studyjne warte naśladowania także w innych krajach Europy środkowo-wschodniej. Kraje te posiadają bowiem wiele scentralizowanych systemów grzewczych, które wymagają modernizacji i ich pracy w sposób bardziej prztyjazny dla środowiska – można to osiągnąć poprzez włączenie energii geotermalnej jako jednego ze źródeł energii.

SŁOWA KLUCZOWE

Sieci c.o., energia geotermalna, oszczędność spalania gazu naturalnego, redukcja emisji CO_2, Słowacja