Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Geothermal Heat and Water Management in the View of Improving Economic Conditions of Geothermal District Heating in Uniejów

Aneta Sapińska-Śliwa, Andrzej Gonet

Drilling, Oil and Gas Faculty, AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Cracow, Poland

ans@uci.agh.edu.pl, gonet@uci.agh.edu.pl

Keywords: geothermal utilization, district heating, economic analysis

ABSTRACT

Possibilities of potential managing geothermal water and heat in Uniejów (C-Poland) are presented in the paper. Multivariant analyses treated the existing state of management as a basis to be developed and broadened by unused low-temperature heat potential and new possibilities of increasing the heat and water demand. The economic analysis lied in checking out how the NPV values are changing. The analysis was preceded by the analysis of environmental influence on the development of a geothermal district heating operating in the Polish conditions. The results of analyses are also applicable to other planned investments making use of geothermal waters in the Polish Lowland region.

1. INTRODUCTION

Uniejów town (3200 of population) is localized in the north-western part of Łódź province at the Warta River, Central Poland. The Uniejów town and county cover a total area of 129 km^2. The Lower Cretaceous geothermal waters (artesian production rate of 67 m^3/h and 120 m^3/h with a deep pump, temperature 69^{o}C) were documented with three wells in the Uniejów area. Waters were classified as chloride-sodium, with mineral content ca. 6.8 to 8.8 g/dm^3. Geothermal waters can be found at ca. 2000 m of depth. The water-bearing horizon consists of Lower Cretaceous sediments belonging to the Mogilno-Łódź Synclinorium (Bojarski and Sokołowski 1991; Bentkowski et al. 2001; 2005).

2. GEOTHERMAL DISTRICT HEATING

The geothermal district heating system has been operational since 2001. At present the maximum rate of ca. 100 m^3/h water is used during heating season and the water is cooled to maximum ca. 45^{o}C. Accordingly, the employed power of geothermal source is ca. 2.75 MW. The power of the peak source of heat (biomass-fed boilers) is 1.8 MW, and the reserving sources (oil boilers) 2.4 MW. Biomass-fed boilers were installed in 2006 owing to the very high cost of unit energy production with two oil boilers during the peak season.

Geothermal district heating providing heat to the municipal network water system is based on a triplet of wells, two of them being injection wells: Uniejów PIG/AGH-1 and Uniejów IGH-1 (the latter one implemented in 2005). The geothermal water production from well Uniejów PIG/AGH-2 can be either artesian or with a deep pump. Water is running through a pipeline to one or two injection wells. This system is equipped with a set of filters. The peak boiler is to heat up network water to ca. 56^{o}C to 70^{o}C in the case of low temperatures outside. The outside temperature of atmospheric air at which the peak sources are employed to cover the total power demand is –2^{o}C. According to Sapińska-Śliwa 2007, after the development of the geothermal district heating, the temperature at which the peak sources were involved was –5^{o}C. The measurement data of 2007/08 reveal that the peak source was not used and the lowest observed air temperature was -12^{o}C (archives of „Geotermia Uniejów" Sp. z o.o.) However, it should be noted that the power demand was only 2.65 MW.

The Uniejów heating system was made of pre-insulated pipes adjusted to heating water parameters (70/35^{o}C). The system providing hot tap water (HTW) for household and public purposes is central. The HTW demand is based on two two-grade heat exchangers. As the four-line network could not be employed there for all indicated objects, therefore the amount of heat for HTW was compensated for with heat from the central heating system. A technological scheme of the Uniejów geothermal system is presented in Fig. 1.

The power potential of Uniejów geothermal system has not been fully used. As many other geothermal district heating in Poland, Uniejów also has problems with managing heat that can be produced in summer season, when the demand is lowest. The analysis of versatile utilization of water and heat over a 12 month-period shows to the possibility of improving financial output of the geothermal company.

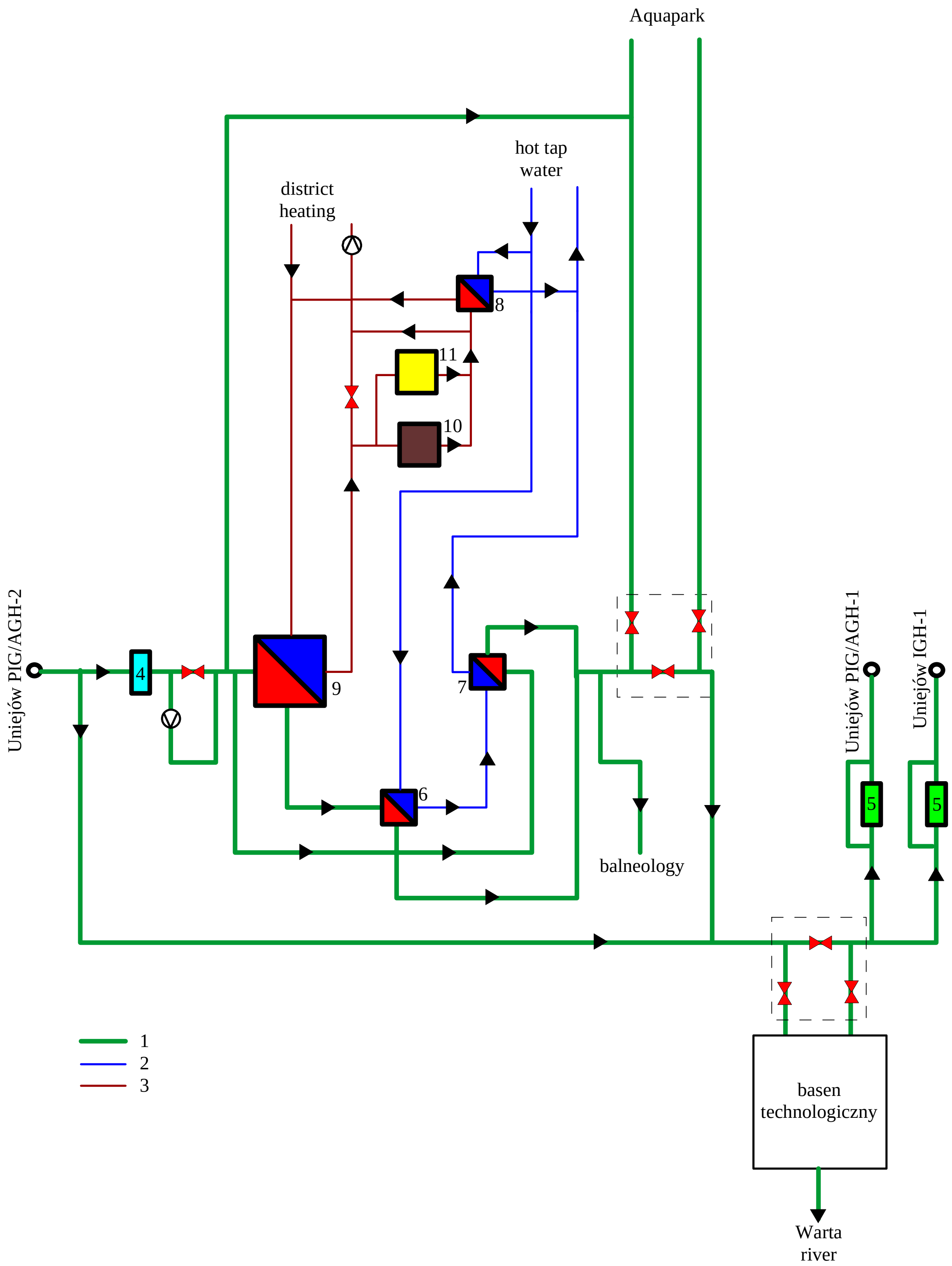
3. USE OF PRESENT GEOTHERMAL POTENTIAL

Since 2002 the amount of sold heat has had a decreasing trend (Fig. 2), which was mainly caused by the fact that regular heat customers thermoinsulated their households and public objects. Moreover, the heat users were more frugal when individual heat counters have been installed. The sales are also influenced by meteorological conditions. In the years 2006-2008 relatively high temperatures were observed in Poland in the heating season.

The quantity of sold HTW should remain on a relatively stable level owing to the unchanged water demand in the years 2002-2008. A lower HTW consumption was probably caused both by its more economic use and conservation works in bigger housing estates and public objects.

Since 2002 a balneology centre has offered effervescing baths, partial baths and inhalations in the seat of the Company, making use of ca. 1 m^3/h of geothermal water.

For recreation purposes ca. 10-15 m^3/h of geothermal water are spent. Since 2008 a Communal Company "Termy Uniejów" utilized a 25 m swimming pool (water 25-27^{o}C in summer and 28-30^{o}C in winter), with a shallow summer pool for children (water 30^{o}C). There is also another shallow pool with geothermal water (33^{o}C in summer and 36^{o}C in winter). Part of geothermal water used for heating purposes in the recreation complex is then directed to the fountains – local attractions.



Denotations: 1 – geothermal water pipelines; 2 – HTW circulation; 3 – district heating circulation; 4 – bag filters; 5 – candle filters; 6,7 - HTW heat exchangers; 8 – reserving HTW heat exchanger; 9 – central heating exchangers;10 – biomass-fed boilers; 11 – oil boilers

Figure 1: Technological scheme of Uniejów geothermal system

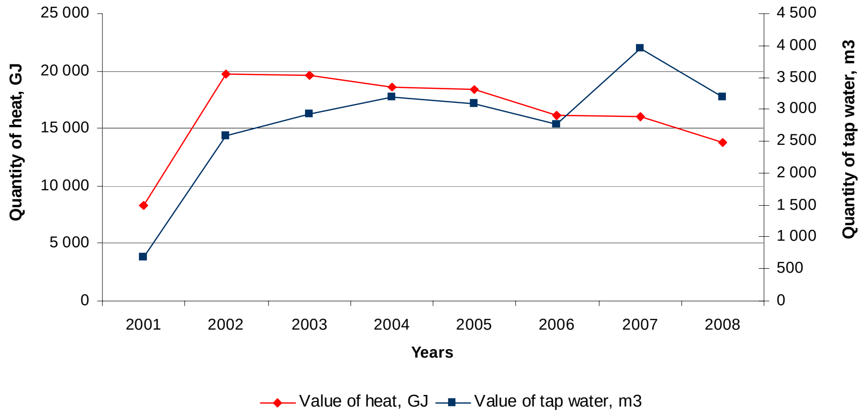


Figure 2: Quantity of heat and water in the years 2001-2008

4. WAYS OF MANAGING HEAT

After giving off the heat to network water in heat exchangers, the Uniejów geothermal water has temperature of ca. 45°C. It suffices to use the encapsulated energy for other purposes. To increase the use of geothermal water, a suggestion was made to recuperate heat from cooled geothermal water for other purposes than heating interiors or hot tap water. Low-temperature heat was used for heating swimming pools, greenhouses, fish farms or soil heating, sport-ground heating or drying.

The analyses and calculations of low-temperature heat utilization were made for greenhouses, swimming pools, fish farms and sport-ground heating purposes. Meteorological data used in the calculations for greenhouses, fish farms, sport-ground heating, drying plant and swimming pool were taken from the Atlas of Climate in Poland (2007), Atlas of Poland (1998), and Yearly of Environmental Protection (1999).

5. WAYS OF MANAGING WATER

Apart from balneological and recreation purposes, geothermal water with its microlelements is proposed to be used in cosmetology. When analyzing Uniejów geothermal waters for cosmetology applications, attention was paid to their composition, physicochemical and microbiological properties as well as hazardous elements. They were also analyzed for similarity with mineral and geothermal waters already used in cosmetology. The qualitative mineral composition of Uniejów water is similar to that of Vichy geothermal water. Uniejów water has low concentrations of zinc and selen – very important elements for skin and hair treatment. However, if cosmetics production is to be considered, further analyses have to follow to confirm the stability of mineral composition and microbiological purity of water. Uniejów water can be possibly used for the production of sensitive skin preparations, shampoos, shower or bath gels. First recipes have to be worked out and stabile preparations made in laboratory conditions. Then the results have to be confirmed dermatologically.

6. CONCEPT OF DEVELOPMENT

Fig. 3 gives an idea of the proposed heat management thanks to which the geothermal district heating is better employed in the summer season (Sapińska-Śliwa 2009). A full-cascaded system accounting for the analyzed possibilities of heat management in Uniejów as well as suggestions stemming out of the performed analyses are proposed.

Poor management of heat energy for the needs of HTW in its basic variant with derivatives, where no development of heat network is accounted for, is a result of the lack of HTW installations in the housing estates. Therefore, the heat consumption in summer months is very low, which negatively affects the income of the Company in that period. The use of geothermal energy beyond the heating season should be one of the priorities related with the development of the Company.

Bearing in mind the agricultural character of the Uniejów area, the heat is proposed to be used for, e.g. drying in the summer season. The solutions presented in Fig. 3 may be used in a different configuration of the proposed cascade. The potential investors shall dictate the direction of heat management, especially low-temperature heat, which according to the economic analyses is financially profitable.

7. ECONOMIC ANALYSIS OF SELECTED SOLUTIONS

Owing to the influence of numerous macro- and microeconomic factors on the financial output of geothermal district heating companies, three scenarios were accounted for in view of exploitation fee, financial support and energy price trends on local market (Sapińska-Śliwa 2009). The elements defining specific scenarios are listed in Table 1.

Three variants of the scenarios were analyzed. In all of them the necessity to enhance the injection capacity every 5 years has been accounted for, with first such operation in the third year of the planned investment. This frequency was assumed on the basis of similar works performed in other Uniejów wells. According to the plan of reservoir management, the same intervals of study realization were assumed for the existing three wells. The cost of these works is given in Table 2.

For a variant, in which low-temperature heat was assumed (variant II), geothermal water was to be cooled to temperature of 35°C. The unit income from the sale of low-temperature heat was assumed to be 5.74 EUR/GJ (50% the price of present heat). The energy of geothermal water which passed through the heat exchangers used for the production of central heating and HTW was assumed to be the saleable low-temperature heat.

It was also assumed that the construction of utilities for low-temperature heat consumers, e.g. greenhouses, additional swimming pools burdens neither the Company nor the investor. The Company only covers the cost of an additional network with all its elements for the needs of low-temperature heat sales. The most important assumptions for selected scenarios and variants are presented in Table 3.

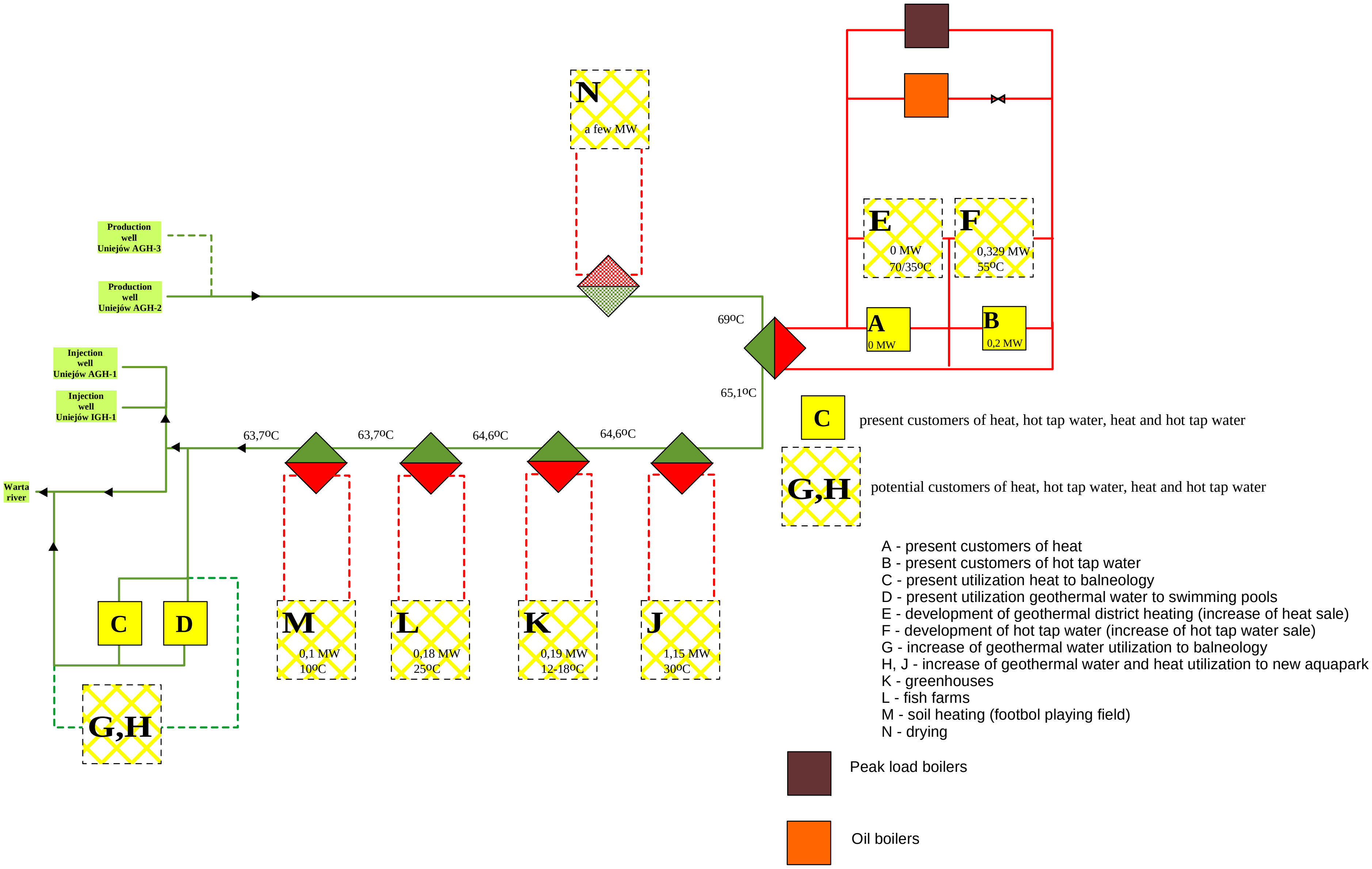


Figure 3: Idea diagram of possible heat management in a cascaded system in June

Table 1: List of macroeconomic factors for specific scenarios

Scenario			pesimistic	reference	optimistic
State's geothermal policy (exploitation fee)			0.0574 EUR/m^3	-	-
State's (region, county) policy regarding energy production from renewable energy sources and environmental protection	financing of improved absorption quality	donations	0%	50%	50%
		credit	90%	40%	40%
		own means	10%	10%	10%
	financing of investments	donations	0%	50%	75%
		credit	90%	40%	15%
		own means	10%	10%	10%
Heat and water prices against the present state[1, 2]			100%	100%	150%

[1] pessimistic/optimistic variant vs. entrepreneur

[2] only prices of balneology service are stable

Table 2: Investment cost of injection enhancement and investigations in the wells

Cost of one well, EUR	Number of wells	Total cost, EUR
Enhancement of injection capacity	2 injection wells	137 700
Tests in wells	2 injection wells and 1 production well	61 965
Total		199 665

Table 3: Assumptions for all scenarios and variants

Assumed parameters	Unit	Value
Costs assumed for the analysis on the basis of data of "Geotermia Uniejów" Ltd.	season	2007/2008
Exploitation time of the installation	years	25
Income tax rate	%	19
Discount rate	%	8
Interest rate of credits	%	10

Table 4: Predicted operating costs of the Company of 2009

Type of cost	Value, EUR	Share in total cost
Material and energy consumption	48 069	22.04%
External services	30 199	13.85%
Taxes and fees	67 741	31.06%
Selaries and liabilities	68 512	31.42%
Other costs	8 518	3.91%
Total	223 039	100.00%

7.1 Description of Selected Solutions

7.1.1 Variant I

Variant I is based on the present situation of " Geotermia Uniejówl" Ltd. as far as costs and income are concerned. Income (197 993 EUR) from heat sales for central heating and HTW was calculated according to the Uniejów geothermal price table (heating season 2008/2009). The average unit net price of heat is 12.35 EUR/GJ, taking into account all the cost-bearing parameters. The rest of the Company's predicted income for 2009 from the sale of geothermal water and balneology services equals to 41 341 EUR.

The predicted cost-bearing factors and other operating costs were calculated on the basis of Company data of 2007/08, see Table 4.

7.1.2 Variant II

This variant accounts for the existing state with the low-temperature heat sale. The income was calculated as a sum of incomes for variant I and additionally incomes from the sale of low-temperature heat. The quantity of the heat and the predicted income from its sale are presented in Table 5. It was assumed that the sale covered 50% total energy that can be managed for low-temperature purposes.

Table 5: Income from the sale of low-temperature heat with assumptions for variant II

Specification	Value
Quantity of recoverable energy	135 093.4 GJ/year
Quantity of energy for central heating purposes	16 036.7 GJ
Quantity of energy for HTW purposes	765.5 GJ
Quantity of geothermal energy for low-temperature purposes	59 145.7 GJ
Pricing of low-temperature heat sales	5.74 EUR/GJ
Income from low-temperature heat sales	**339 496 EUR/year**

7.1.3 Variant III

In this variant the installation was assumed to operate in the present state (variant I) with an additional system for injecting inhibitors and a system for monitoring the physicochemical and bacteriological composition of geothermal water. This variant is focused on operating costs which burden the Company. Assumption was made that an inhibitor injection system will be installed on the bottom-hole. The assumed concentration of inhibitor in the exploited geothermal water was of 3 mg/dm^3. The required quantity of inhibitor was established in view of average geothermal water production from 10 October 2007 to 30 September 2008.

The yearly cost of geothermal water monitoring for physicochemical properties was assessed on the basis of previously proposed method of observation of specific parameters of geothermal water to early indicate changes in water composition, as such changes may later unfavorably affect the installation and the reservoir. The operating cost, including monitoring and inhibitor, totals to 3523 EUR.

7.2 NPV

The results of calculations of NPV after 25 years of life of the investment for the proposed variants are listed in Table 6.

Values of NPV for all scenarios of variant II, where the use of low-temperature heat was assumed, are positive, which makes the investment profitable.

When the operating costs assumed in variant III are reduced, the investment is profitable only for the optimistic scenario.

The present activity of the Uniejów geothermal company does not bring about economic profits. Among the greatest costs are those connected with the necessity to periodically restore the ductability of injection wells. Local taxes are another source of costs. The analysis of NPV values for specific scenarios and variants reveals a possibility of improving Company's situation at definite technological-economic assumptions.

Table 6: List of NPV values after 25 year of life of the investment, EUR

Variant	Scenario			
	pessimistic	reference	optimistic	mean NPV
I	-853 708	**-426 906**	581 537	-329 966
II	1 156 167	2 008 441	4 263 961	2 242 315
III	-962 309	-290 330	911 427	-202 033

7.3. Sensitivity Analysis

The sensitivity analysis was performed for all three scenarios of variant I.

The results enable one to determine the most important factor deciding about the profitability of the geothermal plant. Selected factors were changed from 50 to 200% the values assumed for reference variant I. The results of sensitivity analysis are presented in Figs. 4 to 6.

The plots from above figures may turn out usable for taking strategic decisions. This comparison enables one to determine directions of investment activity for specific assumptions. The increase of discount rate results in more advantageous NPV values for reference and pessimistic scenarios. In the optimistic scenario the NPV value is lowered with the increasing value of discount rate. NPV values decrease both for the reconstruction cost and increase of interest rate of credits. At the increase of yearly sold heat and the unit heat price, the NPV value increases. For all scenarios the investment is most sensitive to the change of heat prices. Similarly, but to a lower degree, it is sensitive to the quantity of sold heat. The reconstruction cost influences the NPV value, most evidently for the pessimistic scenario. The lowest sensitivity was observed to the interest rate of credits.

Owing to the great influence of low-temperature heat sale on the financial effect, also the change of sale on the NPV value was analyzed. The analysis was made for all scenarios of variant II (Fig. 7).

For the reference scenario even a 50% sale brings about positive NPV values, which makes the investment profitable. In the optimistic scenario the NPV value is positive over the entire period of low-temperature heat sale changes; only for the pessimistic scenario the investment is not profitable.

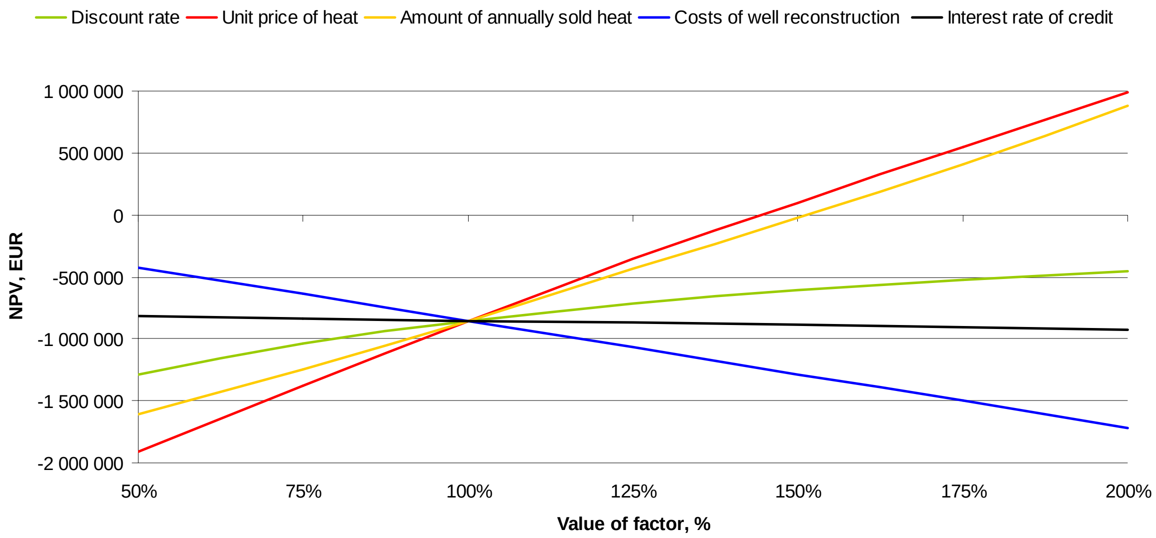


Figure 4: Results of sensitivity analysis of reference variant I for pessimistic scenario.

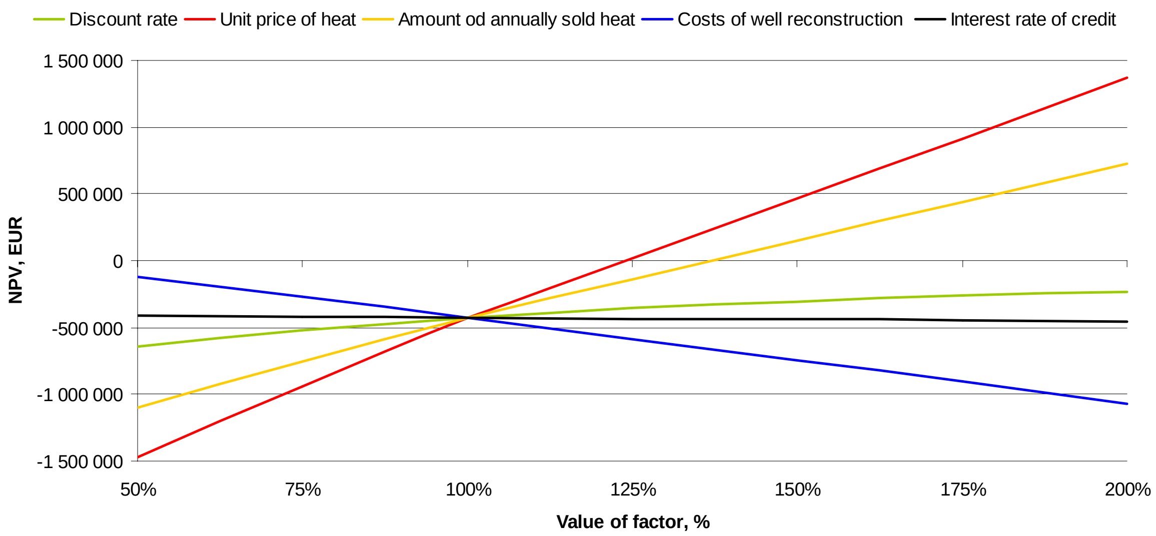


Figure 5: Results of sensitivity analysis of reference variant I for reference scenario.

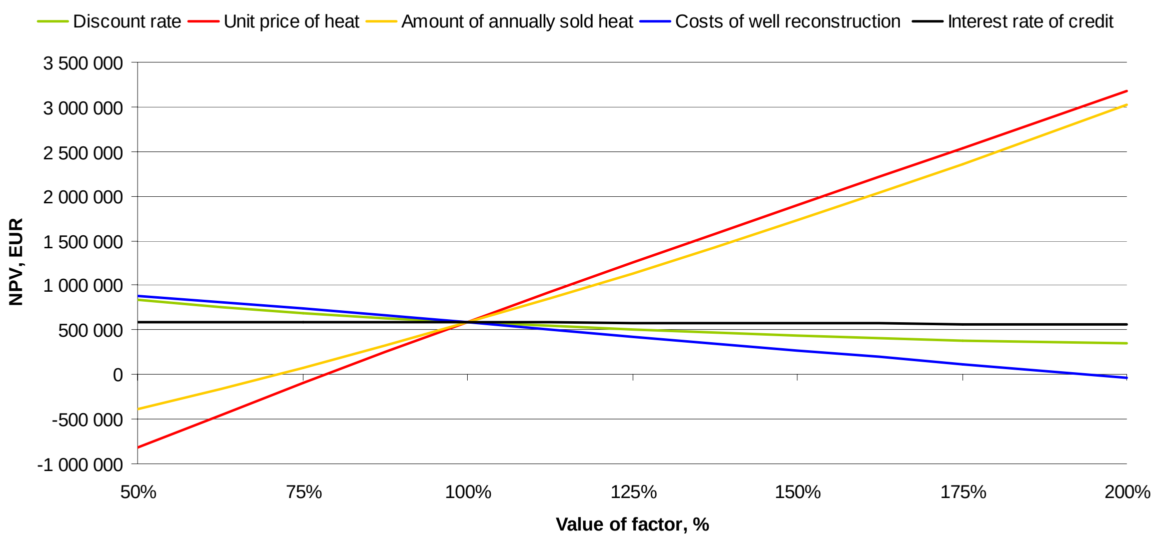


Figure 6: Results of sensitivity analysis of reference variant I for optimistic scenario

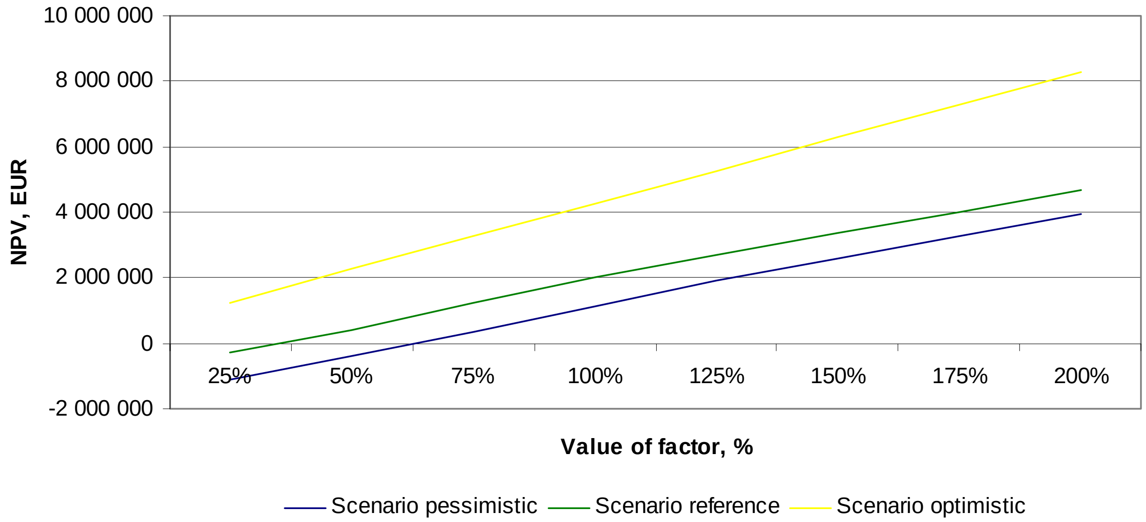


Figure 7: Influence of low-temperature heat sales on NPV

8. CONCLUSIONS

1. After geologic and reservoir recognition, all potential geothermal water investments should be preceded by a detailed technological and economic analysis accounting for all factors which might affect the correct operation of the future installation.

2. Multidirectional use of geothermal water and heat are desirable owing to the increased economic efficiency of and lowering of unit cost of the produced heat. The economic assessment should be made for every undertaking, owing to the existence of numerous factors that can influence the investment. The low-temperature heat can be successfully used for heating swimming pools, greenhouses, fish farms, for soil heating, sport grounds heating or drying. The latter one may be especially profitable in the summer and autumn months because of the agricultural character of the Uniejów area.

3. The cascaded use of heat significantly influences the economics of the undertaking. This is related with the sales of heat and/or water for balneology and recreation purposes. The cascaded use of heat enables introducing its pricelists depending on temperature.

4. Apart from recreation and balneological purposes, geothermal waters can be also used in cosmetology because of their physicochemical and microbilogical properties, lack of hazardous components and presence of healing elements that give no side-effects.

5. The present activity of Uniejów geothermal company is not profitable. The highest cost is related with restoring ductability of injection wells. The Company is also burdened with high local taxes.

6. For analyzing the profitability of the future investment of Uniejów geothermal district heating, three scenarios were assumed: pessimistic, reference and optimistic, for which three technological variants were analyzed. The NPV value for all the scenarios and variants with the assumed use of low-temperature heat, were positive, which speaks for the profitability of the investment.

7. The sensitivity analysis was made for the basic variant and all the tree scenarios. In all scenarios the investment turned out to be most sensitive to the heat price. Similarly, but less sensitive was the quantity of sold heat. Reconstruction costs most influence the NPV value in pessimistic scenario. The investment is least sensitive to the interest rate of credits.

8. The analysis of NPV values for specific scenarios and variants reveals a possibility of improving Company's situation at specific technological and economic assumptions.

REFERENCES

Bentkowski A., Biernat H., Bujakowska K., Kapuściński J.: *Annex to „Documentation of geothermal water resources of category B and C from the Lower Cretaceous beds in Uniejów area,* Geological Company POLGEOL 2001.

Bentkowski A., Biernat H., Kapuściński J, Posyniak A.: *Supplement to documentation establishing productive resources of geothermal water from the Lower Cretaceous beds in Uniejów area, determining the hydrogeologic conditions of injecting waters to the Lower Cretaceous water-bearing beds*. Geological Company POLGEOL S.A 2005.

Bojarski L., Sokołowski A.: *Documentation of geothermal water resources of category C and B in the Lower Cretaceous beds of the Uniejów area,* Polish Geological Institute 1991.

Lorenc Halina (ed).: *Atlas of Climate in Poland,* Wydawnictwo IMiGW, Warszawa 2007.

Data of geothermal district heating in Uniejów. Documents archives of „Geotermia Uniejów" Ltd.

Najgrowski Michał (ed).: *Atlas of Poland. Poland's Geodesist-in-Chief.* Warszawa 1993-1997. Published in 1998.

Yearly of Environmental Protection. Central Pomerania Scientific Society for Environmental Protection. Koszalin. Wydawnictwo ŚPTNOŚ 1999.

Sapińska-Śliwa A. (red.).: *Renewable energy resources in Malopolska region*. *Handbook.* Stowarzyszenie Gmin Polska Sieć "Energie Cités". Kraków 2007.

Sapińska-Śliwa A.: *Technological-economic conditions of geothermal water management in Uniejów*. PhD thesis. AGH University of Science and Technology . WWNiG. Kraków 2009.

The paper was prepared as a part of statutory researches of Faculty of Drilling, Oil and Gas, AGH University of Science and Technology no. 11.11.190.01.