CONSUMER POTENTIAL ANALYSIS OF FEASIBILITY CRITERIA OF GEOTHERMAL PROJECTS

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Abstract: The University of Debrecen, Faculty of Engineering, has been conducting a research program in geothermal energy since 2008. This program enabled me to devise an analytical study of the monetary and non-monetary criteria of geothermal projects. The monetary criteria of a region or a location for geothermal energy production cover the investment costs of the surface installations and the cost of the drillings. Non-monetary criteria include the geological and geothermal evaluations of a reservoir and the evaluation of consumer potential. This paper represents a small part of the larger study and focuses on consumer potential.

1. Introduction

In order to better understand this article, a definition of geothermal energy is necessary. Geothermal energy is heat (thermal) derived from the Earth (geo). It is the thermal energy contained by the rock and liquid that fills the fractures and pores in the rock in the earth's crust.

Geothermal resources can be classified as
- low temperature (less than >90 ºC)
- moderate temperature (90 ºC –150 ºC)
- high temperature (greater than 150 ºC)

The utilization to which these resources are applied is also influenced by temperature. The highest temperature resources are generally used only for electric power generation. Uses of low and moderate temperature resources can be divided into two categories:
- direct uses,
- ground source heat pumps.

Direct use, as the name implies, involves directly applying the heat in the water (without a heat pump or power plant) for a variety of uses, such as the heating of buildings, industrial processes, in greenhouses, aquaculture (the farming of fish) and resorts. Direct use projects generally operate with resource temperatures between 40 ºC to 150 ºC.

Ground source heat pumps use the earth or groundwater as a heat source in winter and a heat sink in summer. Applying resource temperatures of 4 ºC to 40 ºC, the heat pump is a device which moves heat from one place to another, transfers heat from the soil into the house in winter and from the house into the soil in summer. This national resource is significant from both the points of view of potential and perspectives. Hungary has favourable geothermal conditions, as in other countries, the temperature increases by 30–33 ºC per kilometer downward, while this value is 42–56 ºC in Hungary. At a depth of 2,000 meters, the temperature of rock (and water in porous rock) usually exceeds 100 ºC. The estimated volume of Hungary's thermal water is 2,500 cubic kilometers, and the heat energy stored is 604 000 PJ (petaJoule). Presently, the number of licensed, thermal water producing wells *(table 1.)* registered at the

Table 1. Hungarian geothermal well data

Utilization		40–50 °C	50–60 °C	60–70 °C	70–80 °C	80–90 °C	90–100 °C	>100 °C
		Temperature range						
Number of wells	Agricultural	14	14	15	18	28	20	1
	Industrial	13	14	14	4	3	1	0
	District heating	2	2	1	3	1	5	1
	Multi purpose	17	12	28	14	1	0	0
	Balneological	89	39	29	8	3	4	0
Total mass flow rate kg/s		659	665	955	841	696	811	62
Mass flow rate per well kg/s		14,32	15,83	16,47	21,56	21,09	25,85	31
Total thermal capacity Mw		95,19	125,9	219,92	228,88	215,65	292,03	23,62
Thermal capacity per well Mw		2,07	2,99	4,87	4,87	6,53	8,59	11,81

Mining Bureau of Hungary exceeds 100. They are widely used for heating of agricultural facilities (greenhouses), public and residential buildings, and the water supply of baths and swimming pools.

Geothermal power requires no fuel and is therefore immune to fuel cost fluctuations; but in contrast, capital costs tend to be high. Drilling accounts for over half of the costs and exploration of deep resources entails significant risks, as well. Since the identified geothermal resources in Hungary are low to medium enthalpy, 50 °C to 200 °C, they are better suited for heat supply. Therefore, there is still no current utilization of geothermal energy for electricity production. Several projects for the construction of geothermal power plants are, however, currently underway.

Until now, geothermal energy has been used mainly for balneological purposes and for the heating of the bath facilities. In the last 10 years, several projects were also the south-eastern part of Hungary involving greenhouse and district heating.

Water here has the role of an energy source; the suitable placement of cooled salt waters is presently one of the biggest problems with the utilization of thermal waters. On the Great Plain, a great part of waters with temperatures higher than 50 ºC are used for heating gardening and stock keeping sites. The majority of the 170 hectares of greenhouses and several hundred hectares of plastic greenhouses in the country are situated here.

The study area is situated in the Great Plain, which is the largest flatland of the Carpathian basin. The Great Plain covers nearly 100-thousand km^2 and is divided into two main regions, the Southern Great Plain and the Northern Great Plain (a smaller territory penetrating into the Central Hungarian and Central Transdanubian region).

This article provides a contribution towards objectifying the basis for decisions on implementing geothermal energy projects. Furthermore, a detailed and comprehensive evaluation of geological/geothermal, technical, economic, legal and administrative conditions is carried out for such projects in Hungary.

Elaboration of geological/geothermal evaluation methods for the suitability of hydrogeothermal reservoirs aims to objectify the basis for decisions on the implementation of geothermal energy projects. On the one hand, different possible locations become comparable and, on the other hand, the investigation of technical, consumer, legal and administrative conditions, as well as economic feasibility studies, can be restricted to regions with a certain degree of suitability.

In benchmarking and comparison of geothermal energy production conditions, the geological, geothermal and energy technical criteria of reservoirs or locations can be divided into monetary and non-monetary criteria.

Non-monetary criteria
– The geological, geothermal and reservior mechanical evaluation of the reservior (e.g., well productivity, reservior temperature, reinjection risk, and fluid salinity, gas content).
– Evaluation of the consumer potential.

In the following pages, we deal with the evaluation of consumer potential.

2. Analysis of consumer potential

The evaluation of the consumer potential for geothermal heat cannot and should not be done independently from the selection of the regions or sites which are geologically relevant for geothermal supply. Against this background, the order of the respective investigations and the extent of the evaluation of the consumer potential are defined as:
1. Selection of regions and sites under geological aspects.
2. Evaluation of the consumer potential in selected regions or at the sites.

When geothermal power generation is taken into consideration, then infrastructural aspects have only minor importance. In this case, possibly high thermal water temperature and flow rates are more significant. At this point, only the possibility of supply into a medium-voltage grid within the area of extension of the geological resource needs to be checked.

Just as with the geothermal cogeneration of heating and power, the use of a geothermal heat supply presupposes the assessment of local heating sales. Basically, heat is a stationary form of energy.

The
– bigger the connected load of a heat consumer/district heat supply network is
– more favourable the demand characteristics (number of full load utilization hours) are
– lower the heating network temperatures are, in particular of the return flow temperatures, the more favourable the conditions are for geothermal heat supply.

Geothermal energy is typical base load energy. The total costs are essentially determined by the fixed capital costs. The specific costs (HUF/GJ) decrease almost proportionally with the increase of the heat sales (service life of the plant).

Clear factors with measurable quantities, which can be determined apparently and serve as the basis for a classification of a region according to an evaluation matrix, cannot be indicated.

Thus, the existence of a district heating supply system in the region concerned is not of decisive importance – the history of such systems' development has to be understood under certain administrative and economic aspects, which are familiar to existing large individual consumers (e.g. in agriculture, greenhouses) outside of the district heating supply systems.

The evaluation must be more general and also include decisions supporting infrastructural aspects about the investment in geothermal energy utilization. Along with the mere capacity of consumer systems, the qualities of the infrastructure and of course of the qualification structure of the population are concerned. Many aspects, some of them

also described here qualitatively, can be decided basically and finally only within the framework of assessments of the economic profitability.

Principally, the following aspects have influence on the geothermal heat supply:
- Consumer concentration in the catchment area of the resource (characterising the potential capacity)
- Typical building in the catchment area of the resource as a measure of the expenditures on the development
- Condition of the buildings

- Characteristic external conditions determining the heat consumer behaviour (e.g., outdoor temperature behaviour curve in terms of time)

The following key parameters were chosen for the evaluation matrix:
- Specifics of the surrounding field
- Settlement specifics
- Condition of the buildings
- Annual Heating Degree Days (HDD)

No.	Criteria	Indicator	Share	Scoring	Points*	Weighting
C1.	Specifics of surrounding field		Share of building areas			
		Large towns(>50 000 inhabitants) and the near surroundings or areas essentially marked by the above towns	0%	30		
		Medium-size towns (20 000–50 000 inhabitants) and the surroundings or areas essentially marked by the above towns, very large industrial and agricultural consumers (greenhouses > 25ha)	0%	27		
		Small towns (5000-20 000 inhabitants) and the surroundings or areas essentially marked by the above structure, very large industrial and agricultural consumers (greenhouses > 10ha)	100%	20		
		Very small towns or large villages (<5000 inhabitants) and the surroundings or areas essentially marked by the above structure		10		
		Small villages or areas essentially marked by the above structure		1		
						35%
C2.	Specifics settlements					
		Arrangement of big multi-family houses in rows, block- and city-type building, large public or industrial or agricultural special consumers (e.g., hospital, greenhouses)	30%	30		
		Row houses, settlements with small multi-family houses, arrangement of small and big multi-family houses in rows	60%	15		
		Stand-alone buildings, loosely and openly built areas village cores	10%	1		
						35%
C3.	Condition of buildings					
		New buildings or modernized old buildings with standard insulation at high level	70%	20		
		Old buildings	30%	30		
						10%
C4.	Annual heating degree days (HDD)					
		>4 000		30		
		4 000-3 501		28		
		3 500-3 001		25		
		3 000-2 500		20		
		<2 500		15		
						20%
						of 30 points

* Share x Scoring (Source: Rödl&Partner)

3. Matrix – Consumer potential

In the first step, the parameter to be evaluated is chosen. Then, the conditions at the site have to be classified and the percentages of the respective indicators to be allocated at the site (e.g., building structures, levels of modernization) have to be determined (estimated, as a rule). The product of this share and the respective value from the scoring table then leads to a score for this parameter which contributes to the total result of the geological benchmarking according to its weighting (in the last column).

The weighting is based on the experience from already implemented projects or project studies.

The parameters allow for the evaluation of the regions or specific sites, in the sense of the classification below.

Classification and scoring of the specific characteristics of the surrounding field

Basically, this parameter considers the general consumer capacity which is available in the investigated area for the geothermal development, via the district heating supply network.

The concept of large communities, "Many inhabitants" in this sense means "large walled-in space to be heated", which refers to the heating of flats, but also other heating supply to e.g., places of employment, service and recreational facilities.

The scoring is based on the network capacity of 5–30 MW determined in numerous projects under different boundary conditions. This mega wattage is a minimum requirement so that the favourable conditions can be provided for the operation of geothermal plants. In other words, high numbers of full utilization hours are typical. In towns with more than 50 000 inhabitants and their surroundings, such network capacities are very realistic – which is similar to medium-size town. Under certain conditions, a small town with surroundings marked by agriculture may serve as the lower limit of acceptable system capacities. Capacities within the range from 3–5 MW appear to be feasible. At the margins of bigger networks, the integration of even very small consumers (value assigned to those: 1) may be interesting. This value of "1" is mainly due to the fact that no knock-out criterion shall be provoked from the point of view of the consumer systems, where exclusively geothermal power generation is relevant.

Under many aspects, the parameter of "Specifics of the surrounding field" is a general parameter, same as the following parameter of "Settlement specifics" which are interlinked in many respects. Large towns also have a dense building structure – with certain differentiations. However, the parameters also evaluate other infrastructural factors in the right directions (e.g., qualification structure, quality of development, connection to the system of public conveyance) principally influencing geothermal systems, in particular through costs.

Surrounding field specific	Scoring
Large towns(>50 000 inhabitants) and the nearby surroundings or areas essentially marked by the above towns	30
Medium-size towns (20 000–50 000 inhabitants) and the surroundings or areas essentially marked by the above towns, very large industrial and agricultural consumers (greenhouses > 25ha)	27
Small towns (5 000-20 000 inhabitants) and the surroundings or areas essentially marked by the above structure, very large industrial and agricultural consumers (greenhouses > 10ha)	20
Very small towns or large villages (<5 000 inhabitants) and the surroundings or areas essentially marked by the above structure	10
Small villages or areas essentially marked by the above structure	1

(Source: Rödl&Partner)

Classification of settlement specifics

This parameter aims to evaluate consumer density. It is substantial for the efforts required by the implementation of a certain size of the network. This parameter is also connected with the parameter of "Specifics of the surrounding field". However, it allows a certain differentiation by regional or country specifics of the building structure.

Settlement specifics	Scoring
Arrangement of big multi-family houses in rows, block- and city-type building, large public or industrial or agricultural special consumers (e.g., hospitals, greenhouses)	30
Row houses, settlements with small multi-family houses, arrangement of small and big multi-family houses in rows	15
Stand-alone buildings, loosely and openly built areas village cores	1

(Source: Rödl&Partner)

Classification and scoring of the condition of the buildings

A qualitative factor is introduced which aims to record the reduction of the heat demand of the buildings. While this reduction is of course desired, it cannot be implemented - predominately for economic reasons. The dimensioning of this scoring is difficult, due to the manifold influencing factors and the specifics of the stock of buildings. An orientation is given by the assumption that through improvement measures affecting efficient heat transfer and distribution at the building, an average of savings up to 30% would be possible. This would mean a reduction in heating sales with the consumer situation remaining the same – while scoring would decrease.

Condition of the buildings	Scoring
New buildings or modernized old buildings with standard insulation at high level	20
Old buildings	30

(Source: Rödl&Partner)

Classification and scoring of annual heating degree days

This factor investigates the influence of the regional or typical domestic climate on the evaluation of the efficiency of the geothermal energy use. Under identicall conditions of the stock of buildings, the potential sale of geothermal heat increases or decreases depending on cooler or warmer ambient temperatures. Other climate factors (solar radiation, wind) of course influence the heat demand as well, but as a rule to a lower degree or in the same direction as the temperature. In addition, long-term measured data characterising a climate situation are for the temperature available at many sites.

To determine the heat consumption in a heating period at a special site, often the number of the "Annual Heating Degree Days" (HDD) is applied in heating engineering, which considers both the values of the outdoor temperature and the temperature behaviour throughout the year. In fact, the doubling of the HDD means the doubling of the heat demand of a consumer.

Annual Heating Degree Days (HDD)

$$HDD = \sum_{1}^{z}(Tbase - Tam)$$

With
Tbase = indoor temperature
Tam = average daily outdoor temperature
z = number heating days

Number of heating days (z)	Tbase	Tam	z(Tbase-Tam)
15–31 October	22	10,5	172,5
01–30 November	22	4,4	528,0
01–31 December	22	–0,2	688,2
01–31 January	22	–2,4	756,4
01–28 February	22	–0,5	630,0
01–31 March	22	4,5	542,5
01–15 April	22	10,7	169,5
181 days	–	–	3 491,6

Annual Heating Degree Days (HDD)	Scoring
>4 000	30
4 000–3 501	28
3 500–3 001	25
3 000–2 500	20
<2 500	15

(Source: Rödl&Partner)

The examples given in the following table exist in two towns. These towns are located in the North Great Plain Region. One of them is Berettyóújfalu, a typical Hungarian small town; the other one is Hajdúböszörmény which is a middle sized town. Both towns differ considerably in their extension, population structure and density. In these towns no district heat supply structure exists. At Hajdúböszörmény, geothermal energy has already been used for balneological purposes.

Table 2. Scoring of the benchmark parameter

No.	Criteria	Points of		Weigh-ting	Total points of	
		Berettyó-újfalu	Hajdú-böször-mény		Berettyó-újfalu	Hajdú-böször-mény
C1.	Specifics of surrounding field	20	27	35%	7	9,5
C2.	Specifics settlements	13,7	21,1	35%	4,8	7,4
C3.	Condition of buildings	28	24,5	10%	2,8	2,5
C4.	Annual heating degree days (HDD)	25	25	20%	5	5
	of 30 points				19,6	24,4

(Source: own calculations)

The heat consumer potential of the two towns in possession of geothermal heating is shown in Table 2. Hajdúböszörmény has a better consumer potential, which is mainly due to the "Specific of surrounding field" and "Specifies settlements". The results of the evaluation matrix do not exist as knock-out criterion for geothermal heat projects. Towns, regions with unfavourable conditions such as sparse population or unfavourable consumer characteristics, are expected to have high specific expenditures on developments. Consequently, the economic profitability will be influenced negatively, but the implementation of the technology will not be hindered principally.

4. Conclusion

Geothermal heat production is a supply technique for the base load of large consumer systems. The high expenditures on the development must be refinanced by heat sales with possibly high numbers of full load utilization hours. Geothermal energy use is closely connected to district heat supply, within a higher capacity range.

Hungary has approximately 225 towns, with about 65 having more than 20 000 inhabitants. Such an order of magnitude justifies the assumption of acceptable conditions

for district heating supply, not taking into consideration other concrete boundary conditions. However, there exist more than 3000 communities with less than 1000 inhabitants which do not form a reasonable basis for the installation of district heat supply systems.

Large industrial, but above all agricultural plants (green-houses), offer considerable consumer potentials, too. Particularly for the latter ones, a high degree of flexibility has to be assumed with regard to site selection, which should be a place where good conditions are offered for production, which will be decided by favourably priced heat. From the point of view of site selection, geothermal energy projects do not have to consider the existence of respective consumers. The heating price will be determinate, and each site will be a good agricultural site, as a rule. In the South-East Plain Region, this coexistence has largely already been put into practice.

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