The assessment and inventory of geothermal energy

G. Rezessy[1], A. Szőts[1], T. Hámor[2]

[1]*Hungarian Geological Survey, Hungary H-1440, Budapest POB 17,*
e-mail: szakhat@mgsz.hu
[2]*Joint Research Centre of the European Commission, Italy I-21020 Ispra (VA) TP 460,*
e-mail: tamas.hamor@jrc.it

Abstract

The presentation introduces the efforts for the assessment and the establishment of an inventory of the geothermal energy resource of Hungary. The available works are presented and we give an account on a plan on the elaboration of a dynamic inventory. The establishment of the inventory of geothermal resources is the declared intention of the State as set in the legislation. The paper provides a brief review on the Community legislation of the European Union and that of the Candidate Countries with respect to the direct regulations on the use of geothermal energy.

Introduction

Geothermal resource belongs to the State in Hungary. The State can cede the exploration and exploitation of geothermal energy to entrepreneurs as concession upon the Act XLVIII. of 1993 on Mining. Geothermal resources in Hungary are owned by the state. Upon present Act XLVIII. of 1993 on Mining the state can cede the right of the exploration and exploitation of geothermal energy to entrepreneurs in concession. If the exploitation of geothermal energy is done by water abstraction, then it requires a water use permit and mining royalty must be paid upon the exploited heat quantity according to the Mining Act.

In 1999 the National Audit Office initiated the assessment of public assets. Accordingly, in 2000 the Ministry of Economy:

– initiated the amendment of the Mining Act, the result of which, Article 48 (2) reads that "the Hungarian Geological Survey (MGSZ) manages the inventory of domestic geothermal resources";
– commissioned the MGSZ to make a feasibility study on the cadastre of geothermal resources.

The MGSZ has completed the study but the proposal has not been realised yet due to the limited financing. Some examples are presented hereby on calculations done for the determination of geothermal energy resources. A discussion is shown why the static survey doesn't satisfy the requirements of a nationwide inventory of this renewable, flow-type natural commodity. As a conclusion, an outline on the possible elements of a dynamic inventory is presented.

The static survey of geothermal resource

The geothermal resource is the heat quantity stored in the rock framework and pore fluid of a given underground space as compared to a definite temperature level.

If the surface of a given space is "A" and the thickness is "Δz", the heat quantity stored in this space is "H_0". According to Haenel, R. et al.:

$$H_0 = [(1-p)\,\rho_m c_m + p\,\rho_v c_v]\,(T_t - T_0)\,A\,\Delta z$$

Where: p = effective porosity;
ρ = density;
c = specific heat;
T_t, T_0 = temperature in porous rock and at the surface;
m, v = indices indicating rock matrix and pore fluid.

The value of H_0 heat quantity – in joule (J) – can be named *"the geological resource"* as it is a geophysical quantity independent from the technology and profitability of production. Haenel et al. (1988) defined two more terms:

– *economical and legally exploitable resource in the near future:*

$$H_1 = R_0 H_0$$

where $R_0 \approx 0.1$–0.2, depending on the efficiency of exploitation and utilisation, and the temperature of re-injected water;

– present economical and exploitable known reserve:

$$H_2 = R_1 H_1$$

where $R_1 < 1$.

General remarks on the static survey:

– the calculation on geothermal resource is just a snapshot, it can't consider the effects of heat quantities either exploited from or naturally recharged to the given space;
– the geological resource can be determined quantitatively according to the level and reliability of the geological-geophysical parameters;
– marginal conditions must be determined for the calculation of geological resource (e.g. minimum temperature, maximum depth);
– the exploitable geothermal resource depends on the technology of exploitation (e.g. in case of doublet system when water is re-injected:

$$R_0 = 0.33\,\frac{T_t - T_r}{T_t - T_0}$$

where T_r is the re-injection temperature);
– the determination of the present economical and exploitable known reserve can be carried out in case of a defined geothermal reservoir and in case of a particular project.

Previous works on the assessment of the geothermal resources of Hungary

Intensive geothermal exploration organised by the Hungarian State has been on since the sixties of last century. Hydrocarbon explorations played a major role in the discovery of the deep geological setting, and many unproductive hydrocarbon rigs then served as thermal water production wells. The national oil company ceded these unproductive rigs to the local administrative bodies for free.

From this time several authors and working groups made attempts to determine the geothermal resource of Hungary. These calculations are mainly related to the determination of the thermal water quantity then the geothermal resource has been assigned to them. Beside static assessment of thermal water resource there were attempts to determine the dynamic water resource as well.

In the 80's Pál Liebe [2] made studies on the geothermal potential and thermal water resources of the country. His working group – according to practical considerations of the exploitation – took those porous and karstic formations into account from which thermal water could be exploited well by re-injection or free artesian flow. Pliocene thermal water reservoirs giving water hotter than 50 ºC have been categorised into the following regions:

1. Plain in Northwestern Hungary (Kisalföld)
2. Lenti basin and outskirts
3. Zala – Somogy basin and outskirts
4. Dráva valley and outskirts
5. Szeged part of south off the River Tisza depression
6. South off the River Tisza and NW outskirts
7. Central part of depression in South Lowland, southern and northern outskirts
8. Békés depression, northern and southern outskirts
9. Jászság depression and outskirts
10. depression of Central Tisza region and Nyírség.

Beside porous thermal reservoirs further 26 Early Palaeozoic and Mesozoic thermal reservoirs in carbonate rock formations are mentioned in the study. P. Liebe also estimates the stored energy resource. According to his estimation the volume of thermal water stored between depth 0–2,400 metres is 2,500 km^3 which doesn't include the brines of deep basin sediments older than Upper Pannonian with low permeability nor the unexplored thermal water and steam occurrences of the basement rock formations. Heat volumes assigned to the thermal water of 2,500 km^3 (referring to surface mean temperatures) are the following:

geological resource in thermal water:	$5.73 \bullet 10^{20}$ J
geological resource in thermal water and reservoir:	$1.49 \bullet 10^{21}$ J

The exploitable resource can be estimated one order less than the above mentioned values. The annual naturally recharging heat volume in Hungary calculating with 100 mW/m^2 heat stream is $2.9 \bullet 10^{17}$ J/year. This value is the 10% of the annual national energy consumption and, in principle, it is the upper limit of the sustainable exploitation.

Geothermal resource in the national mineral assessment

The Hungarian Geological Survey (MGSZ) manages the national mineral assessment as prescribed by the Mining Act. The Survey publishes a booklet entitled "The mineral resources in Hungary" annually [3] which covers and evaluates the national geothermal resources too.
The assessed geothermal resource is the heat quantity stored in thermal water situated not deeper than 3,000 metres. Thermal water is defined as groundwater with temperature higher than 30 ºC. In calculating heat quantity the temperature difference is the actual thermal water temperature above +10 ºC. The determined geothermal resource by regions is shown as follows:

Specification	Region					
	Plain in the NW Hungary	South Trans-danubia	Southern Great Plain	Northern Great Plain	Basement rocks	in total
Volume of stored thermal water [10^3 km^3] (hotter than 30ºC, down to 3,000 metres)	0.5	0.2	1.1	0.6	0.1	2.5
Heat quantity [10^{20} J] (in case of cooling down to +10 °C)	1.15	0.38	2.99	1.25	0.27	6.04

The assessment is founded upon P. Liebe et al. earlier calculations since MGSZ doesn't have the necessary database for the assessment.

Geothermal resource of Hungary, as assessed by a European Commission project

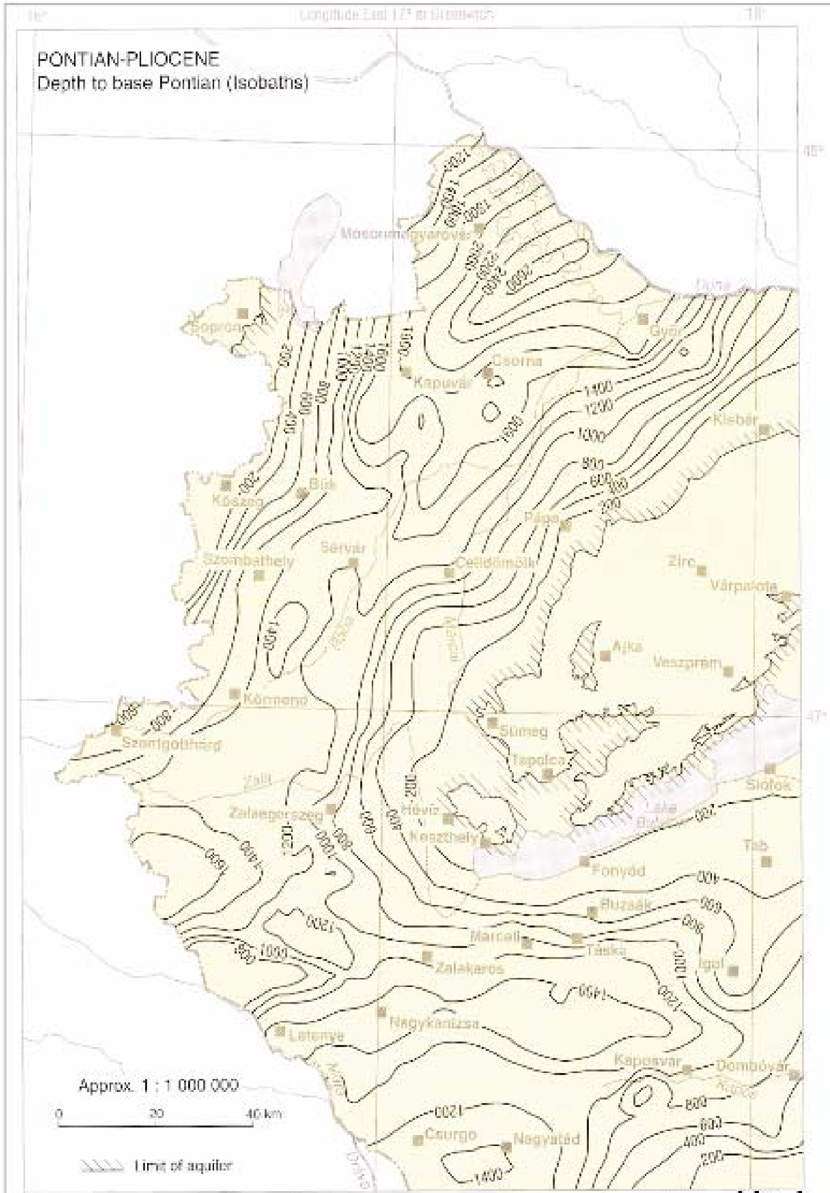
S. Hurter and R. Haenel, as editors, completed an atlas on the exploitable geothermal resource of Europe [4]. The information on Hungary was given by P. Dövényi, F. Horváth, D. Drahos and M. Árpási.

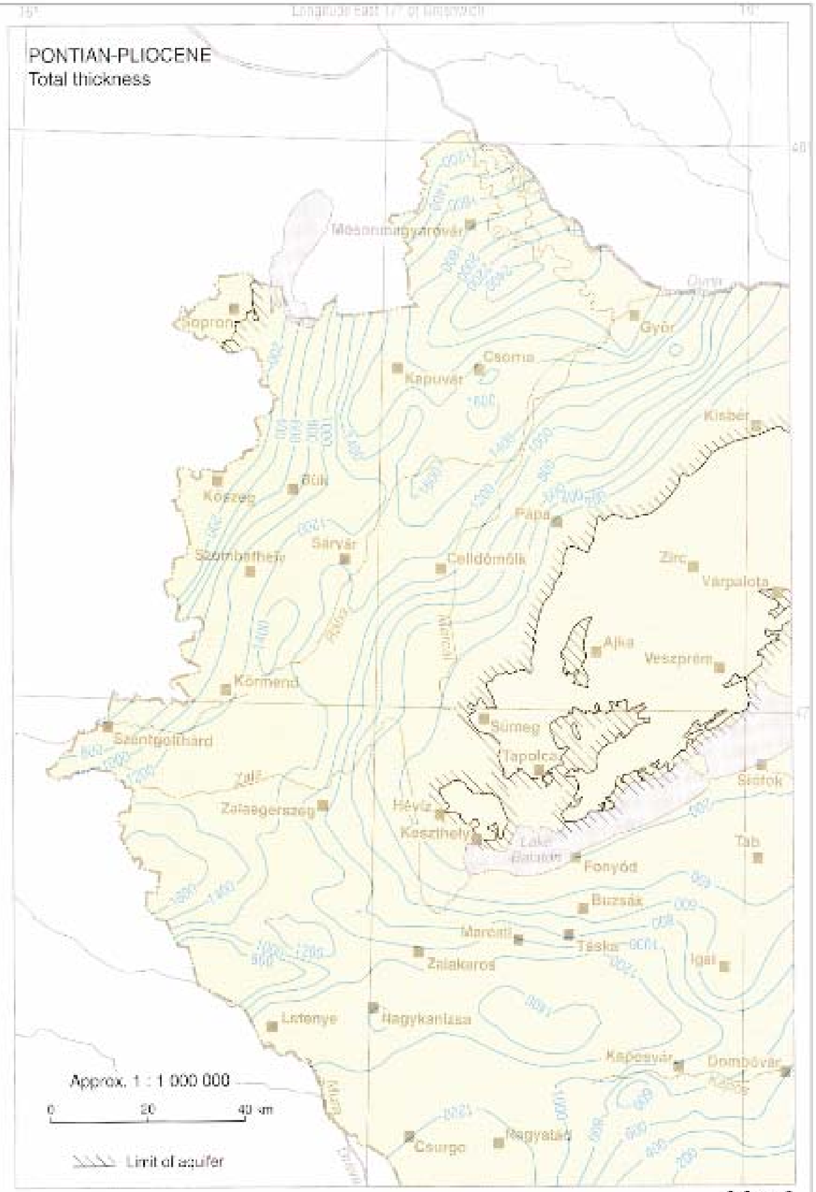
More than 12,000 temperature data were used based upon 4,666 well-logging and other geological and geophysical data. With a survey of Quaternary and Upper Pannonian porous sediments and Mesozoic carbonated reservoirs the following maps have been compiled: depth contours of formations, total thickness, temperature distribution at the bottom layer of the formations, geothermal resources. The latter ones present heat quantity stored in geological formations in GJ/m^2 for every region. As an example the map of West Transdanubian Upper Pannonian reservoir is presented here (maps 1, 2, 3 and 4).

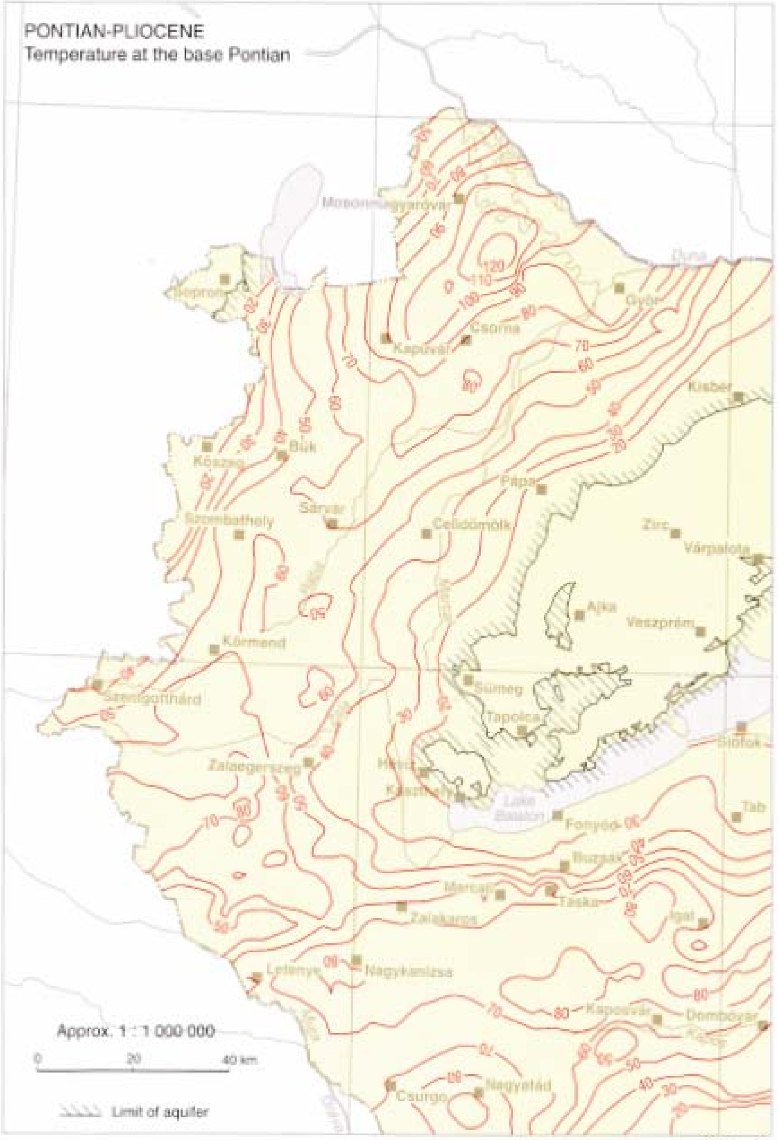
Proposal for the balance-like assessment of geothermal resources

The proposed assessment has two levels [5]. As a first step a *"starting or initial resource"* is determined. This survey reflects a static condition. This is a complete survey that considers realistic future technical and technological conditions between defined marginal limits (minimum temperature, minimum heat quantity, maximum depth, etc.). This survey is viable as shown by earlier results of the past decades. Therefore the experience of earlier surveys and experts has to be involved. The determination of the initial resource is carried out for greater geological units so called "geothermal provinces" (see [2], [4], [5]). For the delineation and characterisation of geothermal provinces, and for the validation of the database for calculations the use of all the experiences from national assessments and data from the National Geological and Geophysical Archives and expert knowledge of the Geological Institute of Hungary (MÁFI) and the Eötvös Loránd Geophysical Institute (ELGI) is needed.

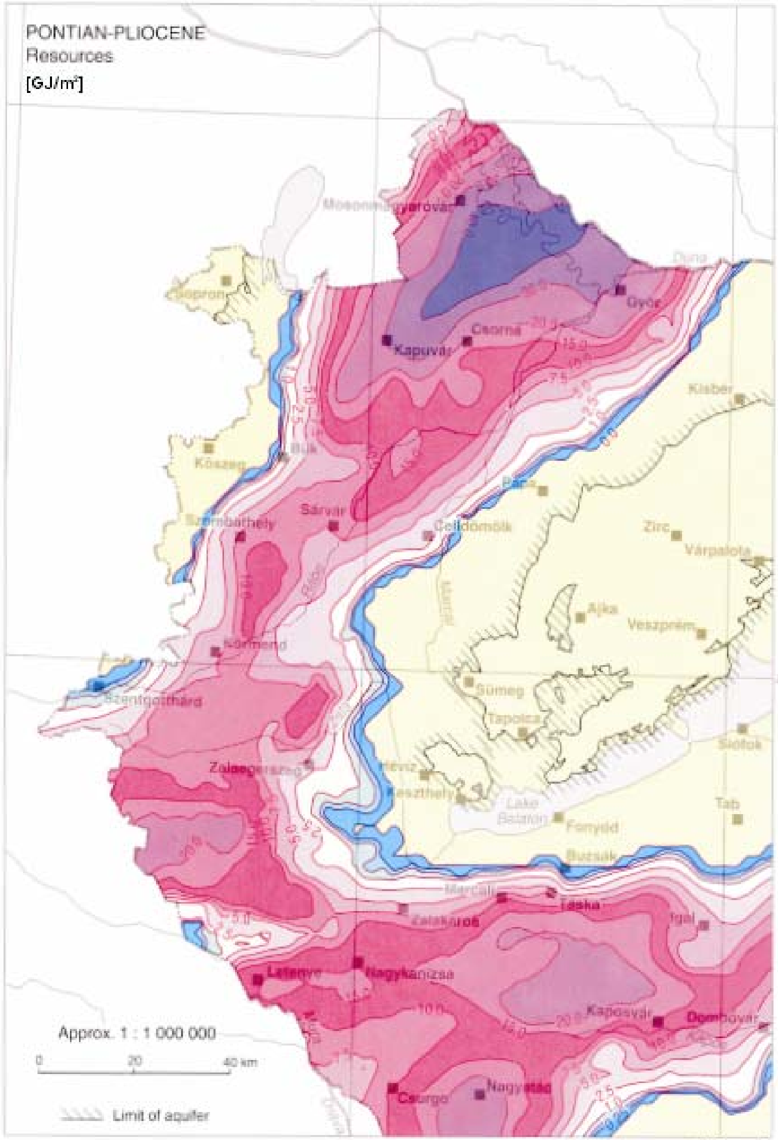
The second level of the assessment is a *balance-like assessment* which registers changes annually. Its development is realisable gradually in several years. The unit of the assessment is a calculative block of reserve which is smaller than a geothermal province and can be considered as homogenous block from the geological, mining and economic aspects.


Longitude East 17° of Greenwich
PONTIAN-PLIOCENE
Depth to base Pontian (Isobaths)
Mosonmagyaróvár
Duna
Sopron
Győr
Csorna
Kapuvár
Kisbér
Bük
Kőszeg
Pápa
Sárvár
Szombathely
Celldömölk
Zirc
Várpalota
Ajka
Veszprém
Körmend
Sümeg
Szentgotthárd
Tapolca
Siófok
Zala
Zalaegerszeg
Hévíz
Keszthely
Lake Balaton
Tab
Fonyód
Buzsák
Marcali
Táska
Igal
Zalakaros
Nagykanizsa
Letenye
Kaposvár
Dombóvár
Csurgó
Nagyatád
Approx. 1 : 1 000 000
0
20
40 km
Limit of aquifer
Map 1


Longitude East 17° of Greenwich
PONTIAN-PLIOCENE
Total thickness
Mosonmagyaróvár
Duna
Sopron
Győr
Csorna
Kapuvár
Kisbér
Bük
Kőszeg
Pápa
Sárvár
Szombathely
Celldömölk
Zirc
Várpalota
Ajka
Veszprém
Körmend
Sümeg
Szentgotthárd
Tapolca
Siófok
Zala
Zalaegerszeg
Hévíz
Keszthely
Lake Balaton
Tab
Fonyód
Buzsák
Marcali
Táska
Igal
Zalakaros
Nagykanizsa
Letenye
Kaposvár
Dombóvár
Csurgó
Nagyatád
Approx. 1 : 1 000 000
0
20
40 km
Limit of aquifer
Map 2


PONTIAN-PLIOCENE
Temperature at the base Pontian
Longitude East 17° of Greenwich
Mosonmagyaróvár
Sopron
Kapuvár
Csorna
Győr
Kisbér
Kőszeg
Bük
Pápa
Szombathely
Sárvár
Celldömölk
Zirc
Várpalota
Ajka
Veszprém
Körmend
Sümeg
Szentgotthárd
Tapolca
Siófok
Zalaegerszeg
Hévíz
Keszthely
Lake Balaton
Fonyód
Tab
Buzsák
Marcali
Táska
Zalakaros
Igal
Letenye
Nagykanizsa
Kaposvár
Dombóvár
Csurgó
Nagyatád
Approx. 1 : 1 000 000
0
20
40 km
Limit of aquifer

Map 3


PONTIAN-PLIOCENE
Resources
[GJ/m²]
Longitude East 17° of Greenwich
Mosonmagyaróvár
Sopron
Kapuvár
Csorna
Győr
Kisbér
Kőszeg
Bük
Pápa
Szombathely
Sárvár
Celldömölk
Zirc
Várpalota
Ajka
Veszprém
Körmend
Sümeg
Szentgotthárd
Tapolca
Siófok
Zalaegerszeg
Hévíz
Keszthely
Lake Balaton
Fonyód
Tab
Buzsák
Marcali
Táska
Zalakaros
Igal
Letenye
Nagykanizsa
Kaposvár
Dombóvár
Csurgó
Nagyatád
Approx. 1 : 1 000 000
0
20
40 km
Limit of aquifer

Map 4

For the determination of changes in geothermal resource the mathematical and geological *models* for the geothermal reservoir must be elaborated. Peculiar processes of heat production and heat recharge should be clarified. According to geological, hydrogeological and geophysical aspects the boundaries of the reservoir and its marginal conditions and characteristic parameters (basic data) of materials filling the reservoir should be determined. *Basic data* for the assessment can be divided into two categories:

- data constant in time: density, porosity, specific heat and thermal conductivity;
- changing figures during production: quantity of exploited heat (water), quantity of heat (water) arriving in and leaving the reservoir, reservoir temperature.

We know that basic data are incomplete and inaccurate and will remain the same after control and assessment. Geological considerations and using of analogues are needed for filling in the gaps. *For repeated supervision and further specification* the same method as being used in hydrogeological modelling can be used as well. According to the difference between the condition defined by mathematical modelling and its realisation dubious basic data of the model can be corrected.

Data necessary for the assessment of geothermal resources must be obtained from the archives and the authorities and completed with the changing data generated during production. Data control could be ensured by comparing authority registers with each other and by applying mathematical model for the assessment of geothermal resources. The applying company should determine the initial resource of a geothermal reservoir according to the provisions set by the law. The calculated data of resources shall be supervised by the MGSZ as the manager of the assessment. The annual change in geothermal resource equals to the total of exploited heat and heat arriving in and leaving the reservoir in a natural way. The increasing heat gradient of the reservoir due to exploitation must be considered as well. The relation between the two levels of the planned assessment system is assured by the uniform database.

The Community legislation of the European Union on geothermal energy

Energy affairs affected the history of the Community from the establishment of the European Coal and Steel Community. The Rome Treaty (1951) declared among its objectives in Article 3(d) *"... to promote a policy of using natural resources rationally and avoiding their unconsidered exhaustion"*. The Euratom Treaty (1957) defined specific provisions on uranium material supplies. Article 52(1) provides that *"supply of ores, source materials and special fissile materials shall be ensured ... by means of a common supply policy on the principle of equal access"* to sources of supply. Article 52(2a) prohibits *"all practices designed to secure a privileged position for certain users"*. The Amsterdam Treaty (1997) implemented a coherent Community policy on the environment by adopting the international concept of sustainable development. According to Article 174(1) this policy shall contribute to pursuit of the objective of *"prudent and rational utilisation of natural resources"*. Geothermal energy is an obvious subject of these Community policies.

From the mid seventies the Commission has been supporting the enhanced use of geothermal energy which is reflected in numerous Council resolutions, decisions and communications. The engine of the early actions was the first oil crisis but later on the changing policy towards nuclear energy and the new environmental legislation played a major impact on the promotion of the use of renewable energy resources. However, the Community legislation has a deficit in regulating the field by giving only a few direct reference and provisions on geothermal installations, e.g. Council Directive 85/337/EEC as amended by Council Directive 97/11/EC on the assessment of the effects of certain public and private projects on the environment; Directive 2000/60/EC of the European Parliament and of the Council as amended by Decision 2455/2001/EC of the European Parliament and of the Council establishing a framework for Community action in the field of water policy. The exploitation of geothermal energy is not included in the scope of the legislation on mineral extracting industries and it is questionable if the waste legislation or other environmental directives are applicable or not. Similarly, it is unclear whether Council Directive 93/38/EEC on coordinating the procurement procedures of entities operating in the water, energy, transport and telecommunications sectors covers geothermal projects.

Geothermal legislation in EU Accession States

The results of the Enlargement Project "Inventory, Regulations and Environmental Impact of Toxic Mining Wastes in Pre-Accession Countries" of the Joint Research Centre of the European Commission [6] showed that all Candidate Countries have a recent act on mining (or on subsoil use, or on subsurface resources). In general, mineral resources are the original and exclusive properties of the state but exceptions exist where the ownership of or access to mineral resources or part of them belong to the landowners (Latvia, Lithuania, Poland). Almost all countries have a separate legal document on national mineral policy issued by the government or a ministry. In some countries the mineral policy is embedded in mining acts or in the environmental strategy. However, geothermal energy is excluded from the scope of mining acts in half of the countries and no specific thematic acts available for this type of energy. Therefore, a set of environmental protection, water management and energy use regulations applies for the exploitation of geothermal energy resources in these countries.

[1] R. Haenel and E. Staroste, *Atlas of Geothermal Resources in the European Community, Austria and Switzerland, Luxembourg* (1988)

[2] P. Liebe, *Determining geothermal potential at some regions and areas of the country*, Hungarian Geological Society (1982)

[3] B. Fodor, *The mineral resources in Hungary,* Hungarian Geological Survey (2002)

[4] S. Hurter and R. Haenel, *Atlas of Geothermal Resources in Europe*, EC, Luxembourg (2002)

[5] Hungarian Geological Survey, *Proposal for the resource cadastre assessment method of the geothermal energy as an exclusive national asset and the data content of the assessment, proposition for the Ministry of Economy* (2000)

[6] T. Hámor, *Legislation on mining waste management in Central and Eastern European Countries*, Joint Research Centre of the European Commission, Ispra, EUR 20545 EN, 188 p. (2002)