# Environmental Impact Assessment of the Geothermal Area Beiuş (Romania)

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**ABSTRACT**

Europe 2020 Strategy, launched by EU leaders in 2010, highlights the need to modernise the economy, to focus on economic growth and employment by addressing the challenges of globalisation and demographic changes and to support economic, social and environmental objectives.

The subject is inciting through the timeliness and importance in the present context of a globalized economic environment, further less the challenge for the European and national authorities to build a proper correlation between the environmental policy and a renewable resource of energy.

The specific objectives of this paper are to formulate answers to the following research questions: a. which is the accurate possibility of assessing environmental impact for geothermal waters, what are its stages? b. can the types of impact assessment be developed? c. what are the prospects for this research, what are the limits of research in this case?

Therefore, I have chosen the geothermal area Beiuş, situated in the north-western side of Romania, while being a leading example for investments in geothermal heating system with available geothermal primary source through its main characteristic: it stands for the benefit of citizens by way of keeping a clean environment.

From geological viewpoint, this geothermal area is an easternmost part of the regional thermal anomaly located under the Pannonian basin and the Neogene sedimentary basins splitting the western margin of the Apuseni Mountains. The geothermal water is collected into the sole of the Neogene Beiuș basin, with Triassic dolomites and limestone belonging to the Inner Dacides (Codru Nappe System). Some drillings crossed these rocks, allowing the recovery and exploitation of the geothermal water in Beiuș town.

I performed the life cycle analysis of geothermal water by following steps such as: purpose and objectives, life cycle inventory, life cycle impact assessment or interpretation of results of life cycle analysis. In this case, the boundary research is the lack of defining and analysing the impact categories, because they are the subject of a long and thorough study and the interpretation of the data is performed by dedicated software.

## 1. INTRODUCTION

This article summarises the years' work of the author in the matter of the so called "green town of Romania", Beiuş, the author's findings and study of the characteristics of the geothermal water in the area and its production.

The study has two stages: a theoretical selection procedure based both on a geological survey as on an environmental life cycle assessment (e-LCA) and, secondly, an analysis of the life cycle assessment inventory through volumetric and thermal units, used to describe an area with reduced environmental impact.

Renewable energy sources (RES) are a sustainable, a dependable and an economical way of providing the thermal, electrical and/or chemical energy economies and individuals require on maintenances.

As Speth (2006) has stated, a globalized environment refers to the global compression of the interrelationship of economic, political, social and environmental development processes (Speth, 2006) and economic growth. The economic growth, seen in the context of environmental policy, embodies the quantitative and qualitative transformation of existing instruments at a time of economic, political and social structures, lifestyle and quality of life, human consciousness, the environment etc. and the general behaviour of the economic and social system (David, 2009).

Hence, geothermal energy (GE), its significance regarding political, legal, environmental, social and cultural aspects and not only geological and economical ones are to be taken into consideration while speaking about the environmental and economic benefits it carries. In the world scenario, energy consumption is projected to increase about 57 % by 2025. Despite the large potential of GE it only supplies 0.4 % of the world's energy demands (Verdejo, 2010).

The main scope of the Romanian agency for Mineral Resources has been to map the geothermal resources. A large numbers of exploratory wells have been drilled and rather intensive research activities have been performed mainly before 1989. Therefore the drilling programs have been an element in the activities of our country.

Romania is basically rich on geothermal resources with wellhead temperature often close to 100 °C or even higher. Many wells have been drilled with specifications like production wells, conducting to the implementation of facilities for exploitation to a smaller extend during time.

Over the last five years, the need for external technical and financial assistance within the exploitation of geothermal energy resources and operation of geothermal district heating (DH) systems is gaining acceptance both for local authorities as for companies. The framework agreement for acceptance of monitoring new DH systems was signed by the local operators and endorsed by the local Environmental Protection Agency (EPA) during the implementation of projects.

## 2. GEOLOGY OF BEIUŞ

My area of interest concerns a sector of the eastern margin of the Pannonian Basin, in north-western Romania. These main Romanian geothermal resources are located either in porous permeable multi-layered formations (upper Miocene – Pontian – sands sealed by clays and shale), or in fissured and fractured collectors (Triassic and Cretaceous limestone and dolomite; Butac & Opran, 1985). The first ones belong to the Pannonian Basin Cenozoic molass filling, while the second to its older basement (Carpathian Inner Dacides; Bleahu *et al.*, 1981, 1994). This basin is notorious for its anomalous geothermal areas and heat flows due to the thinner Earth crust and asthenosphere's upwelling (Săndulescu, 1984). Some drillings crossed these rocks, allowing the recovery and exploitation of the geothermal water in Beiuș town (Codrea & Călburean, 2013).

Apart the older three hypotheses concerning the evolution of the Pannonian Basin exposed by Meissner & Stegena (1988) – i.e.: gabbro-eclogite phase transition, lithospheric stretching and mantle diapirism –, another structural pattern belongs to Ren *et al.* (2012) with a molten asthenosphere sandwiched between the crust and deeper former sunken cold slabs.

## 3. LIFE CYCLE ASSESSMENT

Although LCA-studies were already carried out in the 1960s (Curran,1996; Owens,1997; Ekvall *et al.*, 2005), it was only in 1989 that the Society of Environmental Toxicology and Chemistry (SETAC) initiated the standardization process that led to the well-known ISO 14040 + 44 series (Guinée, 2002). SETAC put out a science-based platform for development of LCA, and they formalized the LCA methodology by outlining the terms to describe LCA as well as laying down the initial framework (Curran, 1996).
The development of the code of practice by SETAC (Consoli *et al.*, 1993) was an important step towards standardization of LCA as the code acted as the forerunner to the activities of the International Organization for Standardization (Guinée, 2002). The International Organization for Standardization (ISO) started working on standards relating to LCA in 1994. The first of the ISO 14040 series of standards (Environmental management – Life Cycle Assessment), which laid down the procedure for performing LCA, was first released in 1997 (Baumann & Tillman, 2004).

The United Nations Environmental Programme (UNEP) is another important international player in LCA, having taken on the role of stimulating global use of LCA (Guinée, 2002). Their work mainly centres on encouraging the application of LCA, particularly in developing nations. In 1996 the UNEP published a user-friendly guide to LCA, as part of their effort to encourage wide application of LCA (Guinée, 2002).

According to these standards, an LCA consists of four steps. Thus, the following steps were performed: defining of the purpose and objectives, carrying out the life cycle inventory (LCI), as well of the life cycle impact assessment (LCIA) and the interpretation of results of the life cycle analysis.

Commonly, LCI results are the ones directly used for decision support in sustainability management and practices. Nevertheless, the lack of a temporal aspect in current inventory analysis creates large doubts and may result in misleading conclusions in real sustainability practices, especially on those long-lived products.

### 3.1 Performing LCI in Beiuș

The medium annual production realised from thermal energy in Beiuș area is of ca. 104.690 GJ. Geothermal water extracted by pumps is distributed in 4 heating plants equipped with heat exchangers and 20 mobile units representing automated heating plants.

In addition, geothermal water is distributed to different beneficiaries as a primary heat conductor (economic agents, institutions, housing associations, private persons).

The centralized utilization of geothermal energy has totally replaced the utilization of conventional energy sources (fuel oil, light fuel oil) in the city of Beiuş. The centralized geothermal energy system provides heating energy and warm supply water for 103 apartment buildings, 3 high-schools, primary school houses, nurseries, churches and public administration buildings.

In Beiuș, two wells serve for the exploitation of geothermal waters (3001H, 3003H) while the other one (3004H) serves for the re-injection of the used thermal water. Up till now, the outputs are around 40 l/s, while the temperatures recorded at the well heads are 70 $^{\circ}$C at 3003H and 84 $^{\circ}$C at 3001H (Codrea & Călburean, 2013). The production level of the year 2013 was 828.323 $m^3$: a volume of 417.736 $m^3$ has been extracted from 3001H and a volume of 410.587 $m^3$ out of 3003H (Table 1). A quantity of 15.081,53 Gcal was prepared as thermal energy out of 436.226 $m^3$, while the difference of 392.097 $m^3$ was sold as $m^3$ (Table 1).

**Table 1: Total geothermal water extracted in Beiuş, year 2013**

| Well | m³ | Gcal |
|---|---|---|
| 3001H | 246734 | 7125.1 |
| 3003H | 145363 | 7956.73 |
| **Total** | **392097** | **15081.83** |

In this aspect, a volume of 329.312 $m^3$ was discharged in the sewerage. The difference of 106.915 $m^3$ between the extracted geothermal water (436.226 $m^3$) and the one discharged in the sewerage (329.312 $m^3$) was injected in 3004H well (Table 2).

**Table 2: Volume of geothermal water discharged in Beiuş, year 2013**

| Well | m³ discharged |
|---|---|
| 3001H | 64087.03 |
| 3003H | 265224.47 |
| **Total** | 329311.5 |

During the year 2014, 358.713,73 $m^3$ of geothermal water were sold in Beiuş: a volume of 226.916,30 $m^3$ out of 3001H and a volume of 131.797,43 $m^3$ out of 3003H, while a quantity of 14.454,67 Gcal was prepared as thermal energy: 13.648,71 Gcal out of 3001H and 805,96 Gcal out of 3003H (Table 3).

**Table 3: Total geothermal water extracted in Beiuş, year 2014**

| Well | m³ | Gcal |
|---|---|---|
| 3001H | 226916.3 | 13648.71 |
| 3003H | 131797.43 | 805.96 |
| **Total** | **358713.73** | **14454.67** |

During the year 2015, 430.000 $m^3$ of geothermal water were sold in Beiuş: a volume of 270.000 $m^3$ out of 3001H and a volume of 160.000 $m^3$ out of 3003H (Table 1), while a quantity of 17.000 Gcal was prepared as thermal energy: 11.000 Gcal out of 3001H and 6.000 Gcal out of 3003H (Table 4).

**Table 4: Total geothermal water extracted in Beiuş, year 2015**

| Well | m³ | Gcal |
|---|---|---|
| 3001H | 270000 | 11000 |
| 3003H | 160000 | 6000 |
| **Total** | **430000** | **17000** |

Taking into consideration the analysed period 2013-2015, we notice an increase both of the quantity of $m^3$ geothermal water sold in Beiuş perimeter (Figure 1), as of the quantity of Gcal prepared as thermal energy (Figure 2).

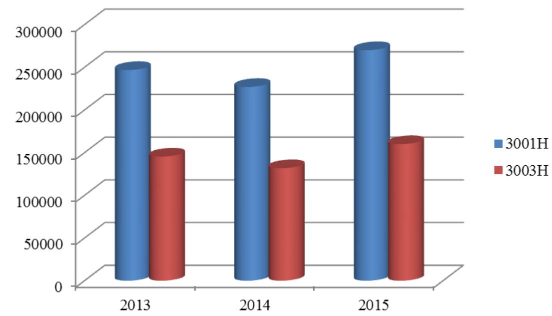


**Figure 1: $m^3$ geothermal water sold in Beiuş in the period 2013-2015**

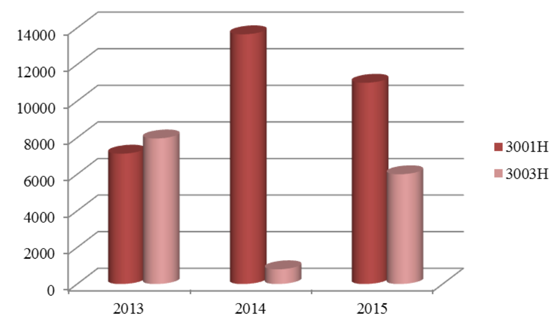


**Figure 2: Gcal thermal energy produced in Beiuş in the period 2013-2015**

## 4. PRODUCTION COMPARISON

At the moment, the main supplier in the area (TGX) is holding a portfolio of exploitation and exploration concession licenses covering 20 hydro-geothermal perimeters, as follows (Table 5):

- 14 exploitation and exploration concession licenses for geothermal waters in the perimeters: Oradea, Săcueni, Marghita, Borş, Beiuş, Livada, Aleşd, Sânnicolau de Munte, Balc, Chişlaz, Cighid, Mădăras (Bihor county) and Tăşnad, Acâş – Beltiug (Satu Mare county);

- 6 exploitation and exploration concession licenses for experimental exploitation for geothermal waters in the perimeters: Beiuş-Delani, Salonta, Ciumeghiu, Diosig, Sântion (Bihor county), Săcăşeni (Satu Mare county).

**Table 5: Average potential of the wells, year 2014**

| Perimeter | Q [l/s] | *Gcal h | T |
|---|---|---|---|
| Oradea | 46.00 | 2.44 | 85.73 |
| **Beiuş** | **45.00** | **4.50** | **77.00** |
| Săcueni | 6.00 | 0.65 | 80.00 |
| Acâş | 7.00 | 0.60 | 58.50 |

| | | | |
|---|---|---|---|
| Aleşd | 10.00 | | 40.00 |
| Borş | 12.00 | 1.81 | 92.00 |
| Chişlaz | 6.00 | | 56.00 |
| Cighid | 15.00 | 1.89 | 85.00 |
| Livada | 22.00 | 3.56 | 95.00 |
| Mădăras | 11.00 | 0.32 | 48.00 |
| Marghita | 5.50 | 0.33 | 67.00 |
| Sânnicolau | 4.00 | 0.22 | 65.00 |
| Tăşnad | 15.00 | 1.08 | 70.00 |
| Salonta | 15.00 | 1.08 | 70.00 |
| Ciumeghiu | 10.00 | 1.80 | 100.00 |
| Balc | 5.00 | | 46.00 |

TGX is Romania's largest company involved in the work of prospecting, exploration and exploitation of geothermal water deposits, having under concession approx. 60% of these resources, while performing activities like: highlighting deposits of geothermal water due to drilling works (prospecting, exploration); exploitation of geothermal water in concessional perimeters and capitalization of production in the forms: volume, thermal energy and hot domestic water; thermal energy conversion into electricity; works of mine closures; small and deep wells; installation of heat pumps; installation of pipelines for geothermal water transport and geothermal heat work points, as well as farming of vegetable crops in greenhouses.

As shown in Figure 3, Beiuş is one of the main suppliers of extracted geothermal water, its importance in environmental aspects being taken into consideration when speaking about renewable energy and the benefits it carries.

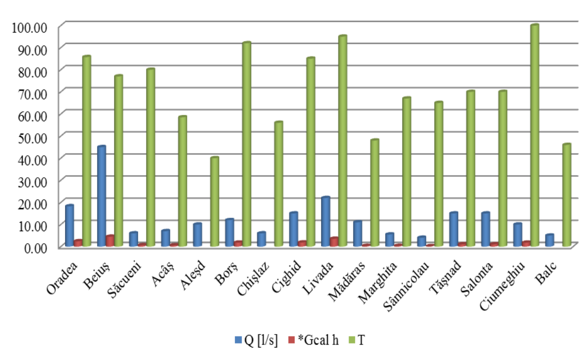


**Figure 3: Average potential of the wells, year 2014**

After finishing of the research both of the characteristics as of the volume of geothermal water extracted in the above mentioned perimeters, Beiuş proves to be one of the two perimeters (out of 20 perimeters) which provide both geothermal water in form of $m^3$ as in form of thermal energy (Table 6 & Figure 4).

**Table 6: Physical production in the perimeters, year 2014**

| Perimeter | m³ | Gcal |
|---|---|---|
| Oradea | 653557 | 34464 |
| **Beiuş** | **358714** | **14455** |
| Săcueni | 128614 | 0 |
| Acâş | 20150 | 0 |
| Aleşd | 9560 | 0 |
| Borş | 22416 | 0 |
| Chişlaz | 5940 | 0 |
| Cighid | 24105.5 | 0 |
| Livada | 175666 | 0 |
| Mădăras | 7260 | 0 |
| Marghita | 105060 | 0 |
| Sânnicolau | 5505 | 0 |
| Tăşnad | 177394 | 0 |
| Salonta | 0 | 0 |
| Ciumeghiu | 0 | 0 |
| Balc | 0 | 0 |

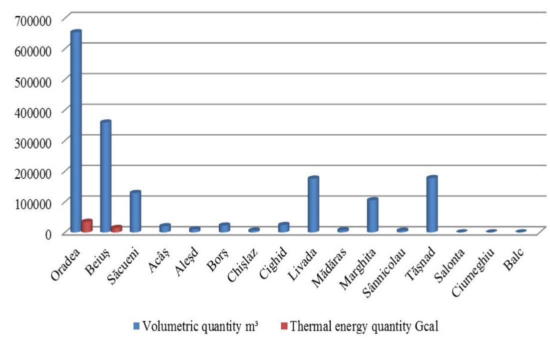


**Figure 4: Capitalization of the geothermal water in the perimeters, year 2014**

The results of this study aim to confirm and justify that Beiuş perimeter deserves the local name it was given to. Therefore it stands for the "Romania's green town".

## 3. CONCLUSIONS

The renewable energy sources, such as geothermal energy, offer an affordable solution for medium and long term consumer safety and environmental protection. The environmental aspects of the geothermal energy use are receiving increasing attention with the shift in attitude towards the world's natural resources.

Thus, I focused on the most appropriate way of evaluating the impact on the environment of a natural resource, by studying geological, capitalization's and volumetric aspects of geothermal water. I came to the consensus of doing that through means of the life cycle assessment methodology.

Therefore, I focused on the geothermal resource situated in the north-western side of Romania, Beiuş area.

Key aspects that need to be considered when life cycle assessment is adapted to a full sustainability assessment are: (i) the consideration to report results and (ii) the data that are required.

The paper contributes to the understanding of a technique to assess environmental impacts associated with all the stages of the life cycle of the geothermal water in Beiuş, furthermore illustrates a comparison of various geothermal perimeters.

Hence, it is always helpful to summarise your findings and present them. In this regard, while speaking about Beiuş and the analysed period 2013-2015, I speak about an avarage of 393,603.6 $m^3$ sold and additional 15,512.17 Gcal prepared as thermal energy.

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