ROMANIA AND GEOTHERMAL ENERGY: AN UNCONVENTIONAL, CLEAN AND RENEWABLE ENERGY SOURCE

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Rezumat: *Energia geotermală este energia termică generată și stocată în Pământ. Apa și/sau aburul transportă energia geotermală la suprafața Pământului. Variabilitatea temperaturii în ceea ce privește adâncimea scoarței terestre este cunoscută sub numele de gradient geotermic. Căldura naturală a miezului Pământului se datorează diferitelor procese fizice și chimice care apar în interior.*
În funcție de caracteristicile sale, energia geotermală poate fi utilizată în scopuri de încălzire și răcire sau poate fi valorificată pentru a genera electricitate curată.

Abstract: *Geothermal energy is thermal energy generated and stored in the Earth. Water and/or steam carry the geothermal energy to the Earth's surface. Temperature variability in the depth of the earth's crust is known as the geothermal gradient. The natural heat of the Earth's core is due to the various physical and chemical processes that occur inside. Depending on its characteristics, geothermal energy can be used for heating and cooling purposes or be harnessed to generate clean electricity.*

Keywords: geothermal energy, geothermal gradient, thermal energy, clean and renewable resource, the Earth.

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1. Introduction

Geothermal resources lie in abundance beneath our feet, waiting to be exploited. At present, geothermal energy is a practically inexhaustible energy source and, until now, it has not been sufficiently studied and exploited.
The paper aims to highlight the possibilities of harnessing the geothermal energy potential in the development of the country (geothermal projects offer all the benefits to contribute, without pollution, to the development of the country; facilities in remote locations can exceed quality standards of life, bringing distance

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electricity in people's homes). Drilling of geothermal wells is a complex of works for crossing, consolidating and isolating the rocks crossed.
The purpose of geothermal drilling works is to make boreholes in which ground geothermal wells can be placed, which can capture the energy of the earth, later distributing it further to the heating system. These works are performed with the help of special drilling rigs for geothermal wells.
The directional drilling of the wells, *-in a direction other than the vertical one-*, is imposed by certain surface conditions or certain technical-economic conditions. [1, 2, 3, 4]

2. General aspects [1]

The term geothermal comes from the Greek word geothermal, derived from "*Geos (γη)*" = *earth and* "*thermos (θερμος)*" = *heat*, so geothermal energy involves the exploitation of heat inside the earth.
Geothermal energy is a form of renewable energy obtained from the heat inside the Earth. The Earth's temperature rises considerably as it approaches its center (see Figure 1).

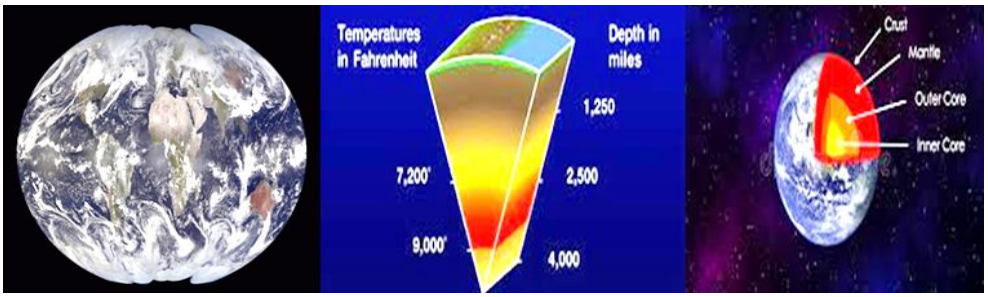

Fig. 1. TERRA (*temperature and energy inside the Earth*) [1].

It is known that the core of our planet is incredibly hot, according to the latest research it is estimated that the temperature exceeds 5,000° C, obviously, the earth's temperature varies greatly, and geothermal energy is usable for a wide range of temperatures (from room temperature to over 300° F ≅ 150° C). [1]
The high temperature at the center of the Earth is explained by the origin of the Earth, by the existence of radioactive isotopes of uranium (^{238}U), thorium (^{232}Th) and potassium (^{40}K) in the Earth (see Figure 2).

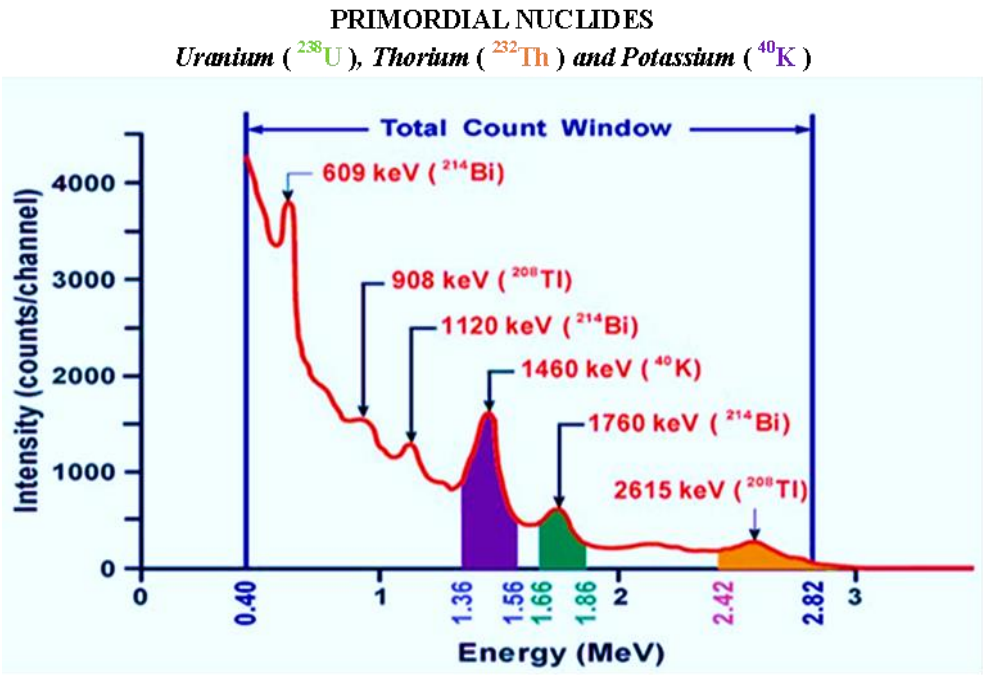

Fig. 2. Typical Gamma - Ray Spectrum [1, 12]

Experimentally, with the help of the MAESTRO program and in accordance with the reference standards IAEA 312 and IAEA 375, the researchers analyzed the peaks corresponding to gamma energies, obtaining the following values: 609 keV, 1120 keV and 1760 keV for ^{214}Bi; 908 keV and 2615 keV for ^{208}Ti and 1460 keV for ^{40}K. We can say that geothermal energy is the thermal energy generated and stored in the Earth. At the same time, thermal energy is the energy that determines the temperature of matter.
Obviously, as it is known, the geothermal energy in the earth's crust comes from the initial formation of the planet and the radioactive decay of materials. Therefore, geothermal energy represents the heat accumulated in rocks and in the fluids that fill their pores. [1]

3. Geothermal energy potential on the Romanian territory

Theoretically, Romania has a remarkable potential in terms of geothermal energy, being considered the third country in Europe, after Greece and Italy.
Figure 3 represents the map with the temperature distribution on the Romanian territory. The map illustrates the areas with geothermal potential of Romania at a depth of 3,000 m. [1, 3]

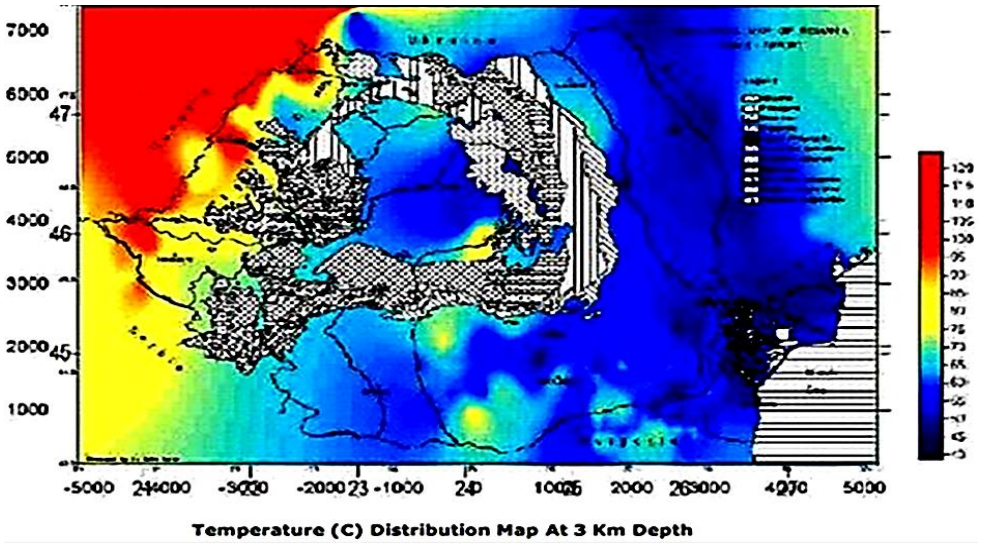

Fig. 3. Areas with geothermal potential of Romania at a depth of 3,000 m, after to the EBRD study [1, 12]

On the Romanian territory, in most drillings performed for hydrocarbons, low and medium enthalpy geothermal resources were found at depths between 800 m and 2,500 m with temperatures between 40 ÷ 120ºC.

Experimental exploitation of approx. 100 drillings, in the last 25 years, allowed the realization of some evaluations of the energetic potential of this type of resource (see Figure 4).

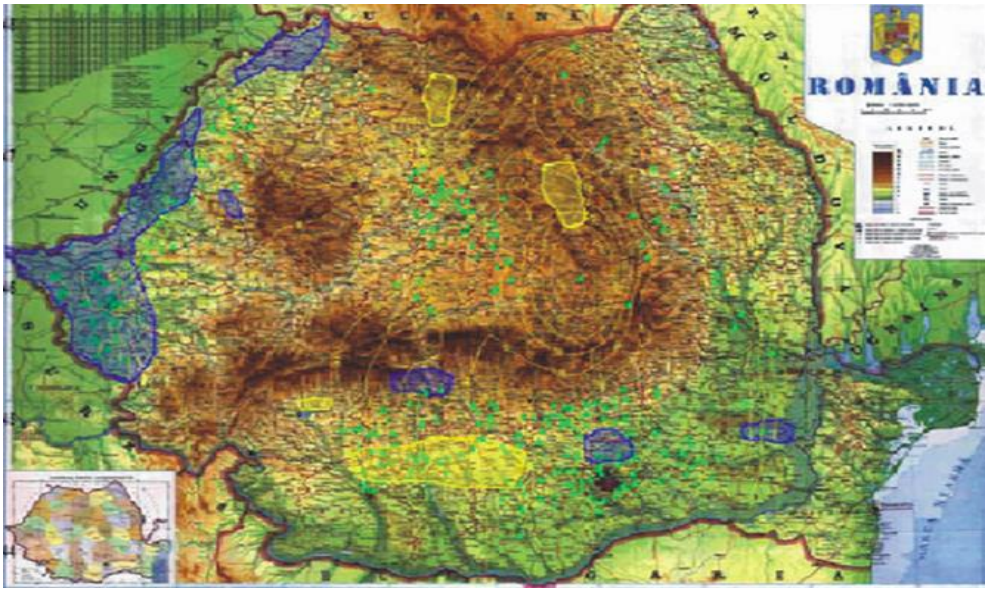

Fig. 4. Map with favorable areas for the concentration of geothermal resources in Romania [1, 12]

Observations:

1) *Geothermal source, by point of view economically, it must be accessible by drilling to depths not exceeding 3,000 m (under favorable conditions this depth can increase up to 6,000 m);*
2) *The geothermal source must have a sufficiently high potential (both quantitative and qualitative) to result in its exploitation in advantageous economic conditions.*

In Table 1 and Figure 5 show the main areas with geothermal energy potential in Romania. [1]

Table 1. The main deposits with geothermal energy potential in Romania [1]

No.	*Deposit area*	*Surface [km²]*	*Depth [km]*	*Drilled wells*	*Use wells*	*Temperature [°C]*	*Flow wells [l/s]*	*Installed power [MW]*
1.	Oradea	75	2,2 ÷ 3,2	14	12	70 ÷ 105	4 ÷ 20	58
2.	Bors	12	2,4 ÷ 2,8	6	5	115	10 ÷ 15	25
3.	Fields West	2,5	0,8 ÷ 2,1	88	37	50 ÷ 85	4 ÷ 18	210
4.	Olt Valley	28	2,1 ÷ 2,4	3	2	92 ÷ 96	12 ÷ 25	18
5.	Otopeni	300	1,9 ÷ 2,6	11	5	58 ÷ 75	22 ÷ 28	32

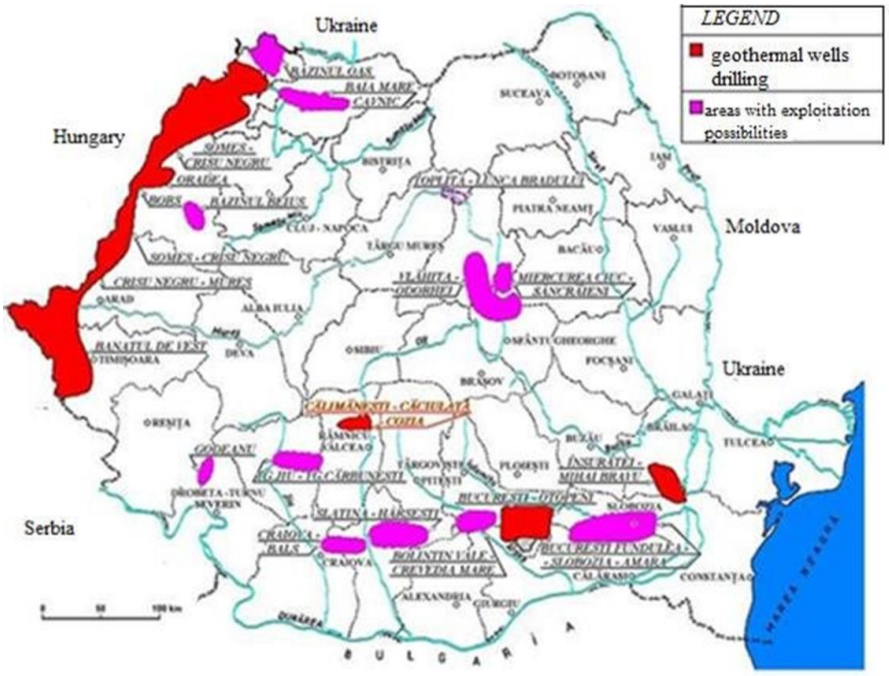

Fig. 5. The main areas with geothermal energy potential in Romania [12]

4. Drilling of geothermal wells

Drilling of geothermal wells is a complex of works for crossing, consolidating and isolating the rocks crossed. [1]
The purpose of geothermal drilling works is to make boreholes in which ground geothermal wells can be placed, which can capture the energy of the earth, later distributing it further to the heating system. These works are performed with the help of special drilling rigs for geothermal wells.
The directional drilling of the wells, *-in a direction other than the vertical one-*, is imposed by certain surface conditions or certain technical-economic conditions (see Figure 6). [4]

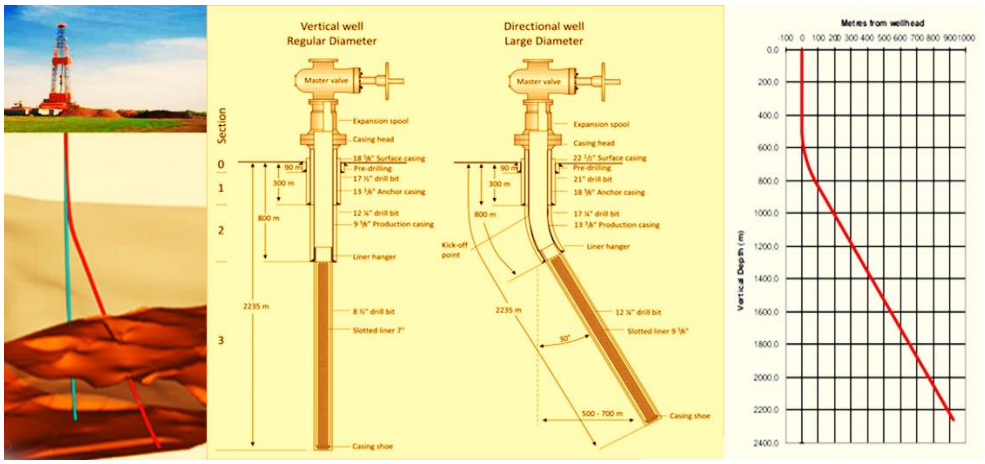

Fig. 6. Drilling of geothermal wells [4, 5]

Figure 7 Illustrates the overview of drilling and operation of geothermal wells: vertically drilled well and directionally drilled well.

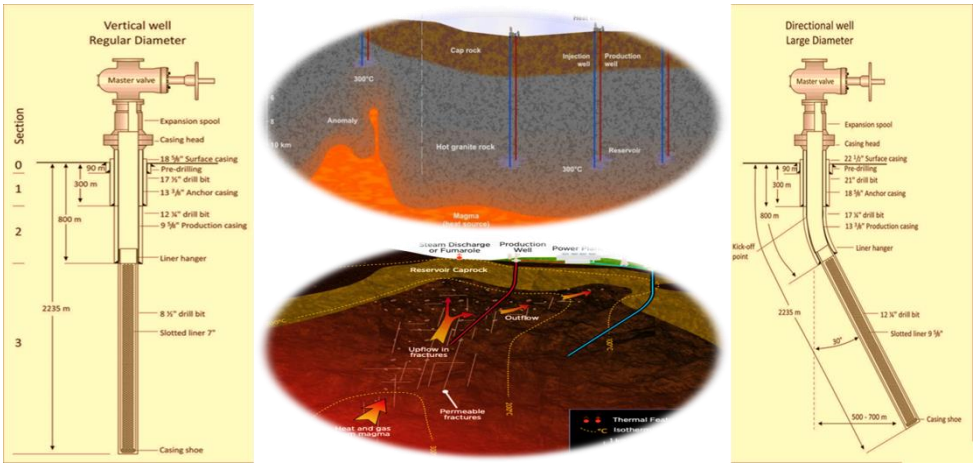

Fig. 7. Scheme - Drilling and exploitation of geothermal wells [4, 5, 12]

So, the deeper you go inside the earth's crust, the higher the temperature and the theoretically more efficient geothermal energy can be used, the only problem being the depth at which this energy is available.
From the point of view of thermal potential, geothermal energy can be classified into two categories:

1) Geothermal energy of high thermal potential;
2) Geothermal energy of low thermal potential.

Table 2 shows the possibilities of using geothermal sources, depending on their thermal potential.

Table 2. The possibilities of using geothermal sources

No.	*Fluid*	*Temperature*	*Use*	*Observations*
1.	Water / Steam	High Temperature (HT> 220 ° C)	When producing electricity	- by binary cycle and / or steam cycle
			Direct	- as a thermal agent - with the help of heat pumps
2.	Water	Medium Temperature (MT = 100 -220°C)	When producing electricity	- by binary cycle and
			Direct	- as a thermal agent - with the help of heat pumps
3.	Water	Low Temperature (LT = 50 - 100 ° C)	Direct	- as a thermal agent - with the help of heat pumps

Therefore, geothermal energy represents various particular categories of thermal energy, which are contained in the earth's crust.
Evident, a geothermal exploitation requires two wells (see Figure 8):

1) ***one of production***, which allows the extraction of hot water

and,

2) ***one an injection***, which allows the reinjection of cold (used) water into the layer.

The second borehole must be drilled so that its extremity is placed at an optimal distance from the first borehole, in order to avoid a too rapid drop in the temperature of the exploited water. [1]

The practical realization of this system consists in drilling two boreholes.
In principle, the geothermal energy from the earth is extracted with the help of the productive probe, from the established depth (depending on the heat demand and the existing geological conditions).
The natural heat of the earth is extracted at the surface of the productive well, then taken over by a system of local pipes through which the thermal water or special thermal agent circulates (for example: water + antifreeze) and transported to the main pipe system for heating and/or air conditioning of production spaces, offices and private homes with the help of heat pumps. [7, 8]

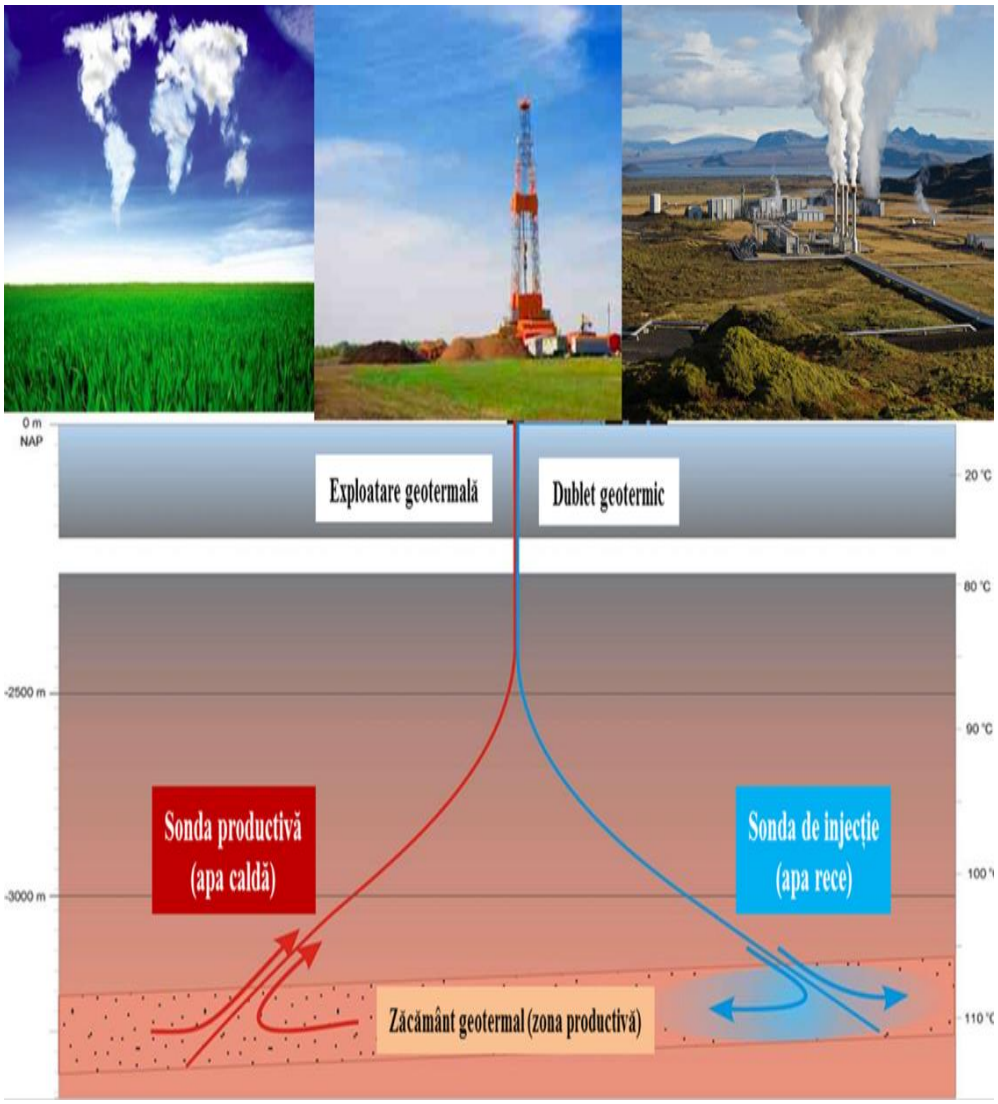

Fig. 8.. Drilling and exploitation of geothermal wells [1]

5. Use of geothermal resources

The use of geothermal energy depends on the thermal parameters of the resource. For resources with geothermal fluids exceeding 150 ° C they can be used for electricity production, being fully technically and economically justified (the current minimum threshold for electricity production is 97 ° C).

Below this temperature, geothermal energy is used in direct processing technologies, most of which are built as cascade systems (see Figure 7). [1]

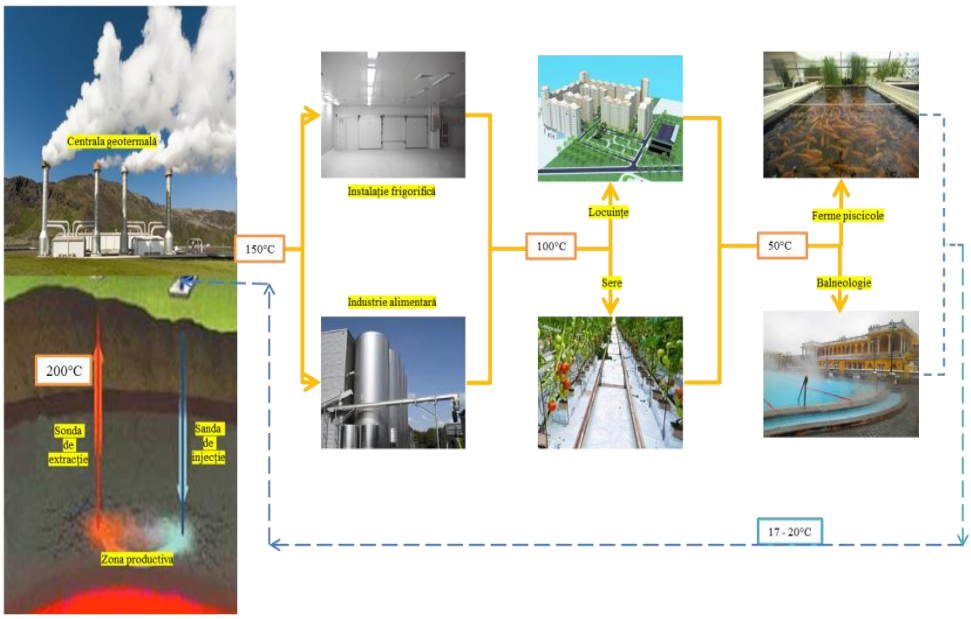

Fig. 9. Use of geothermal energy in the waterfall system [1]

A wide efficient use of geothermal energy, in cascade system, can be in [1]:
- Industry (*heating, drying*) at a temperature of 100 - 90° C;
- District heating (*heating homes, hospitals, institutions etc*.), at a temperature of 90 - 60° C;
- Agriculture (*greenhouses, heating crops*), at a temperature of 70 - 60° C;
- Hot water preparation (*fish farms, balneology, housekeeping*) temperatures below 60° C.

5.1. Advantages and Disadvantages of using geothermal energy

Advantages [1, 9]

Overall, geothermal energy has a number of definite advantages:
- Economic (geothermal water is located exactly where the geothermal power plant is located, and the economic benefits remain in the respective region;
- Non-polluting (geothermal power plants do not require the combustion of fuels to obtain steam in starting turbines; electricity from the use of geothermal energy helps to conserve fuel and, of course, to reduce CO_2 emissions; there is no smoky air around the geothermal power plants to harm the atmosphere, they are built on forests, farms, etc.);
- Flexible (geothermal power plants have a modular design, with additional units that can be installed when demand increases, to increase electricity production);
- Resistant (geothermal power plants are designed to operate 24 hours a day, all year round; such a power plant is resistant to power outages during natural

disasters, adverse weather conditions, political misunderstandings, which can affect the transport of fuel);
- In the development of the country (geothermal projects offer all the benefits to contribute, without pollution, to the development of the country; installations in remote locations can exceed the standards of quality of life, bringing electricity from a long distance into people's homes).

Disadvantages [1, 5, 9]
Among the disadvantages, the following aspects can be highlighted
- There is a danger of earthquakes, caused by wrong drilling;
- There may be leaks of gas or hazardous substances;
- There is a danger of an eruption caused by wrong drilling or natural causes;
- If the drilling and exploitation are not done correctly, the energy production can be significantly reduced.

Conclusions

Conclusion (1). This article highlights aspects regarding the **geothermal energy** on the Romanian territory, - ***an unconventional, clean and renewable energy source*** -, with special emphasis on drilling geothermal wells.
Conclusion (2). Geothermal energy is a source of energy that can be used indefinitely due to its inexhaustibility; being a safe primary energy source it does not require storage facilities.
Conclusion (3). Geothermal energy is one of the alternatives that can meet human need for energy, minimizing the impact on the environment.
Conclusion (4). The resulting pollution level is very low, - it tends to zero - and by using this form of alternative energy in the future we can give up other more polluting forms of energy.
Conclusion (5). Geothermal energy, unlike other forms of renewable energy (eg solar, wind, etc.), can be exploited continuously, regardless of weather conditions. Moreover, due to its inexhaustibility, this energy source can be used indefinitely and, at the same time, being a safe primary energy source, it does not require costs regarding storage facilities.
Conclusion (6). Geothermal energy, at national level, in addition to being a clean and beneficial energy source for the population, is expected to be exploited to its full potential.
Conclusion (7). Consequently, Romania has a remarkable potential in terms of geothermal energy, being considered the third country in Europe. Unfortunately, the degree of capitalization of energy sources of geothermal origin is low, - *today, only a small part of the geothermal potential is used (greenhouses, balneology and leisure)* -, the main cause being determined by the lack of adequate financial

support, which does not favor the development of this energy sector with superior economic and financial effects.

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