BASIC SOFTWARE FOR THE THERMAL ENERGY DEMAND ANALYSIS OF A HOUSEHOLD USING SOLID BIOMASS AS ENERGY SOURCE

Teodora CHIRA, Mugur BĂLAN

TECHNICAL UNIVERSITY of Cluj-Napoca
teodora.chira@maar.utcluj.ro ; mugur.balan@termo.utcluj.ro

Rezumat. În ultimii ani, datorită creşterii condiţiilor de trai a populaţiei din zona rurală a României, nevoia de energie termică în aceste zone a crescut. În aceste condiţii a crescut şi gradul de utilizare a sistemelor de încălzire cu biomasă solidă. Pentru alegerea soluţiei optime a sistemului de încălzirea unei locuinţe este necesară realizarea unei analize energetice. Lucrarea prezintă un model matematic şi un program fundamental, care realizează analiza energetică a unei locuinţe, făcând posibilă determinarea consumului de biomasă, pentru acoperirea nevoilor de energie termică ale locuinţei. Datorită interfeţei simple, programul oferă posibilitatea, locuitorilor din zonele rurale ale României, care au cunoştinţe reduse de termotehnică, să obţină informaţiile necesare pentru alegerea variantei optime a sistemului de încălzire al locuinţei. Programul poate calcula necesarul de căldură şi cantitatea totală de biomasă necesară luând în considerare caracteristicile energetice ale biomasei utilizate, caracteristicile termice ale elementelor de construcţie a casei şi valorile temperaturilor interioare şi exterioarei.

1. THERMAL ENERGY BALANCE OF THE HOUSES

The energetic analyses of the solid biomass heating system for a household involve determination of thermal energy demand to guarantee an optimum temperature inside the house, as indicated in [1].

The thermal balance is necessary to compute the amount of input heat flux, equal with the amount of heat flux losses:

where: $$\dot{Q}_1 + \dot{Q}_2 + \dot{Q}_r = \dot{Q}_3 + \dot{Q}_4 + \dot{Q}_5 \qquad (1)$$

$\dot{Q} = \dot{Q}_1 + \dot{Q}_2 + \dot{Q}_r$ is the heat flux provided [kW]

$\dot{Q}_1$ is the total heat flux release by thermal unit [kW];

$\dot{Q}_2$ is the heat flux release by the people [kW];

$\dot{Q}_r$ is the heat flux due to solar radiation [kW];

$\dot{Q}_3$ are the heat flux losses through thermal transmission [kW];

$\dot{Q}_4$ is the heat flux demand for heating of ventilation air [kW];

$\dot{Q}_5$ is the heat flux demand for heating water [kW].

In admeasurements conditions, in according with STAS 1907, $\dot{Q}_2 + \dot{Q}_r$ can be neglected to compute the heat demand in the worth situation.

The heat flux thermal transmission through inertial elements (walls, windows, floor and ceiling) is divided in four components and is calculate with equation:

$$\dot{Q}_3 = \dot{Q}_{3.1} + \dot{Q}_{3.2} + \dot{Q}_{3.3} + \dot{Q}_{3.4} \qquad (2)$$

where:

$\dot{Q}_{3.1}$ are the heat flux losses through walls [kW];

$\dot{Q}_{3.2}$ are the heat flux losses through windows surface [kW];

$\dot{Q}_{3.3}$ are the heat flux losses through floor [kW];

$\dot{Q}_{3.4}$ are the heat flux losses through ceiling [kW].

Each component of equation (2) is calculate with the equation (3), considering the specifically structure (characteristics) of each inertial elements:

$$\dot{Q}_{3.i} = S_i \cdot k_i \cdot (t_i - t_o) \qquad (3)$$

where:

$\dot{Q}_{3.i}$ are the heat flux losses through inertial elements [kW];

S_i is the total surface of inertial elements [m²];

k_i is the global heat transfer coefficient of inertial elements [W/m²K]

t_i is the value of inside temperature [°C];

t_o is the value of outside temperature [°C].

The global heat transfer coefficient, k_i is calculated considering the structure of inertial elements with equation:

$$k_i = \frac{1}{\dfrac{1}{\alpha_i} + \displaystyle\sum_{j=1}^{n} \dfrac{\delta_j}{\lambda_j} + \dfrac{1}{\alpha_o}} \qquad (4)$$

where:

k_i is the global heat transfer coefficient of inertial elements [W/m²K];

α_i is the convective heat transfer coefficient on the inside [W/m²K];

α_o is the convective heat transfer coefficient on the outside [W/m²K];

δ_j is the thickness of the layer j of the inertial elements [m];

λ_j is the thermal conductivity of the layer j of the inertial elements [W/m²K].

The determination of k_i involves knowing data about the structure and dimensions of the inertial elements.

In order to simplifying the software algorithm the structure of outside walls is considerate composed by two layers one resistance layer and one of thermal insulation. The structure of ceiling is composed by the resistance layer (concrete layer), thermal insulation layer and hydro insulation layer. The structure of floor is composed by the wood plank or parquet layer, the resistance layer (concrete material) and hydro insulation layer.

German standard classifications divide houses in tree categories considering the quality of thermal insulated layer:

– houses with normal thermal insulation: the thickness of thermal insulation equivalent with 5...7 cm of polystyrene;
– houses with low energetic consumption: the thickness of thermal insulation equivalent with 10...15 cm of polystyrene;
– passive energetic houses: the thickness of thermal insulation equivalent with 15...25 cm of polystyrene.

The heat flux demand to compensate the ventilation demand was calculate with equation (5) in the case of houses with normal thermal insulation or with equation (6) in the cases of houses with low energetic consumption or passive energetic houses. In the last two situations mechanical ventilation of the house must replace the traditional ventilation system based on windows opening.

$$\dot{Q}_4 = 0,8 \cdot \dot{Q}_3 \qquad (5)$$

$$\dot{Q}_4 = \dot{Q}_3 \qquad (6)$$

where:

$\dot{Q}_4$ is the heat flux demand to compensate the ventilation [kW];

$\dot{Q}_3$ are the heat flux losses through thermal transmission [kW];

The heat flux demand for heating water is calculated with equation:

$$\dot{Q}_5 = \dot{V} \cdot \rho_{water} \cdot c_p \cdot (t_{owater} - t_{iwater}) \cdot n \qquad (7)$$

where:

$\dot{Q}_5$ is the heat flux demand for heating water [kW];

ρ_{water} is water density [kg/m^3];

c_p is the specific heat of water [kJ/kg·K];

$\dot{V}$ is water consumption/person/day (DIN 4701 $\dot{V} = $ 35l/person/day at 60°C water temperature or 50l/person/day at 45°C water temperature);

t_{owater} is the water temperature at outside [°C];

t_{iwater} is the water temperature at inside [°C].

n is number of person from house.

2. SOFTWARE INTERFACE DESCRIPTION

A basic software was developed according to the presented mathematical model. The interface of the software is suggestive and easy to use without any special knowledge. The main interface (Fig. 1) does the connection between the input data modules of the software and allows starting the calculations.

The input data interface for walls is presented in figure 2. Similar interfaces are available for each of the building part (figure 3 – figure 5). Figure 6 presents the interface for the input data concerning the type of the ventilation system and figure 7 is presenting the interface for the input a data concerning the hot water. The choice of the biomass type interface is presented in figure 8.
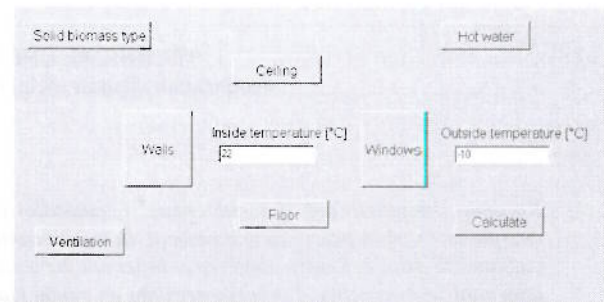

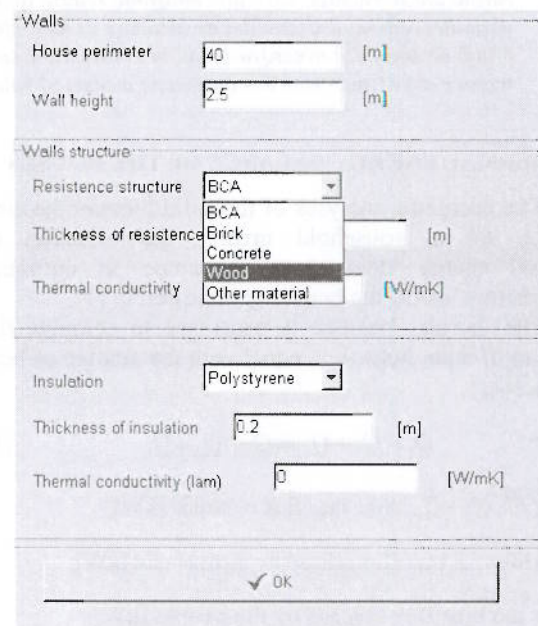**Fig. 1.** The main software interface.

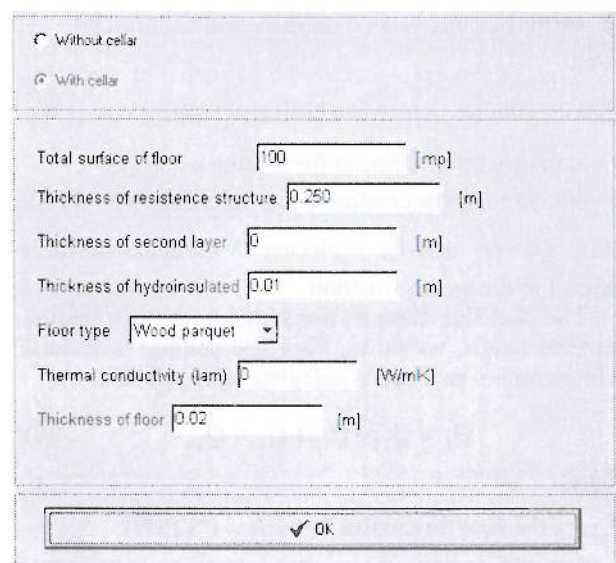**Fig. 2.** The walls interface.

Fig. 3. The floor interface.

Fig. 4. The ceiling interface.

Fig. 5. The windows interface.

Fig. 6. The ventilation interface.

Fig. 7. The hot water interface.

Fig. 8. The solid biomass interface.

In the figure 9 is presented the results interface with a synthesis of the input data and the heat demand, the hourly biomass consumption and the monthly biomass consumption.

Fig. 9. The results interface.

3. RESULTS

The results obtained using the basic software for different input data, offer the possibility to analyze the influence of different parameters on the global heat flux demand and on its structure.

According to figure 10, the heat flux losses through the walls are decreasing with the increasing of the thickness insulation layer of walls. It can be observed the high difference between the value of heat flux losses through without insulation walls and insulated walls. Comparing the values of the heat fluxes indicated it is easy to observe that the use of the thermal insulation on the building walls is compulsory, because the first 5 cm of insulation, in the case of the polystyrene for instance, is reducing the heat flux through the walls with about 50% and this amount is very important for the thermal energy balance of the house.

In figure 11 it is presented the structure of the total heat flux demand in the case of no insulation, and in figure 12, the same structure in the case of the use of 10 cm of polystyrene as insulation. Comparing the two graphics and taking into account that the value of the heat demand due to the preparation of the warm water, is the same in the two situations, it can be observed that the total amount of the others heat flux, can be dramatically reduced using the 10 cm of polystyrene insulation, as indicated in the two figures.
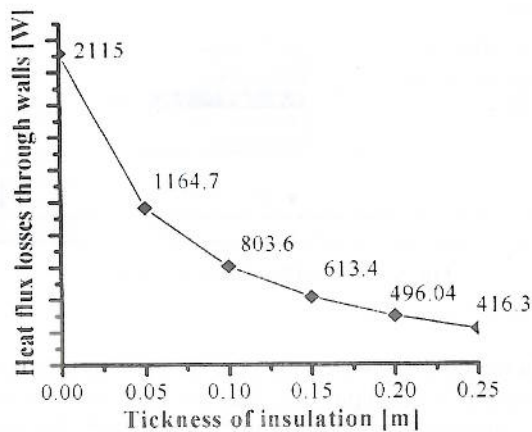
Fig. 10. Influence of the thickness insulation (polystirene) of walls on the heat flux losses through walls.
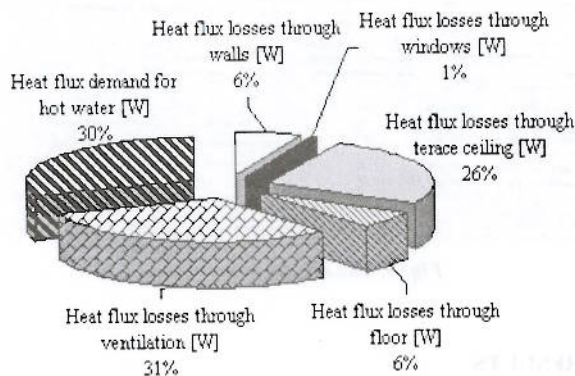

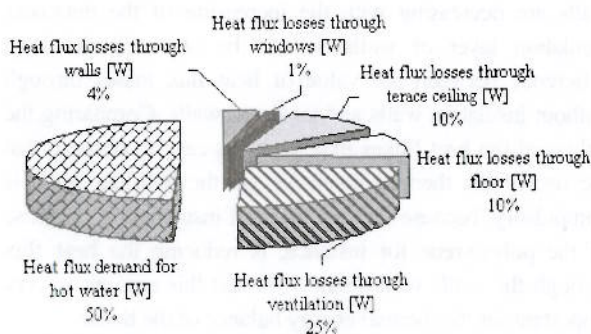*Fig. 11. The structure of the heat flux demand in the case of no insulation.*

Fig. 12. The structure of the heat flux demand in the case of 10 cm of polystyrene.

The influence of the insulation type used for walls on the heat flux losses through walls is showed in figure 13. It can be observed that polystyrene and mineral wod, the most used insulation materials, have almost similar effects on the heat flux reduction, because of almost similar thermal characteristics. Polyurethane is

used in the case of houses build by sandwich type panels and this material ensures the best quality of thermal insulation.
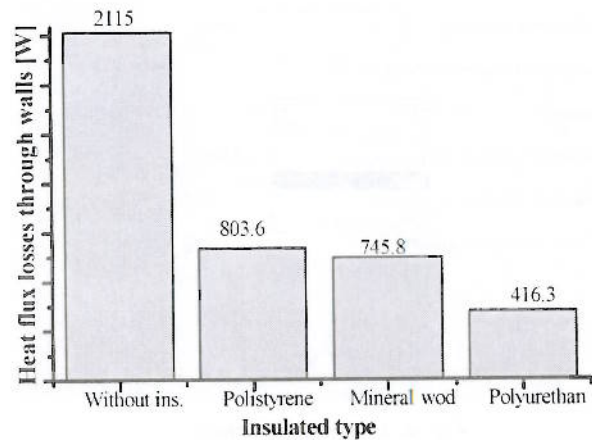

Fig. 13. Influence of insulation type on the heat flux losses through walls.

The heat losses through windows obviously depend of the windows type as it is indicated in figure 14. It can be observed the influence of the windows type on heat flux losses through windows. There is a high difference between the heat flux losses through windows with simple glass windows and Low Emission thermoresistent windows.
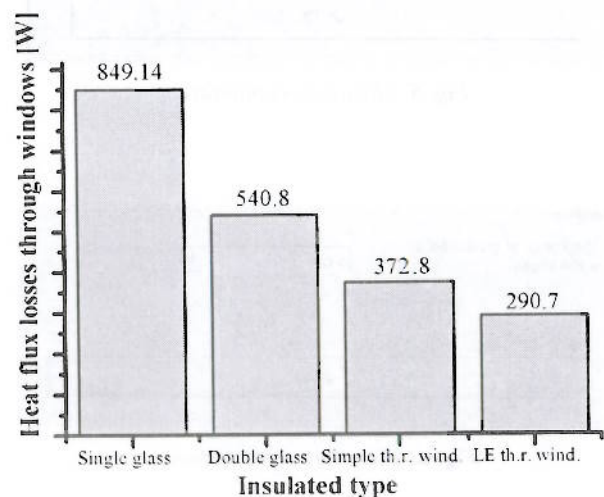

Fig. 14. The influence of windows type on the heat flux losses through windows.

The heat losses through terrace ceiling depend of the insulation, in a similar way as the walls. In figure 15 can be observed the difference between different types of 10 cm insulation. BCA and wood are representing cheaper but not as effective solutions as polystyrene or mineral wod.
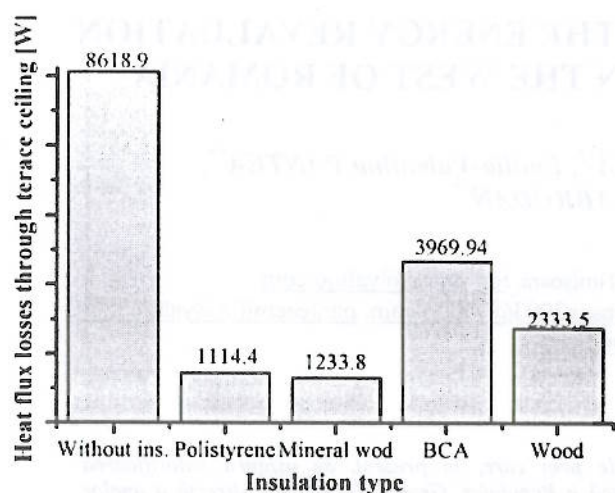
Fig. 15. The influence of ceiling type of the heat flux losses through ceiling.

The heat flux demand have a linear variation with the inside temperature and outside temperature as indicated in figures 16 and 17.
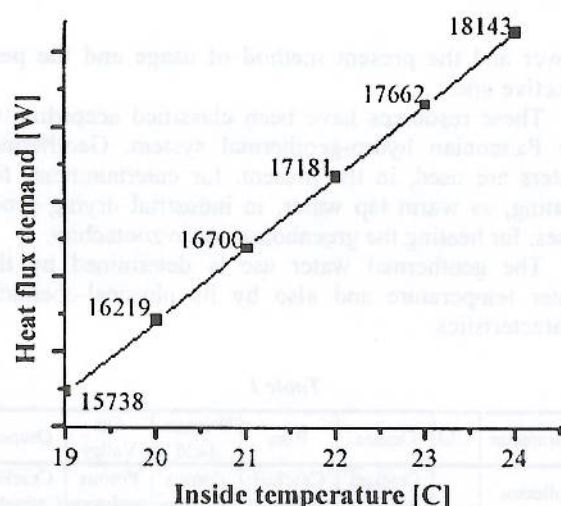

Fig. 16. The influence of inside temperature on the heat flux demand.

Increasing the inside temperature from 20°C to 22°C, will increase the heat demand with about 6%, but taking into acount the huge reductions of the heat demand, that can be done using a good insulation with high quality materials, economies done by decreasing the thermal confort are not justified.
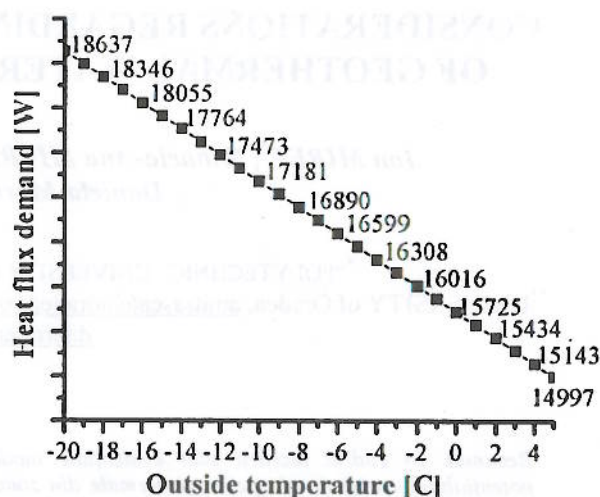

Fig. 17. The influence of outside temperature on the heat flux demand.

The graphic represented in figure 17 is indicated that the total amount of heat demand in a period with an average outside temperature of 0°C is with 15% lower that in a period of −15° outside temperature. This amount will be reflected in the biomass consumption corresponding to the lower outside temperatures and the householders should consider these aspects.

CONCLUSIONS

The basic software is able to calculate the quantity of heat and the total quantity of biomass necessary for heating household considering the energetic characteristics of solid biomass, the thermal characteristics of construction elements and outside and inside temperature. The basic software is a useful tool for the people from rural area because the interface is suggestive, the input dates are simple, but the results have a big importance for to choose the optimum solution of the solid biomass heating system for his household. So, it helps the people to design themselves an efficient biomass heating system.

REFERENCES

[1] *** Manual of Installations, Heating Installations, Ed. ARTENCO, Bucharest, 2002 (in romanian).
[2] *** Handbook of Agricultural Engineering, Energy & Biomass Engineering, Ed. CIGR – The International Commission of Agricultural Engineers, vol.V, USA, 1999.

CONSIDERATIONS REGARDING THE ENERGY REVALUATION OF GEOTHERMAL WATERS IN THE WEST OF ROMANIA

Ion MIREL, *Mihaela-Ana MITRAŞCĂ**, Emilia-Valentina PANTEA**,*
*Daniela-Mariana ABRUDAN***

*"POLYTECHNIC" UNIVERSITY from Timişoara, ion_mirel@yahoo.com
**UNIVERSITY of Oradea, amitrasca@uoradea.ro, mitrasca2003@yahoo.com, panteaemilia@yahoo.com, dabrudan@uoradea.ro

Rezumat. În cadrul lucrării sunt evidenţiate modalităţile prin care, în prezent, se asigură valorificarea potenţialului energetic al apelor geotermale din zona vestică a României. Gradul de utilizare directă a apelor geotermale pentru încălzirea spaţiilor de locuit, preparatul apei calde menajere şi a altor utilizări (sere, piscine, piscicultură, balneologie, industrie etc.) este determinat de prezenţa sărurilor care dau sedimente şi încrustaţii, a gazelor sub formă de metan şi dioxid de carbon, precum şi de cea a substanţelor chimice şi a gazelor dizolvate, care acţionează cu agresivitate asupra construcţiilor şi a instalaţiilor, făcându-le inapte funcţionării după perioade relativ scurte de timp (0,5-1,6 ani). Aceste neajunsuri, frecvente la majoritatea instalaţiilor de la forajele existente, se pot elimina numai prin aplicarea unor tehnologii de tratare specifice apei captate de la fiecare sondă. Pentru exemplificare, se prezintă tehnologia de tratare constituită dintr-o degazare combinată cu o dedurizare chimică, aplicată la sonda 4004, prin care se asigură încălzitul spaţiilor de cazare, apă caldă menajeră şi apa caldă de la piscina hotelului „Elite" din Oradea. Tehnologia utilizată conduce la reduceri importante de combustibili convenţionali, dar şi la majorarea duratelor de funcţionare a instalaţiilor aferente.

1. GENERAL CONSIDERATIONS

Geothermal waters are unconventional energy sources which, in the near future, will progressively replace, for certain consumer categories, the natural gas, petrol and coal – thus they represent an alternative for reducing or saving consumption of classical fuels.

In year 2000, the ratio of renewable resources to total production of primary energy at a global level was 13.8%.

In Romania, it's forecasted that at the end of 2015, the ratio of renewable energy sources to total consumption of primary resources will be 11.2%.

Exploration and geological research of the geothermal deposits began in Romania in 1962, with the activation of the wells in Oradea, Felix, Calacea and Timisoara. The 200 geothermal wells drilled until now have confirmed the presence of very valuable geothermal resources.

The geothermal water usage degree for heating, running warm water and for different types of activities is determined by the water sources characteristics and also by the consumers' needs [4].

The aggressive and encrusted nature of water and gases captured determines the fast degradation of constructions and installations that insure the geothermal water transport to different categories of consumers.

These shortcomings, frequent for many installations in existent wells, can be only eliminated by applying some treatment technologies specific for the water collected from each source.

2. ENERGETIC CHARACTERISTICS OF GEOTHERMAL RESOURCES IN ROMANIA

The geothermal resources of Romania are shown in table 1, according to water temperature, the installed power and the present method of usage and the perspective one.

These resources have been classified according to the Pannonian hydro-geothermal system. Geothermal waters are used, in the present, for entertainment, for heating, as warm tap water, in industrial drying processes, for heating the greenhouses or in zootechny.

The geothermal water use is determined by the water temperature and also by its physical-chemical characteristics.

Table 1

Parameter	UM	Oradea	Borş	Western field	Olt Valley	Otopeni
Collector		Cracked Carbonate	Cracked Carbonate	Porous sandstone	Porous sandstone	Cracked Carbonate
Area	Km²	75	12	2,500	28	300
Depth	Km	2,2 ÷ 3,2	2,4 ÷ 2,8	0,8 ÷ 2,1	2,1 ÷ 2,4	1,9 ÷ 2,6
Drilled wells	(total)	14	6	88	3	11
Used wells		12	5	37	2	5
Temperature	°C	70 ÷ 105	115	50 ÷ 85	92 ÷ 96	58 ÷ 75
Thermal gradient	°C/100	3,5 ÷ 4,3	4,5 ÷ 5,0	3,8 ÷ 5,0	4,6 ÷ 4,8	2,8 ÷ 3,4
Mineralization	g/l	0,8 ÷ 1,4	12 ÷ 14	2 ÷ 7	13	2,2
Dissolved gases	m³ₙ/m³	0,05	5 ÷ 6,5	0,5 ÷ 2,5	2 ÷ 2,8	0,1
Production type		Artesian	Artesian	Artesian+ Pumping	Artesian	Pumping
Flow capacity/well	l/s	4 ÷ 20	10 ÷ 15	4 ÷ 18	12 ÷ 25	22 ÷ 28
Uses	no.	11	2	37	2	2
Annual saving	t.e.p.	9700	3200	18500	2600	1900
Installed power	MWt	58	25	210	18	32
Exploiting reservoirs (for 20 years)	MW/day	570	110	4700	190	310

The geothermal perimeter Oradea-Băile Felix-1 Mai is generally considered as being made up of two distinct deposits (Oradea and Băile Felix-1 Mai), at different depths and made of rocks of different ages but interconnected hydro dynamically. The geothermal deposit form Oradea is billeted in cracked limestone and triassic dolomite at 2200 and 3200 m depth, with an area of around 110 km^2, found almost entirely in Oradea's underground. The water temperature at the surface decreases from 100°C in the western part to up to 70°C in the eastern part, the average balanced temperature of the 11 production wells from the area (one is used for injection) is of 87°C well spring and 90°C by pumping. The geothermal water does not have en encrusted nature and it does not corrode, it just contains some dissolved gases traces and the mineralization is relatively small (0,9÷1,2 g/l, according to the well), so that it does not represent a danger for chemical pollution. The geothermal deposit from Băile Felix-1 Mai Spas is billeted in cracked cretaceous limestone, at depths between 45 and 175 m (for complex I, which insures for over 90% of the extracted volume) and between 200 and 500 m, in areas with finer configuration (complex II). The chemical composition of the geothermal deposit form Felix-1 Mai Spas is similar to that from Oradea deposit, being part of the same water natural circuit. The geothermal water temperature at the surface decreases slowly from west to east, having 35÷45°C in complex I and 40÷50°C in complex II.

The Borş geothermal perimeter is billeted in limestone and cracked Triassic dolomites at depths between 2000 and 3000 m; it is tectonic closed deposit, with an area of only 12 km^2. the geothermal water has a high content of dissolved solids of 13÷16 g/l, a concentration of dissolved gases of 5 m$_N^3$/m^3 (70% CO$_2$ and 30% CH$_4$) and a high potential of crust deposition. The deposit temperature is higher than 130°C, at average depths of 2500 m [2].

The Ciumeghiu geothermal perimeter is located in the Western Field (between Oradea and Arad) and is billeted in porous sandstone of the Inferior Pannonian, at 2200 m average depth. The geothermal water temperature at the surface is of 105°C, the concentration of dissolved gases 3 m$_N^3$/m^3 (98% CH$_4$) and the mineralization 5÷6 g/l, with a high potential of crust deposition.

The geothermal perimeter from Cozia-Călimăneşti-Căciulata is billeted in porous sandstone between 1900 and 2200 m depth. There are three existing artesian wells, the water temperature is of 90÷95°C, the pressure is of 16÷20 bar, the mineralization is of 14 g/l, without encrusting potential, and the dissolved gases concentration is of 2 m$_N^3$/m^3 (90% CH$_4$).

The geothermal perimeter from Otopeni is located north of Bucharest and is only partially delimitated (around 300 km^2) according to the last investigations. The 12 drilled wells indicated a enormous deposits, billeted in limestone and cracked dolomites, found at depths between 1900 and 2600 m, pertaining to Moesic Platform. The geothermal water has temperatures between 58÷72°C and mineralization of 1,5÷2,2 g/l, but with a high content of H$_2$S (over 25 ppm), so that the reinsertion is absolutely compulsory. The production is achieved only with submersible pumps as the water dynamic level in the wells is at 80 m below ground level.

3. THE ENERGETIC REEVALUATION OF GEOTHERMAL WATER FROM THE WESTERN PART OF ROMANIA

The multifunctional reevaluation of geothermal resources is meant to become the dominant type of geothermal water use. The geothermal resources can include gaseous, liquid and solid resources. The resource's structure also includes a system for the warm current and the accumulation room, which can be refilled; the geothermal resources can have climatic balneologic qualities and a high potential for mechanical power (geo-pressure fields); they can transmit the radioactivity and can form around the geothermal deposit mineral deposits.

Thus, the geothermal resources are unique and unrivaled by any other natural resources due to the multitude of potential applications. The components' multiplicity of geothermal resources, varying form one type to another, allows a great number of different models of resource's use. Besides a unique direct use of the resource's components there are other methods – partially have been applied – the reuse of some components (such as heating vapors, water).

The direct use of geothermal water can be achieved for: heating rooms and preparing the warn tap water, heating the greenhouses, pisciculture, aquaculture, balneology and industry.

The main uses of geothermal water in Romania are: heating the spaces and preparing warm tap water, balneology, heating the greenhouses, wood kiln drying, milk pasteurization, flax and hemp retting, fish intensive breeding, etc. (figure 1). The total saved energy achieved annually is over 35 000 t.e.p.
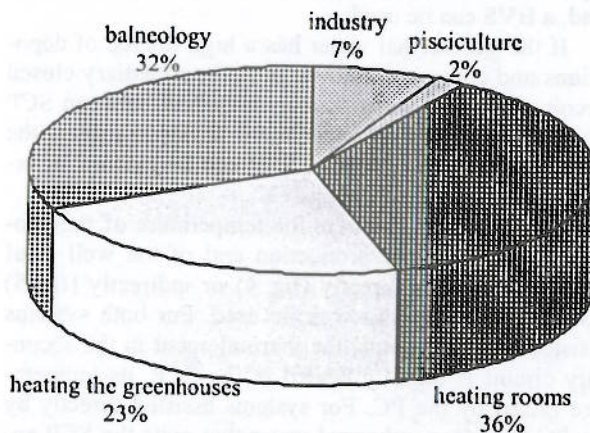

Fig. 1. The use of geothermal water in Romania.

4. TECHNOLOGICAL DIAGRAMS FOR CAPTURING AND REEVALUATION OF GEOTHERMAL WATER

Taking into account all the economical aspects that appear for heating the rooms using classic fuel, also the present energetic crisis, geothermal water use applications were developed for heating the rooms and for the preparation of warm tap water. A few technological diagrams examples used are shown next.

The most profitable way of exploitation, when the geothermal deposit can produce only a reduced flow capacity – but continuous – is its use for preparing warm tap water as it has a constant consumption level all year long. In this respect can be used a system of the type shown in figure 2.
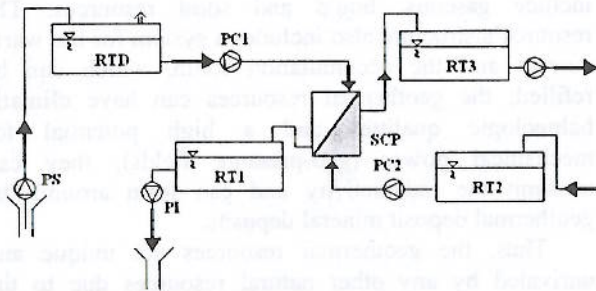

Fig. 2. System for preparing warm tap water.
PS – submersible pump; RTD – buffer and degasifying reservoir; PC – circulation pumps; RT – buffer reservoir; SCP – plated heat exchanger; PI – injection pump.

The buffer reservoirs are dimensioned to cover the variations of the flow capacity during 24 hours, so that the submersible pumps can function at a constant rotation rate. In this way, the initial investment of capital is reduced, as there is no need for frequency regulators for supplying the engines and at the same time it increases the pumps' reliability.

In case the geothermal water temperature at the production end of the well is lower than 30-40°C, it cannot cover the heating needed, not even at small partial loads, even if radiant panels are used. In this situation, a heating pump can be used to increase the temperature of the second thermal agent (figure 3). If heating devices convective type is used, during maximum load, a BVS can be used.

If the geothermal water has a high degree of depositions and corrosion, the use of an intermediary closed circuit with fresh water is recommended, between SCP and the heating pump vaporizer in order to protect the latter, because, obviously, a SCP can be cleaned or replaced easily and less expensive.

For the deposits where the temperature of the geothermal water at the production end of the well is of 40÷60°C, systems directly (fig. 4) or indirectly (fig. 5) assisted by heat pumps can be used. For both systems assisted by heat pumps, the thermal agent in the secondary circuit is initially heated in the SCP, its temperature raised by the PC. For systems assisted directly by the PC (fig. 4), geothermal water that exits the SCP enters the vaporizer, thus directly reducing its exit temperature.
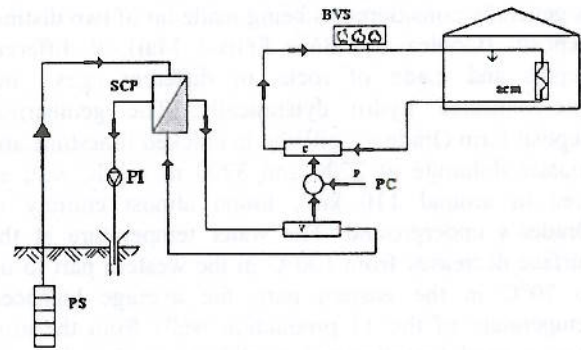

Fig. 3. Heating pump system type.
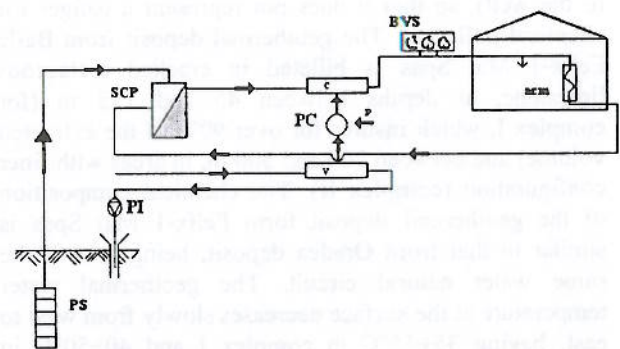BVS – load top boiler

Fig. 4. System directly assisted by w.t.w. (warm tap water) heat pump.

For systems indirectly assisted by heat pumps, PC (fig. 5), the vaporizer is supplied with returning, secondary thermal agent, lowering its temperature, thus indirectly decreasing the temperature on exit of the geothermal water. If the consumers are using radiators, during very cold periods BVS' can be used to raise the temperature of the secondary thermal agent on its way in. The heat pumps are selected so that they raise the temperature enough to cover the basic thermal load, because once the temperature in the condenser rises, their efficiency decreases.
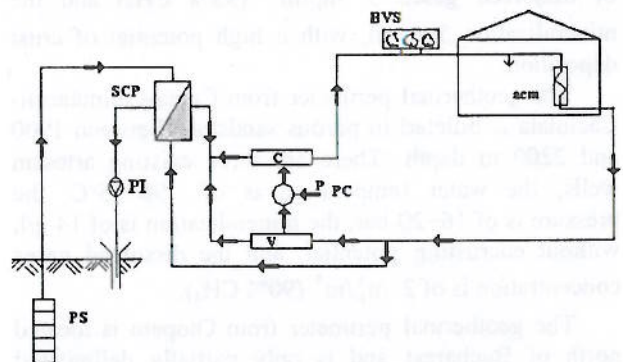

Fig. 5. System indirectly assisted by heat pump.

The figures presented above represent the basic constructive solutions, used in the present for central heating systems. Based on the conditions specific to each well and on the demand for thermal energy in its vicinity, one of these solutions or, typically, a combination of the two can be chosen so as to achieve the maximum possible economic efficiency in each particular case. An example of a combined central heating system is the one proposed for a hotel in Baile Felix, which shows in the pre-feasibility study that the economic indices have acceptable values. The basic representation of this system is shown in Figure 6. The temperature of the geothermal water at the exploitation end of the well in the Baile Felix deposit is 50°C.
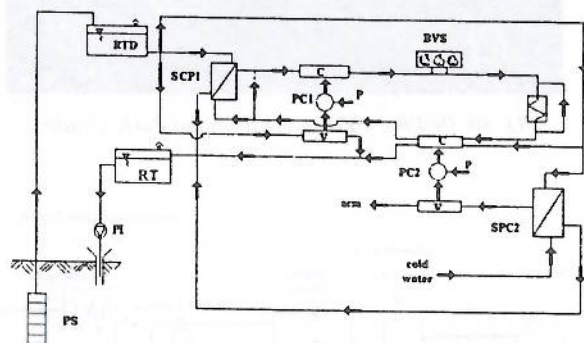

Fig. 6. A combined system, with direct heat exchange and assisted directly and indirectly by a heat pump.

Adjustment of the thermal load is made by modifying the entrance temperature in the secondary circuit. For small partial loads, when the necessary temperature is ≤45°C, the heating system works exchanging heat directly through SCP1. The condenser of the heat pump (PC1) is, in this case, bypassed. When the necessary entrance temperature in higher than 45°C, PC1 is turned on. The exit temperature rises in the same time, causing the exit temperature of the geothermal water in SCP1 to rise, which is then passed through the PC1 vaporizer. When the exit temperature reaches 40°C the direct heat exchange through SCP1 becomes inefficient so SCP1 is bypassed, the PC1 vaporizer being supplied with fresh geothermal water, at the temperature of the exploitation end of the well. When PC1 is working on partial loads, it's not recommended to continuously modify its functioning parameters in order to adjust the radiator entrance temperature. It's considered more efficient to have the possibility to mix part of the exiting thermal agent with the entering one, thus controlling the radiator entrance temperature, by adjusting the two mixed debits, while PC1 works with a constant partial load. If the necessary entrance temperature is higher than the maximum temperature that PC1 can supply, BVS is turned on.

For the preparation of warm running water, the cold water is initially warmed to 45°C in SCP2 and, after-

wards, to the standard temperature of 65°C, in the condenser of the PC2 heat pump. If the PC2 vaporizer extracts the heat from the way out of the secondary circuit, the result is an improved heat exchange in SCP1 and a decrease in the exit temperature of the used geothermal water.

The representation of the first system for using geothermal water, built in the Sacuieni exploitation perimeter, Bihor county, connected to well 4058, is shown in figure 7 [1, 5].
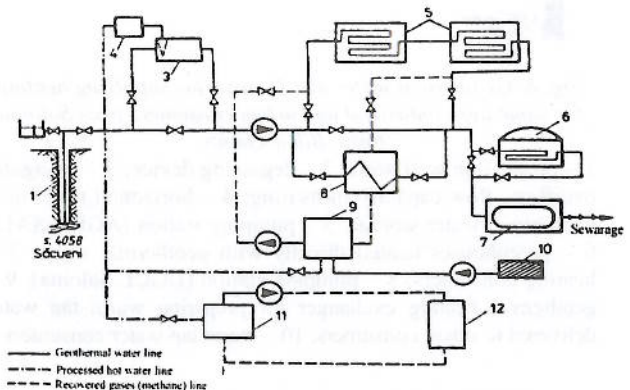

Fig. 7. Installations' diagram of geothermal water, linked to well 4058 from Săcuieni village, Bihor county.
1 – production well 4058; 2 – deltoid spill pipe for measuring the discharge; 3,4 – getter with intercepting device of combustible gases (methane); 5 – greenhouses heated indirectly with geothermal water (2 ha); 6 – greenhouses heated directly with geothermal water; 7 – swimming pool with geothermal water; 8 – geothermal heat exchanger; 9,10 – top boiler and housekeeping with liquid fuel (CLU); 11 – top boiler running on methane gas saved form geothermal water; 12 – pigs breeding.

The distribution and utilization schema (geothermal water and gases) for the resources supplied by well 4667, for almost 15 years, to the consumers in the town of Salonta, Bihor county, is shown in figure 8.

Figure 9 shows the utilization schema for the geothermal energy produced in the Bors perimeter (42 ha of glass greenhouses, of which 8,4 ha designed to be heated with geothermal water), which is based on the alternative (or simultaneous) production of three double wells, of which only two will remain in use later on. In winter time, wells 529 and 4157 are used for injecting thermally worn out geothermal water and in the summer – for infusing fresh water, when the production wells are stopped and a renewal of the deposit pressure is desired, preparing for the new season of warming greenhouses. In the 1996-2000 periods, the level of water production has stayed at the level of previous seasons, with an average exploited debit for warming up greenhouses of 24l/s, on both production wells exploited in doubles. Still, the operator of the wells in the Bors perimeter has suggested a reduction of the produced debits, after observing an accentuated and continuous decrease in pressure and temperature in the deposit [1].
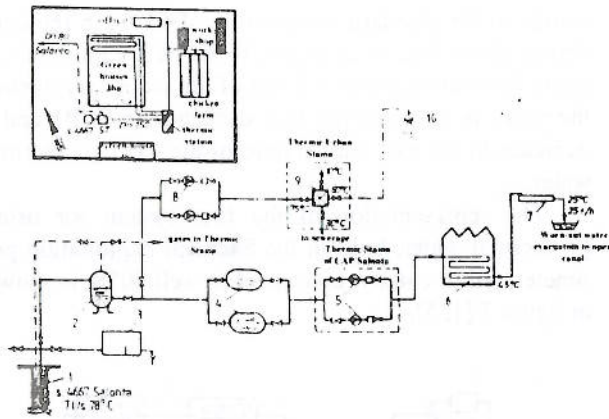
Fig. 8. *Geothermal water use diagram for supplying heating for some agro industrial and urban consumers from Salonta town, Bihor county.*

1 – production well 4667; 2 – degassing device; 3 – triangular overflow, flow capacity measuring; 4 – horizontal reservoirs, geothermal water storage; 5 – pumping station (AGRINSAL); 6 – greenhouses heated directly with geothermal water; 7 – heating consumers; 8 – pumping station (IJGCL Salonta); 9 – geothermal heating exchanger for preparing warm tap water delivered to urban consumers; 10 – warm tap water consumers.
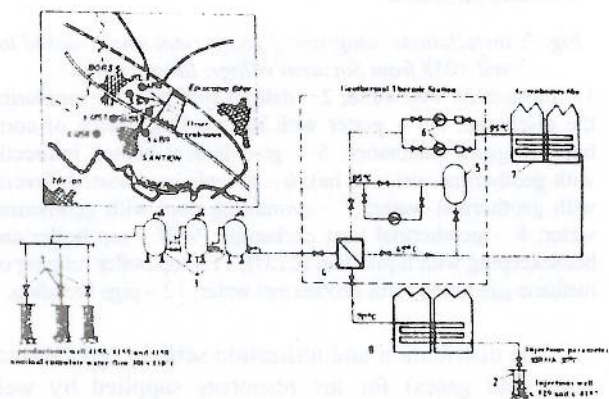

Fig. 9. *Installations' diagram of heating the Orser green-houses using geothermal water from Borş-Sântion perimeter, Bihor county* [1].

1 – production wells (4155, 4159 şi 4158); 2 – injection wells (529, 4157, 4156); 3 – degasifying reservoirs; 4 – geothermal heat exchanger, for greenhouses indirectly heated; 5 – closed expansion vessel; 6 – circulation pumps secondary agent heating; 7 – greenhouses with indirect geothermal heating; 8 – greenhouses heated directly with geothermal water (second cooling stage).

Another example is the schema for the central heating system used by Hotel "Elite" in Oradea, Bihor county. The heat source is the drilling in the I.C. Bratianu Park, at a distance of 80 m from the hotel. The drilling, shown in figure 10, was carried out for the swimming pool of Hotel Dacia (now called Hotel Continental). The water temperature is de 80°C, the debit of the drilling is 1100 m³/day, water mineralization at 1,1 g/l, the water contains gases [3].

The thermal station heating system (figure 11) is the first step in using the geothermal water; in the second phase, the water is used for the hotel swimming pool

inside the building, and from here, readily cooled at 30°C, evacuated in the sewer system. Magnetic treatment of the water will be done directly, before entrance in to the heat exchangers. This treatment will be carried out water-softening devices with magnetic filters [3, 6, 9].
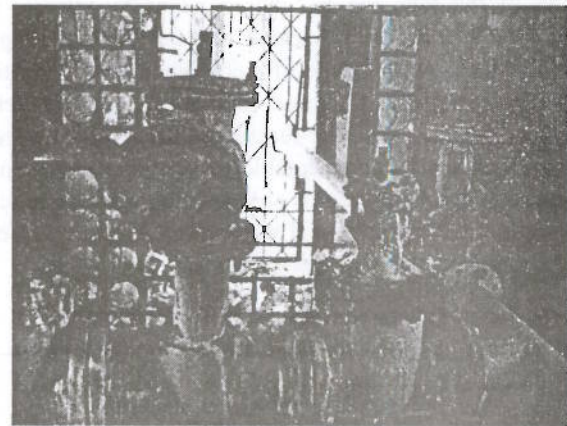

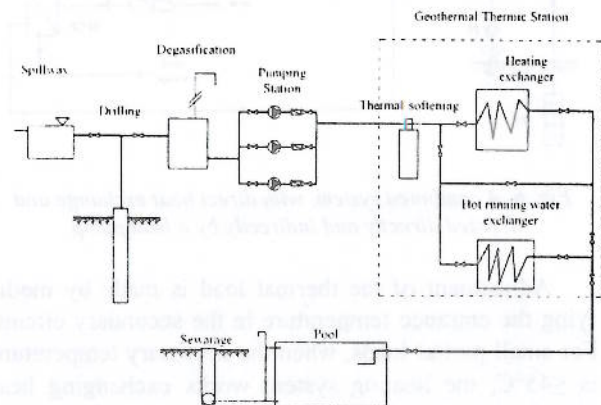**Fig. 10.** *Drilling 4004 in the Bratianu Park, Oradea.*

Fig. 11. *Installation for heating and processing hot running water, by using geothermal water [3, 7, 8].*

The technology used by Hotel "Elite" in Oradea leads to important decreases in the use of conventional fuels:

✓ The annual cost of producing thermal energy with a thermo-central running on natural gases is: the investment – 8200 Euro; the fuel/year – 3587 Euro.

✓ The cost of producing thermal energy with a thermal station, with geothermal water at 80°C as main agent, is: the investment – 4850 Euro; the cost of geothermal water per year – 1673 Euro.

When using unconventional energy from geothermal water, 25620 m³ₙ /year natural gases, and 1914 Euro/year, are saved.

If the cost of heat supplied by the geothermal source, through the network of the distribution enterprise, is higher than the cost of heat supplied by a traditional thermal source (in our case, natural gases from a thermo-central), the geothermal water solution will not be adopted, and if the opposite is true, and the cost of heat supplied by the geothermal source is lower than the cost of heat supplied by a thermo-central running on natural gases, then the geothermal solution will be adopted.

The convenience of adopting the geothermal water solution, from an economical point of view, will be analyzed using the diagram in figure 12.
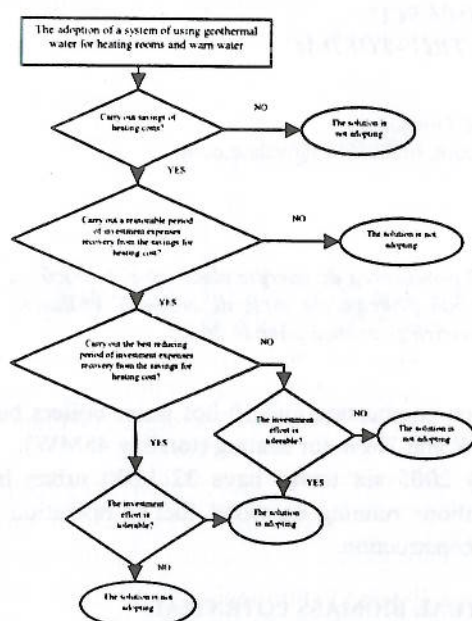

Fig. 12. Logic diagram for taking the decision of adopting the heating installation with geothermal water.

The economic and energetic efficiency of a solution based on geothermal heat can be determined with the help of the following indices and specific ratios:
- Investment costs, I (lei, Euro);
- Net fuel saving, E_c (t_{cc}/year);
- The cost for delivered heating, C (lei/MWh);
- The specific investment afferent to net fuel saving, i_c (lei/t_{cc});
- The period of investment expenses recovery from the heating cost savings, n (years).

The net saving E_c, is the difference between the fuel consumption for the natural gases thermal power point and the consumption for the thermal water solution.

The cost for the heating delivered using geothermal water, C, is made of:
- Expenses with labour force;
- Repairs;
- Cost of water;
- Electric energy;
- Payments, taxes.

The heating cost using fuel – natural gases – includes:
- Electrical energy for pumping;
- The price for natural gases fuel.

The specific investment afferent to net fuel is determined by the relation:

$$i_c = \frac{I}{v \cdot E_c} \text{ (lei / } t_{cc}),$$

where: v – life span of geothermal system (usually 20 years).

The lower the „i_c", the more efficient the geothermal solution will be.

The period of investment expenses recovery, from the savings for heating cost is obtained from:

$$n = \frac{I}{Q_{an} \cdot \Delta C} \text{ (year)},$$

where: Q_{an} – annual quantity of delivered heating (MWh/year).

$$\Delta C = C_{CT} - C(\text{lei/MWh}),$$

where: C_{CT} – the cost for the heating delivered with thermal station.

Conclusion: A solution with geothermal water is profitable if $n < 5$ [3, 7]. Thus,
- the specific investment afferent to net fuel saving , taking into account that $E_c = 26$ t_{cc}/year, will be:

$$i_c = \frac{I}{v \cdot E_c} = \frac{4850}{20 \cdot 26} = 9,3 \text{ Euro/}t_{cc},$$

- the period for expenses recovery:

$$n = \frac{I}{Q_{an} \cdot \Delta C} = \frac{174600000}{194,56 \cdot 352800} = 2,54 \text{ ani} < 5$$

$$\Delta C = C_{CT} - C = 18,40 - 8,60 = 9,80 \text{ Euro/MWh}$$

When using natural gases, the cost of a MWh/year is of 18,40 Euro, and when using geothermal water the cost is 8,60 Euro.

5. CONCLUSIONS

The use of geothermal water is mainly centered in the field of heating rooms, institutions, greenhouses, for preparing warm tap water, balneology and entertainment.

As we have noticed, any attempt of using geothermal waters has some problems to solve, related to crust deposition that obturate the pipes and worsen the thermal transfer or the emergence of corrosion which can cause important material expenses and installations' functioning interruption.

In order to establish ways of implementing the geothermal resources in rural areas, establishing the financial costs for such operations is compulsory, with the purpose of reducing the possibility of price rising for conventional fuels.

REFERENCES

[1] Burchiu, N., *Contributions for promoting geothermal energy for a durable development in the rural areas* (2002), PhD thesis, Bucharest.
[2] Romocea, T., *Studies regarding the corrosive action of geothermal waters from Bihor county for exploitation, transport and use* (2005), PhD thesis, Timişoara.
[3] Mitraşcă, M.A., *Contributions to the study of geothermal water treating processes* (2006), PhD thesis, „Polytechnic" University, Timişoara.
[4] *** Manualul de Instalatii (Installations manual), vol. Heating, Editura Artecno, Bucharest, 2002.
[5] Mirel, I., Ionescu, Gh.C., Mitraşcă, M.A., *Considerations regarding the geothermal water from Săcuieni area, Bihor county.* University of Oradea Annals, „Constructions and Hydro-technical Installations" Fascicule, 2003, Oradea, vol.V, p.17-26.
[6] Mirel, I., Mitraşcă, M.A., *Geothermal water chemical softening.* University of Oradea Annals, "Constructions and Hydro-technical Installations" Fascicule, 2004, Oradea, vol.VII, p.37-43.
[7] Mitraşcă, M.A., Mirel, I., Ionescu, Gh.C., Prichici M.A., Romocea T., Păcurar, I., *The use of geothermal water for hotel complex.* University of Oradea Annals, "Constructions and Hydro-technical Installations" Fascicule, 2005, Oradea, vol.VIII, p.67-75.
[8] Mitraşcă, M., Mirel, I., Prada M., Romocea T., Pantea E., *Geothermal water degassing.* University of Oradea Annals, "Constructions and Hydro-technical Installations" Fascicule, 2005, Oradea, vol.VIII, p.76-82.
[9] Romocea, T., Mitraşcă M.A. et.a.: *The Impact of geothermal water use in the west of Romania on the social-economical activities and on the environment*, (2003), Research contract, cod C.N.C.S.I.S. 677.