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Chapter 1.7

GEOTHERMAL HEALTH AND TOURIST SPAS IN ROMANIA

Marcel ROSCA and Dorina Maria FARCAS
University of Oradea, Romania

INTRODUCTION

Of the about 160 thermal spas in Romania, 23 are of national importance and also internationally recognised for the therapeutic effect of their geothermal waters. Felix Spa is probably the best known of them, and definitely the largest. It is located 10 km SE from the Oradea City, in the north-western part of Romania, in the largest geothermal area of the country.

The existence and development of the Felix Spa is bound directly to the natural thermal springs existent in the area, and to the positive effects of the geothermal waters for the health, well known and certified along the centuries. One of the first known documents which certifies that the waters near Oradea were well known and appreciated in Europe dates since 1405. Many suppositions were made on the name Felix Spa. Some researchers considered that the happiness of the recovered patients has given the name, others associated the name of the spa with the name of its first superintendent, Helcher Felix.

Felix Spa total more than 7,000 beds, of which 5,750 in 12 hotels ranging from 1 to 3 stars, 1,250 beds in villas of different comfort levels. Each hotel has its own treatment facilities. A physical recovery hospital with 150 beds is also operated in Felix Spa. Due to many different problems, mainly managerial and financial, the number of patients coming to Felix Spa for different treatments (depicted in the graph in figure 1) unfortunately decreased in the last ten years, as well as the number of tourists. The situation was more or less similar for all Romanian spas and resorts, the tourism business showing the first signs of recovery only this year.

THE FELIX SPA GEOTHERMAL RESERVOIR

The three geothermal reservoirs identified in the Oradea area are quite different from others located in the Pannonian Basin, of which they are a part of, or in other sedimentary basins. The main reservoir is almost entirely situated within the city limits of Oradea, the second one is in Felix Spa, 10 km SE from Oradea, and the third near the village Bors, 6 km NW from Oradea.

The Oradea reservoir is located in fractured Triassic limestones and dolomites about 2,200 to 3,200 m deep, and the Felix Spa reservoir is located in two layers of fractured Cretaceous limestones, 45-175 and 200-750 m deep. The extraction history shows that both are open and hydrodynamically connected reservoirs. The interference test of 1984 (Plavita and Cohut, 1990) showed a natural recharge of about 300-350 l/s, which originates in the Apuseni Mountains about 80 km east of Oradea. By the ^{14}C method, the geothermal water from the Oradea and Felix Spa reservoirs was found to be about 20,000 years old. In the Oradea aquifer, the temperature decreases from NW towards SE, and continues to decrease into the Felix Spa aquifer. The geothermal bore holes and natural hot springs in Felix Spa have surface temperatures ranging from 35 to 55ºC.

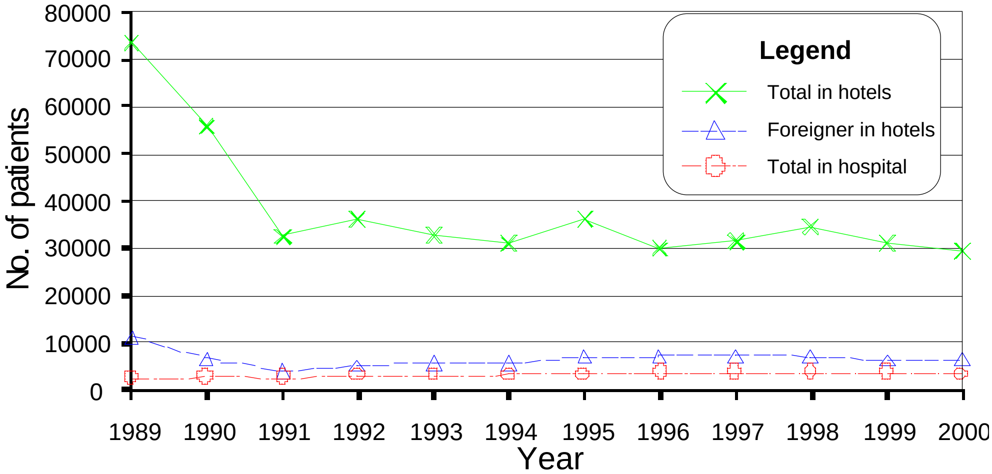

Figure 1: Evolution of the number of patients treated in Felix Spa between 1989 and 2000

The chemical composition of the geothermal fluid in the Oradea and Felix Spa reservoirs is basically the same. The concentration of total dissolved solids (TDS) is up to 1,300 ppm, mostly calcium-sulphate-bicarbonate type, the main elements present being Ca, Mg, Na, K, Li, Mn, Fe. There are also small quantities of dissolved non-condensable gasses (up to 200 ppm), mainly CH_4 and CO_2 (Cohut and Tomescu, 1993). A very small content of ^{222}Rn (about 23-70 pCi/l) makes the geothermal water undrinkable in general, but also strongly contributes to its therapeutic effect in health bathing.

Calculations based on the chemical composition of the geothermal fluid (and confirmed by practice) show a very low scaling potential, and only at temperatures below 20ºC (Rosca, 1993). The geothermal water from the Felix Spa reservoirs is neutral (pH 6 at 20ºC). Corrosion problems caused by the geothermal fluid were not reported up to present. As the reservoirs is located in fractured limestones, no sand was reported to exist in the geothermal water.

Out of the 9 geothermal wells drilled in Felix Spa, only 6 are currently in use. The oldest two wells in Romania were drilled in Felix Spa, the first in 1885 (which can still produce up to almost 200 l/s), and the second in 1887 (now closed). All wells are producing in artesian discharge. The total exploitable flow rate in Felix Spa was set by the National Agency for Mineral Resources to 250 l/s annual average, in order to prevent the reservoir pressure decline and to protect the natural reservation of *Nymphaea Lotus*, variety *Thermalis*, a Tertiary remnant which grows naturally in geothermal ponds, a quite uncommon occurrence at this latitude (about 45ºC) and therefore a tourist attraction.

THERAPEUTIC EFFECTS OF THE FELIX SPA GEOTHERMAL WATER

The geothermal waters from the Felix Spa are used for prophilaxy, treatment and physical rehabilitation. They are used in external cure in pools, baths tubs and all the hydro-thermal therapeutic procedures, including vaginal irrigation. The treatment installations include:

- baths with thermal mineral water in tubs and pools;
- kineto-therapy with thermal mineral water in tubs and pools;

- vertebral traction (elongation in the water and on the table);
- electro- and hydrotherapy;
- inhalations;
- rehabilitation and medical gymnastics;
- paraffin wrappings.

These water from the "Balint" well, which has a Radon content below the admissible limit for drinking, is used in internal cure for patients with digestive, liver and renal illnesses.

The actions of the geothermal waters from Felix Sap on the human organism are generated by three factors: the thermal factor, the chemical factor and the mechanical factor.

The thermal factor, due to the water temperature, which is used at about 36 - 37^{o}C in external cure in pools, has the following effects:

- increases the heart rate;
- increases the cardiac flow;
- decreases the blood pressure;
- controls the contractures and the muscular spasms by relaxation of skeletal muscles;
- controls the chronic osteoarticular periarticular and soft tissue pain;
- rebalances the neurovegetativ system.

The chemical factor is represented by the chemical structures of these waters. It determines a skin transmineralisation which leads to some of the beneficial effects such as decreasing the blood pressure, entering K, Ca, Mg, Fe with important roles in the muscular and bone metabolism, an important elimination of Na, urea, acid radicals. During the treatment, the Radon gets through the skin into the blood flow and is eliminated through the lungs. It is disintegrated in three hours after finishing the treatment. It represents a great advantage by avoiding the long action of radiation. The most important effects are:

- the normalisation of the glucidic metabolism;
- the increase of the uric acid elimination, with favourable results in gout and in X metabolic syndrome;
- on the urinary system - increase the diurese (urinary flow);
- the decrease of the blood flow in hypertension and normalise it in hypotension;
- acts on cerebral circulation and microcirculation, controlling the pain in neuralgia and neuritis;
- rebalance the neuro-vegetative and hormonal systems

The mechanical factor is represented in the pools by the hydrostatic pressure according to the Pascal's principle and by the pushing up force according to Archimede's law. That leads to beneficial effects especially on the locomotor system and on the cardiovascular system.

In conclusion, the main indications for the geothermal waters from Felix Spa are:

- inflammatory rheumatic diseases, biologically stable (rheumatoid polyarthritis, ankylosing spondylitis, post acute articular rheumatism);
- degenerative rheumatic affections: spondylosis (cervical, dorsal, lumbar) accompanied or not by cervicobrachialgias, painful lumbar sciatica, arthroses, polyarthroses;
- abarticular rheumatic affections (tendinoses, tendinites, tendoperiostoses, scapulohumeral periarthritis);
- posttraumatic affections (posttraumatic articular stiffness, states following articulations surgery, fractures);
- affections of the central and peripherical nervous system (hemipareses, various pareses and paralyses);
- metabolical illnesses: obesity, gout, diabetus mellitus;
- hypertension stad I and II;
- endocrine illness like hypotiroidia;
- for prophilaxy.

The main target in the last years was to improve the comfort and services quality in hotels and restaurants, as well as the treatment facilities. Up to now, investments were mainly focused to renovate the hotels and parks, and in new and modern installations for treatment.

POSSIBLE HEATING SYSTEM FOR A HOTEL IN FELIX SPA

At present all the hotels in the Felix Spa Resort are connected to a central heating system. The thermal energy is supplied by a co-generation power plant situated just outside the city limits of the town of Oradea, at a distance of 6 km from the Felix Spa Resort. The thermal fluid is hot water pumped through a surface steel pipeline insulated with rock wool and aluminium sheet. This primary agent provides all the thermal energy required for space heating and for hot tap water. Until 13 years ago, when the power plant was set on line, every hotel had its own heating system, usually powered by a heavy fuel fired boiler. The boilers are still in place, as redundancies to cover the heat demand in case of a failure of the current system. The rooms and all the other facilities are heated using cast iron radiators. A separate network provides the hot tap water.

In the hopefully near future the hotels will be owned by private companies, and it is to be expected that these companies will consider the possibility to use geothermal energy for space and tap water heating. It seems reasonable to assume that, at least for the first years, the capital available for investment will be rather limited. This could be different if a hotel were to be owned and operated by a foreign company. Anyhow, a geothermal heating system will be selected, which minimises changes to the current system by making use of the existing installation (i.e. standard cast iron radiators for space heating. Furthermore, modifications due to the new system could be carried out during the summer season, when no space heating is required, to eliminate the need of closing the hotel and cutting off its income.

The standard indoor design temperature is 18°C. The incidental heat gains from external sources, such as solar radiation and human activities (cooking, washing, body heat), increase the indoor temperature usually to about 20°C. The design outdoor air temperature for the Oradea area is -7°C. Slightly lower temperatures are occasionally encountered but, as Karlsson (1984) demonstrated, it is neither economic nor necessary to design the heating system for the minimum measured outdoor temperature because the heat stored in walls, floor, ceiling, furniture etc. tends to level off the indoor temperature variation for short periods of time (up to three days). The maximum temperature demand intensity (Td), defined as the difference between the indoor and outdoor temperatures that has to be replenished by the thermal energy supplied by the heating system, is therefore 25°C for the conditions stated above. The multi-annual average of the number of degree-days is DD = 2,870.

A hotel with 200 rooms is considered an average sized one for Felix Spa. A standard room is defined as a double-room with a bathroom, having a total volume of 70 m3. The additional volume required for all ancillary facilities (such as kitchen, dining room, halls, corridors etc.) is 25% of the total room volume and can be considered as an equivalent number of standard rooms. The maximum thermal power demand for heating an average hotel as it was defined above is therefore $P_{u\ max}$ = 437.5 kW

The maximum number of guests that can be accommodated in this average hotel is approximately twice the number of rooms, which means 400 people. The average daily consumption of domestic hot water per capita is considered to be 100 l/s. In a hotel the total demand is typically 50% higher, including the water for cooking, washing, laundry etc. (excluding geothermal water for health bathing). The temperatures of the fresh and domestic hot water are considered 15ºC and 65ºC respectively. The thermal power required for heating the tap water is therefore P_w = 146 kW. For the purpose of this study it is assumed that geothermal water at a temperature of 50°C is available at the total required flow rate. This is believed to be a reasonable assumption considering that the reservoir is located right below the resort, so that any temperature drop in the main pipeline is insignificant. The most current reservoir simulation also predicts that an increase in the production rate is possible without significant adverse effects on the reservoir temperature and pressure provided all the extracted water is reinjected. A better reservoir simulation model needs to be developed for a more accurate evaluation of the Felix Spa reservoir capacity.

The following geothermal heating system was selected considering available information and the experience gained in this field in other countries (such as Iceland, France, U.S.A.). For the available well head temperature of the geothermal water and the maximum inlet and outlet heating water temperatures, systems employing heat pumps were found to be more economic. The basic arrangement of the proposed geothermal heating system for the hotel is presented in Figure 2.

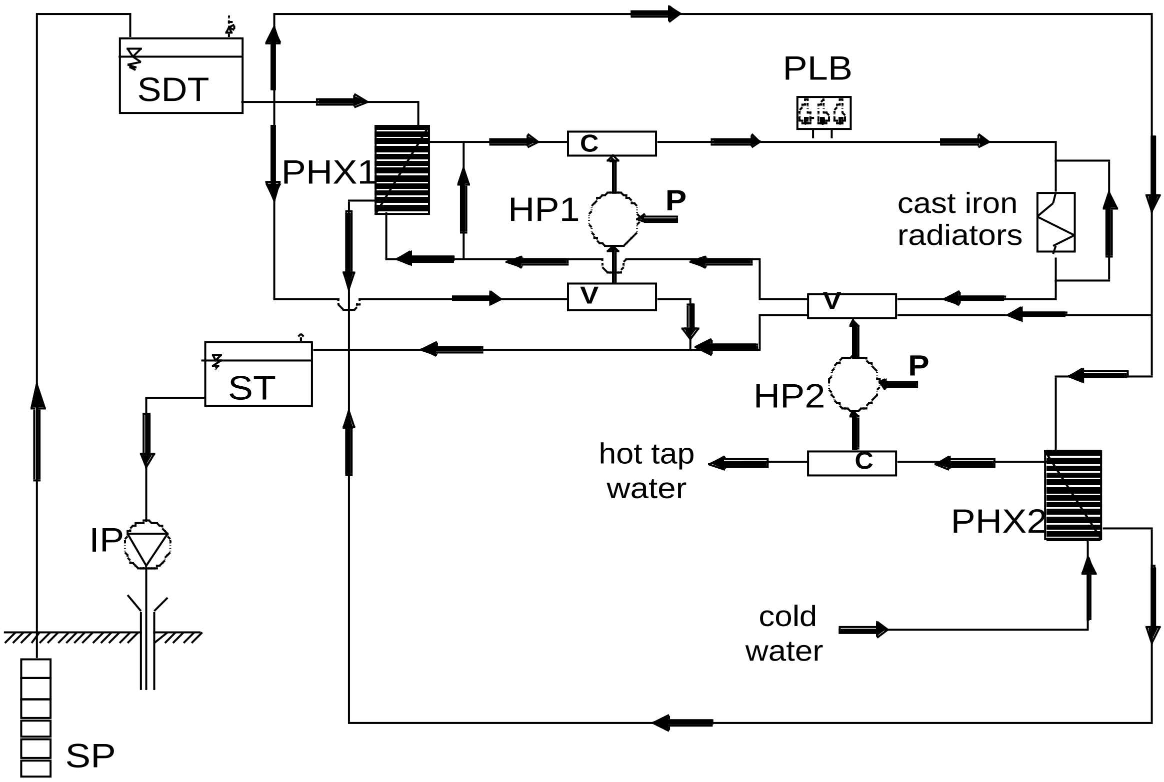

Figure 2: Hotel heating system layout

The system is basically a heat pump assisted with direct evaporator type. At low partial loads, as long as the radiator water inlet temperature is below 45°C, the heat demand is supplied through direct heat exchange from the geothermal water by the primary heat exchanger (HX1). The condenser of the heat pump (HP1) is by-passed in this case. As the required radiator water inlet temperature increases above 45°C, the primary heat exchanger can no longer supply the total heat demand and HP1 is turned on. The radiator water outlet temperature is increasing at the same time, causing an increase in the geothermal water outlet temperature from the primary heat exchanger. The latter is therefore passed through the evaporator of the HP1 in order to lower the temperature of the waste geothermal water as much as possible. When the network return temperature (T_{no}) reaches 40°C the direct heat exchange through HX1 is no longer efficient and it is consequently by-passed. The evaporator of the HP1 is then fed with geothermal water at well head temperature (T_g). During the periods of time when the heat pump is working at partial loads, it is not desirable to regulate its speed continuously in order to ensure all the time the required inlet temperature for the radiator water. It was considered more energy efficient to have the possibility to mix a part of the outlet radiator water with the inlet radiator water. In this way the inlet temperature can be regulated continuously by regulating the mass flow rates of the two streams, while running the heat pump at a certain constant speed. When the required inlet temperature of the radiator water increases above the maximum outlet temperature from the condenser of the HP1, the heat supply is supplemented by the peak-load boiler (PLB).

The fresh water is first heated by direct heat exchange up to the intermediate temperature T_{iw} in the heat exchanger HX2. Subsequently it is heated up to the standard temperature T_{hw} = 65°C in the condenser of the second heat pump (HP2). This arrangement insures a decrease of the radiator water outlet temperature, improving the heat exchange in the HX1. During the time the space heating system is turned off (out of the heating season), geothermal water at the well head temperature T_g can be fed to the evaporator of the HP2.

It is assumed that temperature drop along pipelines is insignificant. For a real system temperatures are decreasing along the pipelines due to the heat loss by conduction, convection and radiation from the inner fluid to the ambient air. Since the whole installation is inside the building it is reasonable to assume that this temperature drop is insignificant, as any heat loss along pipelines will contribute to the heating of the building. The results will, however, not be accurate, but still sufficiently representative and the calculations are very much simplified.

The hot tap water consumption is clearly not constant over the period of a day. It can vary by as much as 50% from the mean value. The system has to provide for the total demand at any time, but it is not economic to design the circulation pumps and the heat pump for the maximum load and to run them at variable speed. It is better to have a storage tank with a volume large enough to compensate for the daily variation in demand. Virtually every hotel already has these tanks in the current system.

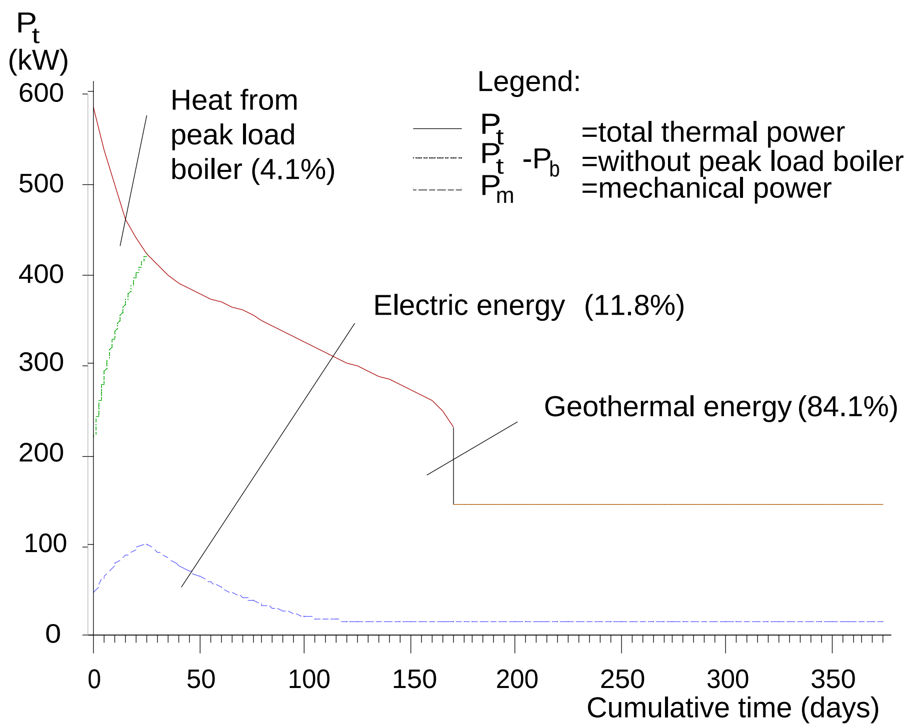

Figure 3: Power demand duration curve

The thermal power demand duration curve plotted by using the calculated data is presented in Figure 3. The area below the curve is proportional to the annual heat demand (by the scale factors used to plot the graph). For the considered average hotel the total annual thermal energy demand is E_t = 2,128.13 MWh, which comprises:

- thermal energy from the peak load boiler: E_b = 86.64 MWh;
- thermal energy from geothermal water: E_g = 1,790.21 MWh;
- mechanical energy from the heat pump compressors: E_m = 251.28 MWh.

The design powers of the two heat pumps, accepting a mechanical efficiency for the compressor of 90% and the electrical motor efficiency of 95%, are:

HP1: - heating power: P_{h1} = 321 kW
- mechanical power: P_{m1} = 86 kW
- electrical power: P_{e1} = 101 kW

HP2: - heating power: P_{h2} = 59 kW
- mechanical power: P_{m2} = 16 kW
- electrical power: P_{e1} = 19 kW

The calculated heat transfer areas of the two heat exchangers are A_{HX1} = 12.6 m^2 and A_{HX2} = 6 m^2 respectively.

Considering the existing peak load boiler as an old one, with an efficiency of 75%, fired by heavy fuel oil with a low calorific value of 11.8 kWh/kg, the annual fuel consumption was calculated as F = 9,790 kg.

The economical appraisal of the geothermal heating system for the average hotel in the Felix Spa resort was carried out basically following the methodologies presented by Harrison et al., (1990) and Piatti et al. (1992). The Romanian economy is still suffering a transition process, from a centrally planned system towards a free market economy. In this situation prices are changing fast and at an uneven rate, due to a rather high inflation rate, changes in the subsidising policy, and changes in the taxation. The general tendency of prices is to approach international market values, energy prices being among the quickest to follow this trend. The project under study here is expected to be implemented in the near future, after the privatisation has been concluded and investment capital becomes available either from own resources or from bank loans at acceptable interest rates (current annual interest rates for loans are about 60%, due to high inflation rates). By the time the possibility to implement a project of this type qualifies for consideration, the Romanian economy will probably be fairly stabilised and the problems outlined above less acute. For the above reasons, it was considered appropriate to carry out the economical appraisal of the project on the basis of economical conditions prevailing in the European Union, all costs being given in Euro.

The capital investment comprises purchasing and installation costs for all equipment required for the new heating system, engineering cost, and additional costs due to contingencies, being estimated at C = 270 kEuro. It has been assumed that the company finances the investment to the tune of 50% through own capital resources (equity contribution - Q) and 50% by a fixed interest loan raised from a bank (debt contribution - D).

The annual running cost of the project comprises the costs of electricity, boiler fuel and geothermal water, maintenance costs (purchase and stocking of spare parts, wages of maintenance staff) and wages for the personnel required to operate the geothermal heating system, and were estimated as R = 82.6 kEuro.

The annual earnings of the project are considered to be the costs of continued running of the former heating system which is to be discontinued. The maintenance costs and wages are considered to be approximately the same. For the specific cost of the thermal energy supplied by the power plant of c_p = 0.043 ECU/kWh, the annual earnings of the project are E = 121.9 kEuro.

The annual running cost and earnings are considered constant for all 20 years of the estimated life span of the project, and inflation is not considered. It is further assumed that the whole of the investment cost is committed at the beginning of the project, before its operation starts. After plant commissioning only running costs, debt charges and taxes have to be paid. All the financial rates are also considered constant over the project lifetime. This may not reflect real life practice, but is sufficiently accurate for a pre-feasibility study. A yearly compound period is considered for all payments.

The company owning the hotel is a taxable company. The annual taxation rate for a company of this type is t = 30%. All expenses, such as running cost, debt repayment and usually the annual depreciation of equity, are tax deductible, called tax allowances. The annual earnings of the project, as defined above, are tax allowances while the current heating system is in use, but because it is not paid any more when the new system is employed, it is added to the revenues of the company and so becomes a taxable quantity.

The discount rate (r) required to calculate the CRF depends on how the company perceives the worth of money. It should compensate the company for future risk (expected payments that may not materialise) and for lost opportunity (to spend the money on other, more profitable, ventures). For a hotel owning company a discount rate of r = 9% is considered to be reasonable.

Assuming that the pay back time for the bank loan equals the project lifetime and an annual interest rate of i = 8%, the CRF for the loan becomes: CRF(n,i) = 0.1019

The Discounted Cash Flow analysis results are:

- Annual debts charges (annuity): C = D·CRF(n,i) = 13,756.5 Euro
- Annual depreciation of equity: p = Q/n = 6,750 Euro
- Total annual tax allowances: A = C + p + R = 103,106.5 Euro
- Taxable annual earnings: X = E - A = 18 793.5 Euro
- Annual tax: T = t·X =5 ,638 Euro
- Net earnings after tax: N = E - R - T - C = 19,905.5 Euro

The indices for evaluating the economical feasibility come out as:

- Net Present Value: NPV = 46,785.4 Euro
- Internal Rate of Return: IRR = 13.6%
- Discounted Pay-back Time: DPT = 11 years

On the basis of the financial premises considered above, the project is shown to be economically viable. The net present value over the 20 years of the project lifetime, although not very high, is still positive. This means that the project is profitable, so the company will not lose money if the decision is made to change the heating system to a geothermal one. The discounted pay back time of 11 years is fairly reasonable at about half the project lifetime. The internal rate of return (IRR = 13.6%) is also a reasonable one, higher than the considered discount rate (r = 9%). Before a binding decision can be made, a more detailed economic appraisal is recommended. The study should be based upon the financial situation existing at the specific time and also take account of available financial forecasts. It is not only possible, but most probable that the inflation will be significant in Romania in the near future, although not as high as now and more constant. This means that the interest rates charged on a bank loan will be considerably higher than the 8% rate considered in this study. When the investment can be made from own capital resources, as equity, the internal rate of return is higher in inflationary conditions. The influence of inflation should also be considered in an economic feasibility study. The IRR value calculated above (13.6%) is probably on the low side for a small company, particularly during the initial stages in the operation of a hotel. Changes of energy prices will also affect the economical viability of this project. Fossil fuel prices are expected to increase in the future, due to depletion of the resources, combined with announced environmental energy taxes. This will make a geothermal heating system more profitable.

A detailed reservoir simulation model is required to estimate the potential of the Felix Spa reservoir and the optimum production strategy. A feasibility study is recommended for a geothermal space heating system for the Felix Spa resort, using low temperature heating, such as air, floor, wall or ceiling heating. A feasibility study is also recommended for a district heating system based upon cascaded uses of the geothermal water from the Oradea reservoir. The users could be divided into two groups, one with high temperature (90/60°C) room heaters (cast iron or steel sheet radiators), the other with low temperature (50/20°C) heaters (floor, wall or ceiling heating).

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