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Kocani Geothermal District Heating System (New Activities for Proper Completion)

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ABSTRACT

After a ten year period of stagnation, the first geothermal development activities in Macedonia have been realized over the past three years. This is underlining the need for the definition of a state strategy for geothermal development and separate strategies for optimisation of the existing projects in order to avoid possible mistakes and wrong decisions.

The definition of the optimisation concept for the geothermal system GEOTERMA in Kocani and its incorporation in the strategy for its full completion and further development are described and discussed in this paper. The discussion includes the consequences to the organization of the exploitation, technological and technical completion of the users and direct results of realized first optimization works (stopping the decrease of the water level in the reservoir, opening possibilities for connection of new users, protection of the reservoir of Fe particles penetration and blocking, etc.). Also the second step of completion is described, consisting of the connection of the industrial zone of the town and completion of the second reinjection well, enabling the increase of the annual capacity of the geothermal resource from 1.350.000 to 1.700.000 m^3/year, which is a significant step towards reaching the final goal of 2.000.000 m^3/year.

INTRODUCTION

The geothermal system GEOTERMA in Kocani, a town located in the North - Eastern part of Macedonia, is based on the hot water use from one of the most important geothermal fields in Europe.

After the production of a cumulative quantity of more than 20 Million m^3 thermal water for the purpose of direct heating (greenhouses, district heating), technical and organisational problems of the system exploitation have been investigated, in order to enable a proper reconsideration of the system development strategy.

1. OUTLINE OF THE PRESENT STATUS

1.1. Hydrogeological Setup

The thermal aquifer is a paleozoic carbonaceous formation (limestones, dolomites) with the formation top at a depth approximately 318 m below the ground (well EB4 at D. Podlog). The aquifer is overlain by volcanic andesitic effusive and tuffitic rocks (194 - 318 m) of tertiary age and the quarternary infill of the depression of Kotcanska Valley (0 - 194 m). The outcrops of the reservoir formation are in the mountainous margins north and south of the Kocanska valley. These are the recharge areas of the hydrothermal system (Fig. 1.)

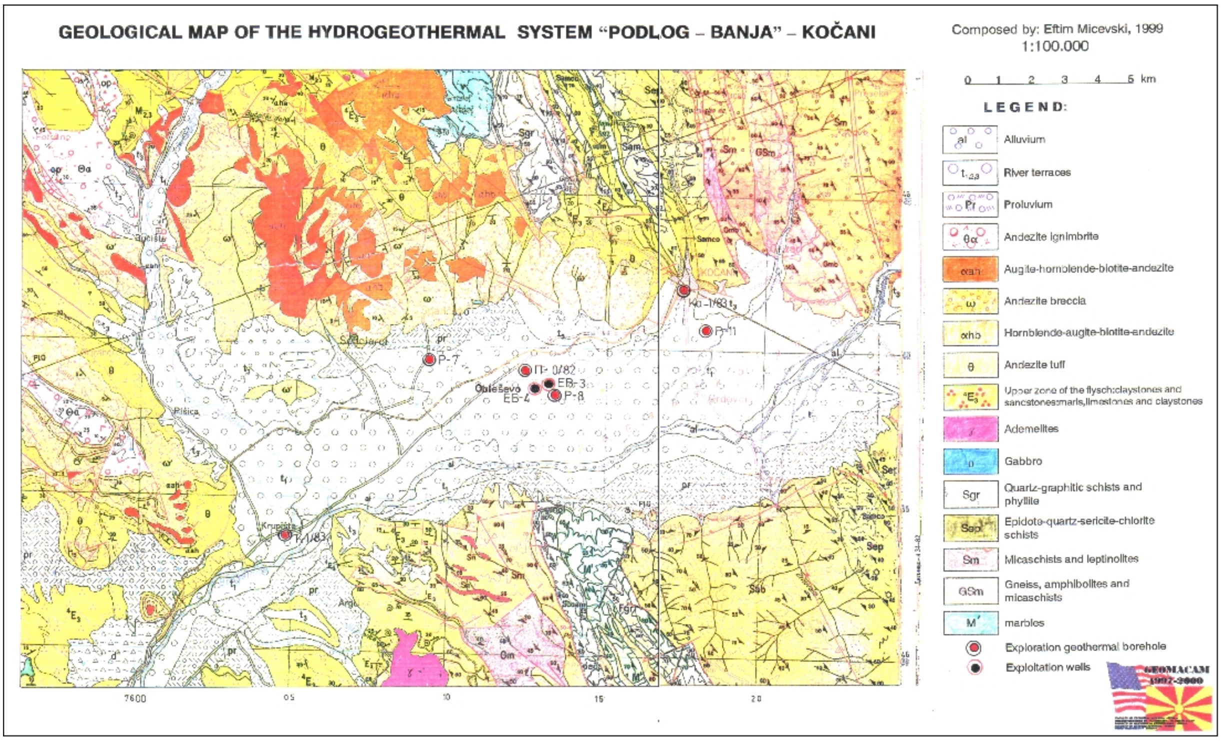

Fig. 1. Hydrogeothermal field Podlog-Kocani

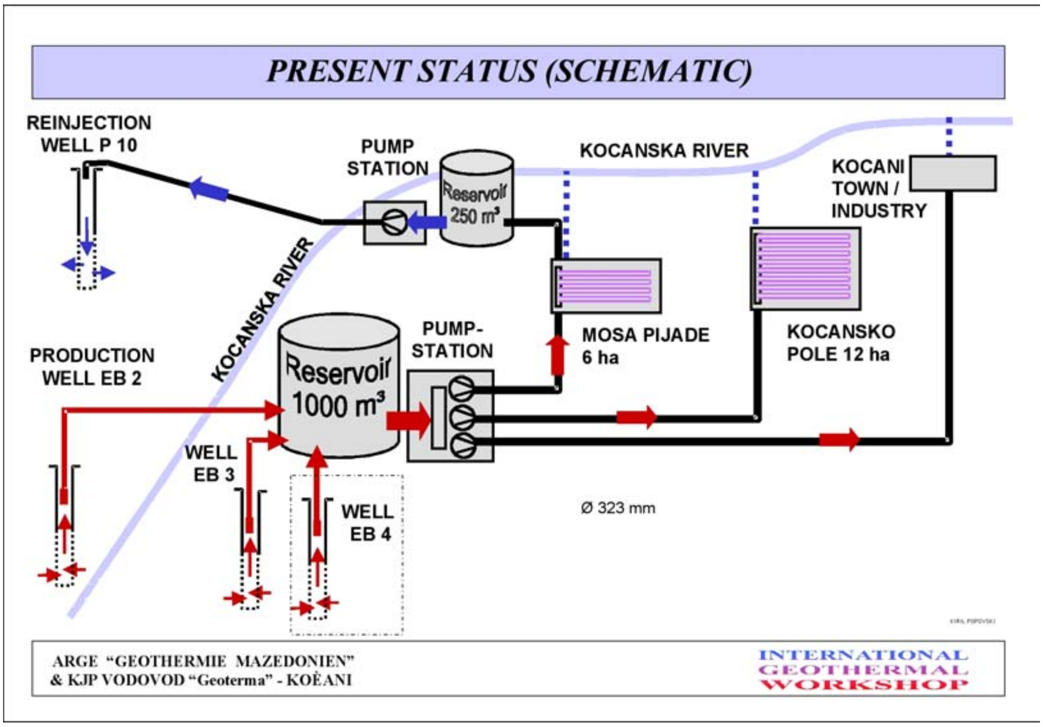

Fig. 2. General scheme of the geothermal system

Excellent permeability with local well capacities of more than 100 l/s is the consequence of extensive fracturing of the paleozoic carbonates in connection with the tectonical features of the geological zone where extensional block faulting after the compressing orogenic phase took place. Karst phenomena may play a role too.

The water temperature reaches up to 80 °C. This high temperature is an effect of the local geothermal anomaly in coincidence with the overlaying volcanic rocks and sediments which act as isolating layers.

Due to the production of thermal water since the 1980s, the static water level changed from significantly artesian (hydraulic head up to 6,5 bar) to slightly under-hydrostatic (static water table approximately 35 m below ground level) at the beginning of the heating season.

1.2. Geothermal System GEOTERMA

Present Operational Status

Production of thermal water (78°C) up to 300 l/s (26.000 m^3/day, 1.350.000 m^3/year).

Direct use of the thermal water in 3 independent heating systems:
- Greenhouse complex "Kocansko Pole" (built 1982) and rice drying plant (1983)
- Greenhouse complex "Mosha Pijade" (built 1983)
- District heating at the town of Kocani and industrial uses.

Reinjection of up to 80 l/s possible (up to 25% of the produced water since 1995)

Seasonal operation (October - May)

During the recent ten years, exploitation of the system is characterized by continual gradual decrease of the capacity of agricultural users and industry and minimal increase of the other users (public buildings, households, etc.). Operational status of the agricultural users is significantly decreased.

Water production

The geothermal water derives from the exploitation water wells EB2, EB3, EB4 and the monitoring well EB1 (also equipped with a pump) and is pumped by the submersible pumps into the 1000 m^3 reservoir tank (max. 300 l/s, T=78°C). The reservoir tank is connected to the central pump station in the operating building near the well EB3. The criterion for switching the submersible pumps on and off is based on the level control in the reservoir tank. This operation is discontinuous and depends on the energy demand of the greenhouses and the other users (outside temperature, local weather conditions, day-night heating regime).

Water Quality and Chemistry

Produced thermal water can be characterised as Sodium-Bicarbonate type with almost neutral pH which is slightly corrosive to uncoated mild steel components. The reason is that the water is not completely saturated with $CaCO_3$. After passing several hundreds of kilometers of pipework, used water is loaded with a significant content of suspended solids, mainly iron-hydroxides. Up to 45% of the solids have a particle size larger than 15 µm. Based on analysis and investigations on the matter and particle sizes of the solid residuals, it is calculated that the amount of solids in the used water is approximately 6000 kg per year of operation. This is the reason that a filter station has been completed three years ago in the reinjection pipe. However, this resolves the problem for only 25% of the effluent water.

Fresh thermal water is partially supplied to the local market as potable mineral water. It is bottled in a small bottling workshop of Vodovod-Geoterma.

1.3. Distribution Facilities

Depending on the heat requirements of the system, thermal water is pumped from the central pump station through 3 independent piping systems (thermally insulated steel pipes) to the greenhouse complexes “Mosha Pijade” (60 l/s, max. 110 l/s) and “Kocansko Pole” (100-150 l/s, max. 280 l/s) and to the town of Kocani (max. 180 l/s for district heating and industrial uses).

The demand of electricity for pumping the thermal water from the wells and its distribution to the users is up to 1 MW.

Control of the whole system is done manually by switching the pumps on and off (stop and go).

1.4. Reinfiltration

The outlet of the heating system of the greenhouse complex “Mosha Pijade” is collected in a storage tank (280 m^3). From this reservoir, the water is pumped to the well P-10 over a distance of 3.260 m to reinject a part of the used water back into the aquifer formation. The piping system is summarised in Table 1.

Table 1

Piping System	Total length of			Reinfiltration / discharge of used thermal water
	pipeline to the greenhouse (1)	reflux pipeline to pump station (2) (to infiltration well P-10)	heating pipes (3)	
Greenhouse “Mosha Pijade” Area: 6 ha max. 110 l/s	200 m 0,2 %	3.560 m 4,1 %	approximately 84.000 m 95,7 % 4 piping cycles	partly reinfiltration up to 80 l/s, actually discharge to river
Greenhouse “Kocansko Pole” Area: 12 ha max: 280 l/s	3.360 m 1 %	6.260 m 2 %	approximately 310.000 m 97 % 8 piping cycles	discharge to river
Town / Industry max: 180 l/s	7.500 m	none	no data	discharge to river

Data: KJP-Vodovod - Geoterma and Popovski, Percentage related to total length of (1)+(2)+(3)

Table 2

Temperature of thermal water	73 - 78 °C
Temperature of used water at discharge	>35 - 40 °C
Capacity of water thermal production	approximately 400 l/s (EB2+EB3+EB4) max. 450 l/s
Users: Greenhouse complexes (approximately 90 % of the total thermal water consumption)	12 ha 36 MW Kotchansko Pole 6 ha 15 MW Mosha Pijade
Users: Town of Kocani and industry (10%)	2 MW (present status)
Thermal power	nominal 60, max. 100 MWT
Oil equivalent of water production	3,11 l/s of oil
Exploitation per year	1.300.000 m³/yr
Oil equivalent per year	approximately 8.000 TOE/yr
Electrical energy demand	1 MWE (exploitation /distribution)

(after L. Gashteovski and K. Popovski, Geothermal Workshop 1999)

1.5. Type of Use, Consumers

The main use of the geothermal energy is the direct heating of total 18 ha of greenhouses for growing of vegetables (tomatoes, cucumbers and others) and a rice drier facility at “Kocansko Pole” (now abandoned). The installations of the Bulgarian and Dutch-type greenhouses have been designed originally for heating media temperatures of 110 - 70 °C (heavy oil fired heating boilers) and later on accommodated to characteristics of the geothermal water on disposal.

In town, some communal buildings and private users are connected to the district heating system. A small amount of water is used for preparation of sanitary water for the paper industry in the town of Kocani (recently under reconstruction). Originally it was planned to connect several buildings and additional users to the district heating system of the town, however it was not possible to find financial funds to realize it.

1.6. Energy Balance, Energy Demand

Energy data of the geothermal system of GEOTERMA - Kocani are as in Table 2:

The most important reasons for the reduced efficiency of the geothermal system are transmission losses, insufficient use of thermal energy due to relatively high outlet temperature (T= 35-40 °C) and seasonally discontinuous operation.

1.7. Environmental Impact

In comparison with conventional energy sources like coal, oil or gas (CO_2-, SO_2-problem; air pollution and others) the direct use of geothermal energy causes less environmental problems. Nevertheless, it has to be taken into account that the discharge of used water in the river causes a thermal overload and has a negative effect to the aquatic biosphere.

1.8. Legal and Economical Aspects

The concession for the use of geothermal water is given to the communal service company of the town of Kocani “KJP Vodovod - Geoterma”. The price of geothermal energy in general is now regulated by the state and should not be less than 40% and not more than 60% of the price level of conventional oil heating. It should cover the costs for exploration and exploitation of the resources as well as the maintenance and running costs of the system (Popovski et al. 1999: Reevaluation of the development strategy; Workshop Proceedings). However, the true cost is very low (less than 20% of the oil heating costs).

The greenhouse combines are on the way to be privatised. This will require a strict separation of producer and consumers of the geothermal energy in the future due to defined responsibilities as well as technical and economical (accounting) aspects.

Nevertheless, in the present situation it is difficult to ensure that the users are able to exploit the maximum of the supplied thermal energy. Proper maintenance of the equipment (piping and heating facilities) will be indispensable.

The supplier of geothermal energy has to have a reasonable reimbursement for his services to cover development and running costs.

2. PROBLEMS AND POSSIBLE SOLUTIONS

In comparison with other geothermal projects in various regions of the world, the site of D. Podlog - Kocani has excellent conditions for development of wide use of geothermal energy, as there are on disposal:

- a relatively shallow aquifer, formation tops within moderate drilling depths,
- high permeability with a potential production of a few hundreds of l/s,
- relatively high temperature related to the depth of the reservoir,
- moderate water chemistry.
- numerous potential users at short distances from the source.

Technical concepts based on the standards of the 1980s and the operation history through the last 20 years have caused problems and conditioned some restrictions to the use and possibilities for further development of the system.

According to the results of previous technical studies (Popovski 1992, Popovski 1999, ARGE 1999, Po 2002) a wide range of possible optimising aspects should be assigned to the following problems:

- *Aquifer Aspects*: Restrictions of water production, reservoir behaviour.
- *Technical Aspects*: System operation, production and distribution of thermal water, energy transfer techniques, use of the full range of energetic levels.
- *Ecological Aspects*: Reestablishing and preserving the balance of the ecological system.
- *Economical Aspects*: Efficiency - Energy output vs. energy demand of the system, scenarios for integrated use of the geothermal resource, specific regional economical background.

All the concepts and alternatives have to be evaluated concerning their environmental and technical priority as well as their commercial and social/economic implications. The measures to improve the operational and energy situation can be reached from adaptations of the system to the complete redesign of parts or of the whole geothermal system at D. Podlog - Kocani.

2.1. Reservoir Aspects (Table 3)

Initial pressure heads of the aquifer were significantly overhydrostatic (artesian up to 6,5 bar) and during the past years of exploitation they have been changed to underhydrostatic. The decrease of the head of the water table during the production periods since 1985 changed from artesian to approximately 30 m below ground (EB3) and the pressure heads after the seasonal standstills do not reach the height of the starting level of the previous production period. Up to now there is a trend to lower levels of the thermal-water table on the site from one operation period to the following.

Problems of reinfiltration/reinjection in general: Need for fundamental changes of the concept of direct use so that reinfiltrated water is not loaded with soluble and suspended components.

2.2. Operational and Technical Aspects (Table 4)

- Exploitation of Thermal Water: Main water production is in during the heating season (October - May) only. The operation is discontinuous, depending on the energy demand of consumers.
- Pumps are shut on and off depending on the level in the reservoir tank.
- The monitoring of operation of the submersible pumps covers only some main parameters (pressure, temperature).

Table 3

Observed Problem / Reason	Possible Solutions / Actions	Priority
Decrease of hydraulic heads and lowering of water table. *Limitation of the reservoir, overload of the natural resources, discharge by water production > recharge and / or limitation of permeability along the flow paths*	Definition of the potential of the reservoir based on existing and future monitoring data: Monitoring of the hydraulic regime and the water properties over time. Investigation of recharge and flow (tracer investigations, hydroisotopes).	very high
	Production of thermal water in respect of the specific reservoir limitations.	very high
	Redesign of reinjection system Establishing of proper reinfiltration system: Water cycles known as duplet concept with heat exchanger equipment. Optimizing reinjection points, establishing additional reinjection wells. Increasing reinfiltration / reinjection rate.	very high

Table 4

Observed Problem / Reason	Possible Solutions / Actions	Priority
Seasonal operation. *Operation depends on the specific use (agricultural use in periods of cold seasons).*	Looking for whole year operation at different levels. Integration of consumers which do need the energy in summer also (e.g. cold storage facilities, drying facilities, balneological use)	moderate
Discontinuous operation. *Only "stop and go" mode possible.*	Adaptation and improvement of steering and control facilities. Flexible operation by using frequency converter equipment according to the needs of consumers demand. Soft steering of pump operation (less wear and tear).	high
Monitoring of operation. *Present monitoring for some parameters only, adaptations of the system required.*	Adaptation of monitoring equipment for the submersible pumps in all exploitation wells. Partly in preparation with completion of well EB4 (water level, flow, temperature, conductivity). Adaptation of existing monitoring panel, establishing automatic registration and data processing of operating data, link to distribution data.	high
Failure of pumps. *Equipment several years old (in the meantime improvement of technical solutions),* *need for maintenance.*	Implementation of adequate pump technology. Installation of specially designed pumps for a heat range up to 80 °C and/or adaptation of existing pump equipment. Adaptation of steering equipment (frequency convt.). Hold out of spare parts and spare pump. Maintenance of pump equipment.	high
Danger of system collapse in periods of peak energy demand	Operation of "reserve" water well (now possible with well EB4). Covering peak load by support with conventional heating techniques (needs proper boiler equipment and additional energy sources - heating oil). Reduction of activities in times with low outside temperatures (already done).	moderate

Table 5

Observed Problem / Reason	Possible Solutions / Actions	Priority
Discontinuous operation of distribution pumps	Implementation of flexible steering facilities and adaptation / replacement of existing equipment.	high
Energy demand for pumps	Exchange of motors and pumps with higher efficiency and flexible steering facilities.	moderate
Energy / water losses	Repair and maintenance of distribution pipes.	high

Table 6

Observed Problem / Reason	Possible Solutions / action	Priority
Leakage of pipework, fittings and outlets	Improvement of maintenance,	high
Corrosion of pipework, occurance of solids at the end of pipe *Corrosive components of the thermal water (CO_2-under saturation ect.). Water - air surface in the reservoir tanks, mixing of water and air by sealing failures at the distribution pumps (subpressure sucks air through seals), mixing of air and water at the reinfiltration well*	Maintenance of pipework, use of material of better quality (costs). Redesign of the geothermal system: Separation of production and consumer cycle. Shortening of pipework at the production cycle, reduction of the contact of the pumped water with 0_2). Implementation of filter equipment at the end of pipe, (short term solution but does not solve the reasons of the problem).	very high

Table 7

Observed Problem / Reason	Possible Solutions / action	Priority
Dumping of used thermal water	cascade use (lower temperature of outlet), implementation of reinfiltration . reinjection (ideal status up to 100%).	high

2.4. Consumers (Table 5)

- Capacity of reinjection is only up to 25 % of the produced thermal water,

- 100 % to 75 % of the thermal water is dumped with up to 35 - 45 °C (Kochanska River)

- Energy demand for pumping and distribution up to 1 MWe

- Variation of capacity by shut on/off of production and distribution pumps.

2.3.Water Distribution System (Table 6)

- The energy demand of the distribution pumps is up to 1 MWe, there are no flexible control facilities.

- Start and shut off of pumps are performed manually at the request of the consumers.

- The monitoring of operating parameters of the distribution system is done only partially.

- Pipework, fittings and valves are showing leaks. The connection pipes to the consumers are partly showing missing insulation and corrosion protection.

- The used water is dumped to the Kocanska river.

2.5. Ecological Aspects (Table 7)

Dumping of Used Thermal Water

- Almost 100% of the used thermal water is dumped after passing the heating systems (greenhouses, district heating, industry).

- Heating of the river system (changing of the ecological system, affect of the biological self-cleaning ability of water), increase of the effect at lowstands of the river (winter time).

- Pollution of the dumping location with suspended material.

2.6. Economical Aspects

Relationship Producer – User: The problems of the present relationship between producer and users of the geothermal energy (mainly of the agricultural sector) seem to be influenced by:

Difficulties due to the general economical situation of the region but also by the regional political developments since 1992 within the Republic of Macedonia and in the neighbouring countries (former common market, export facilities).

Difficulties in the relationship operator - user of the geothermal energy are the open questions of compensations for the delivered energy to cover investment, development and running costs of the geothermal system GEOTERMA.

The privatisation of the agricultural combines do require a clear separation of the producing and consuming cycles to define the responsibilities. The rights (e.g. consumption of energy) and obligations (e.g. proper use, minimal technical requirements) of the partners have to be defined clearly. These aspects are also concerning the communal and private users.

Recent trends in legal regulation of pricing for geothermal energy can help to improve the situation.

2.7. Economical Efficiency

A wide range of strategies to improve the economic efficiency can be discussed from the technical up to market oriented and political aspects. Only a few aspects are mentioned which could help to increase the economical efficiency.

• Improvements of greenhouse heating techniques: Energy supply and distribution, state of the art control - steering techniques.

• Adaptation and changing of cultivation techniques: Soil heating, irrigation - fertilisation techniques also in respect of the ecological impacts e.g. concerning use of fertilisers, pesticides, herbicides.

• Integration of agricultural products that will attain a higher price on the market (eg. asparagus, strawberries, flowers). It is obvious, that these changes do have consequences at the infrastructure (eg. cooling facilities) which have to be evaluated.

• Last but not least, change of the composition of heat users in order to increase the annual heat loading factor and, in that way, economy of the full system in operation.

In connection with these observations, maximal introduction of cascade combinations of heat users should be implemented in order to increase the efficiency of use of the heat on disposal.

2.8. Optimizing Scenarios

The optimisation strategies depend on the present technical setup of the geothermal system and economical possibilities, depending on estimated economic justification for investments in different parts of the total system composition. It is a very big system and each decision must be carefully evaluated and fully proved before any implementation. A limitation to all optimisations is that each one has to proceed in a straight development towards sustainable use of the geothermal resources available. According to the results of previous investigations and studies (Popovski, 1992, Popovski 1999, ARGE 1999) activities for the improvements should be directed towards the following levels:

- reservoir - aquifer level

- operating level: production of thermal water

- operating level: use of the geothermal energy

- organisation, local and regional economical and political level.

Taking into account that proper evaluation of the economic feasibility of necessary technical measures for improvement of present state of the system and its optimisation has never been done, the following presented concepts should be understood only as an initial technical view which should be developed in more detailed solutions which are technically and economically feasible for implementation and which offer acceleration of the development and further profitable exploitation.

<u>Scenario 1: Adaptation of the System</u>

Based on the additional measures, which were implemented in 1998/99 (additional well EB4, filter station for reinfiltration) there is the possibility to shorten the length of the flowpaths through the kilometers of pipework by implementing heat exchangers at the users location. This would also lead to the separation of the produce - user cycles.

The cascaded use in town (e.g. swimming pool, low temperature heating) would improve the thermal efficiency of the system.

A part of the necessary recharge of the geothermal system can be supported by reinfiltration of a significant amount of used thermal water after passing the filter equipment to avoid clogging and precipitation in the aquifer formation.

Step by step implementation of new electrical-mechanical equipment together with state of the art control devices (e.g. frequency converter and pumps) with the maintenance services will improve the efficiency of the system.

An integrated part of this scenario shall be the monitoring of the operation as well as the reservoir behaviour in the subsurface to collect a valid data base to estimate the dynamics of the geothermal system.

This solution can solve a part of the observed problems but does not change the system in terms of sustainable use.

<u>Scenario 2: Change of the System to Doublet-Type</u>

The following scenario is designed to change the geothermal system to a state of the art doublet-type setup. The basic idea is to separate the production and consumer-cycles completely by implementing heat exchangers and to bring the used thermal water back into the aquifer formation without air contact in a pressurised cycle.

Following this concept, there will be a separation of the producer - consumer cycles with defined responsibilities to the supplier and user of geothermal energy. Additional energy sources like boilers (oil, gas, biomass) or heat pumps can be either in the responsibility of the producer/distributor or the consumer.

The following measures are the same as in scenario 1:

Step by step implementation of new electrical-mechanical equipment together with state of the art control devices (e.g. frequency converter and pumps) with the maintenance services will improve the efficiency of the system.

An integrated part of this scenario shall be the monitoring of the operation as well as the reservoir behaviour in the subsurface to collect a valid data base to estimate the dynamics of the hydrothermal system.

Indispensable requirements of this setup are additional infiltration/reinjection wells to increase the capacity of reinjected water. This will help to increase the pressure heads at the exploitation wells and will lead to a refill of the reservoir. The ratio of produced to reinjected water to protect the reservoir from overexploitation can be estimated by the results of a reservoir modelling based on actual monitoring data.

This long term concept will lead to a sustainable use of the geothermal resources.

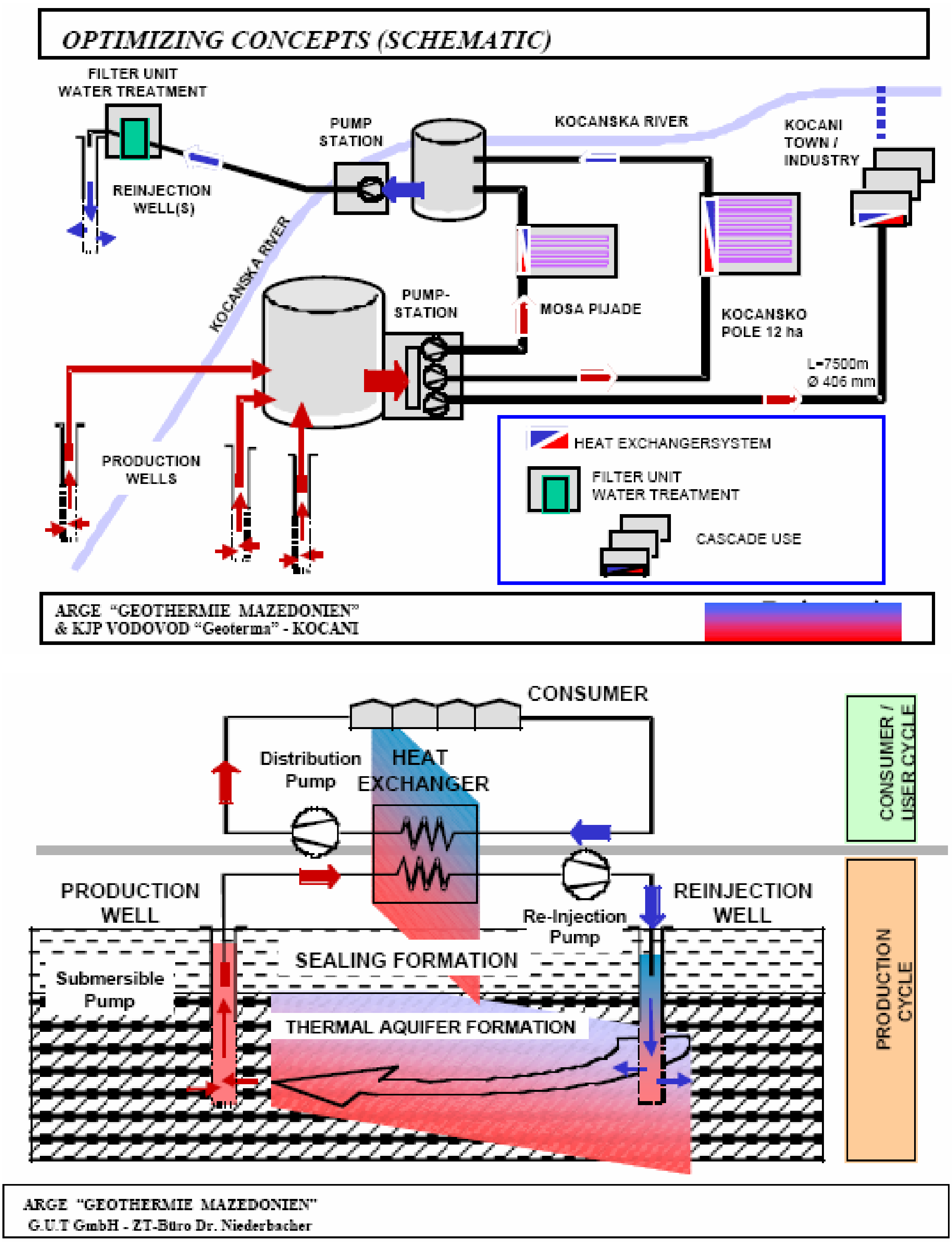

Fig. 3. Schemes of the optimising scenarios. Top: Scenario 1, Bottom: Scenario 2.

Scenarios for Adaptation of the Consumer Cycle

In addition to the changes and adaptations of the geothermal system GEOTERMA at the level of the hydrothermal resources (aquifer, production, reinjection) the optimization should also be performed on the level of distribution and use of the provided energy.

The implementation of thermal cascade use to increase the efficiency of the system should also be used in combination with heat pump technology as well as additional energy supply by implementation of boiler techniques (oil, biomass).

No one concept of optimisation shall be economically feasible if not achieving an increase of capacity of heat consumers and change of their composition. A proper strategy for investment in this part of the system development is of crucial importance for the further destiny of the system GEOTERMA!

Basically, what and where are the possibilities for further development is already clear. However, it is urgently necessary to determine the economically feasible strategy how to implement them over a defined time period.

Future Aspects and Visions

Beside the economical, technical and operational limitations of the geothermal system GEOTERMA at the present status, the scenarios of a prospective configuration concerning the ecological balance of the system could include for instance the following aspects:

- Definition of optimal locations for additional reinjection capacity. Definition of optimized quantity of used thermal water to be reinjected to keep the aquifer system balanced.

- Increase of operation period by implementing additional users with different daily and/or seasonal arrangement of heat requirements, bottling of drinking water (mineral water), implementation of cooling facilities, etc.

- Incorporation of self production of the electricity for the exploitation of thermal water by use of other local renewable sources e.g. hydropower, biomass, wind energy or the thermal water itself (Rankine Cycle technology see references).

- Use of the range of thermal levels by cascade technique.

- Establishment of a new balneological touristic center in the town for multiple use of the thermal water all year around, connection of the existing town outdoor swimming pool to the geothermal network, etc.

In the present situation, it is important to identify and evaluate realistic short and midterm solutions to ensure a continuous improvement of the geothermal system and the profitable work of it. It is obvious that the technical and economical aspects of these scenarios have to be evaluated and adapted to the local regional and national economic conditions. Results of the first investigations and economic analyses are very optimistic. There is practically no energy source in the country that can guarantee repayment of necessary investments in so short a period and with such low prices of supplied energy to the consumers.

3. ACTIONS IN PROGRESS

In order to enable a proper composition of the development strategy for the geothermal system GEOTERMA, the following actions have been taken by the public utility:

- A strong pressure to the state regulatory committee is made to finally resolve the problem of low price of supplied energy to users. Problem is that the present price (less than 2 US¢!) cannot cover properly the exploitation and maintenance costs, and should cover also the development costs;

- An application to the World Bank has been supplied for financing the preparation of a good balanced development strategy; and

- An application to the USAID has been supplied to cofinance the process of privatisation of the system and help in location of possible financial resources for its implementation.

Successful results are expected by the end of 2004, which should enable the beginning of a wider process of system reconstruction, recompletion and optimisation, and (finally) a larger introduction in the city and industrial areas.

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