Geothermal development in Lithuania

Feliksas Zinevicius[1], Vita Rasteniene[2] & Alfonsas Bickus[3]

[1]*Lithuanian Energy Institute, Breslaujos 3, LT 3035 Kaunas, Lithuania, e-mail: felix@isag.lei.lt*
[2]*Institute of Geology and Geography, T. Sevcenkos 13, LT 2600 Vilnius, Lithuania, e-mail: vitarast@geologin.lt*
[3]*UAB "Geoterma", Lypkiu 53, LT 5810 Klaipeda, Lithuania, e-mail: geoterma@aiva.lt*

Abstract
Lithuania is Middle European country possessing rich low-enthalpy geothermal resources ($6000 \cdot 10^{18}$J up to 3km deep). The first geothermal investigations initiated in 1987-1989-s. In Institute of Geology was prepared technical, geological and economical project for district heating of seven towns in western Lithuania from Cambrian, Devonian hydrothermal aquifers and from Hot Dry Rocks.

In 1992-1994-s Government of Denmark financed Baltic Geothermal Energy Project covering Lithuania and Latvia. On the basement of this project and other investigations Klaipeda Geothermal Demonstration Plant was engineered (prospective capacity 49MW, production of heat 598 TJ/year) to cover about 25% of yearly Klaipeda City heat demands.

The plant was built in 2000 and started producing heat. But plant is still not handed over by State Commission because of the problem gypsification in pipeline system.

As experience of KGDP shows, the first well must serve as investigationary one, all necessary geological, laboratorical and long-time hydrodynamics investigations must be done. Core drill extracting from production horizon should be obligatory.

Keywords
Klaipėda geothermal demonstration plant (KGDP), Devonian aquifer, Baltic Geothermal Energy Project, geothermal resources.

Introduction
Klaipeda geothermal demonstration plant is a result of the Baltic Geothermal Energy Project carried out in period 1992-1994 under the framework of the agreement between the Latvian Ministry of the Environment, the Lithuanian Department for Environmental Protection and the Ministry of the Environment of the Kingdom of Denmark, regarding the cooperation in the field of environmental protection [1]. The feasibility study was prepared with the purpose to select preferred sites for the establishment of geothermal demonstration plants in Lithuania and Latvia.

The geothermal aquifer zones within the Devonian and Cambrian strata were studied in detail. Twelve urban areas were selected (Klaipeda, Palanga, Siauliai, Silale, Silute, Gargzdai, Radviliskis, Joniskis - in Lithuania and Liepaja, Riga, Jurmala, Jelgava - in Latvia) with a view to a ranking of preference with regard to geothermal pilot project. Klaipeda and Liepaja, were considered of primary interest. The Klaipeda Geothermal Demonstration plant - the first project in the Baltic states - was made possible by [2]:

- a high transmisivity in the aquifer (~150Dm);

- the possibility of supplying heat to the district heating system through the whole year;
- the good performance of the absorption heat pumps;
- the commitment of the involved;
- substantial grants.

The Danish Environmental Protection Agency, the Government of Lithuania and the World Bank (IBRD) (loan 5.9USD million) have contributed to the establishment of the financial package required for the construction of the plant. Further EU PHARE and Global Environmental Facility Trust Fund granted money for the project also. Total budget - 19.5 million USD.

For the purposes of the construction and operation of the Klaipeda Geothermal Demonstration plant, the company (UAB "Geoterma") was founded with the following shareholders:

- Ministry of Economy of the Republic of Lithuania, (74.6% of shares);
- AB "Lietuvos energija", (25.4% of shares).

UAB "Geoterma" is responsible for the project leadership and management of the geothermal and heating systems of the whole geothermal plant.

Geological situation

The very big geothermal anomaly with high heat flow density and known as Baltic one is situated in the South East Baltic region. Baltic geothermal anomaly is subdivided into smaller ones. The West Lithuanian anomaly with density of heat flow of 90-100mW/m^2 is the biggest among them [3].

There are three hydrogeothermal complexes in the sedimentary cover of the Western Lithuania: the Cambrian (140m), Middle-Lower Devonian (400m) and Upper-Middle Devonian (200m). The porosity of these complexes is: 7-15% (C), 20% (D_{1-2}) and 20-24% (D_{2-3}).

The location of exploration and geothermal wells of KGDP are presented graphically in Figure 1. The geological profile shows alternation in the geological section down to a crystalline basement (Fig. 2). The geological section along the geothermal wells includes Quaternary deposits, Upper Jurassic, Lower Triassic, Upper Permian, Upper, Middle and Lower Devonian rocks. The production horizon is the Lower Devonian (Viesvile formation) aquifer. It is located between 990m-1118m. Their thickness is 128m. The production horizon has been bored without extracting core. Geological, petrophysical and lithological data are estimated according to logging. The lithological conditions of the Klaipeda wells can be described according to the Vydmantai well core. Lithologicaly, the Viesvile formation is a complicated alteration of sandstone and clayey packets. The sandstone packets make up to 70%. Their thickness varies from 2-5 to 10-18m. Their are light gray and gray, different grained, feldspar (3.2-6.2 rarely to 16.4%) – quarciferous (69-95%), not evenly micacious (0.4-1%, rarely 7.4-9.4%), here and there which alloy of glauconitic sandstone (sandy) or siltstone (silty). Sandstone is mostly weakly cemented by clayely or dolomitic cement.

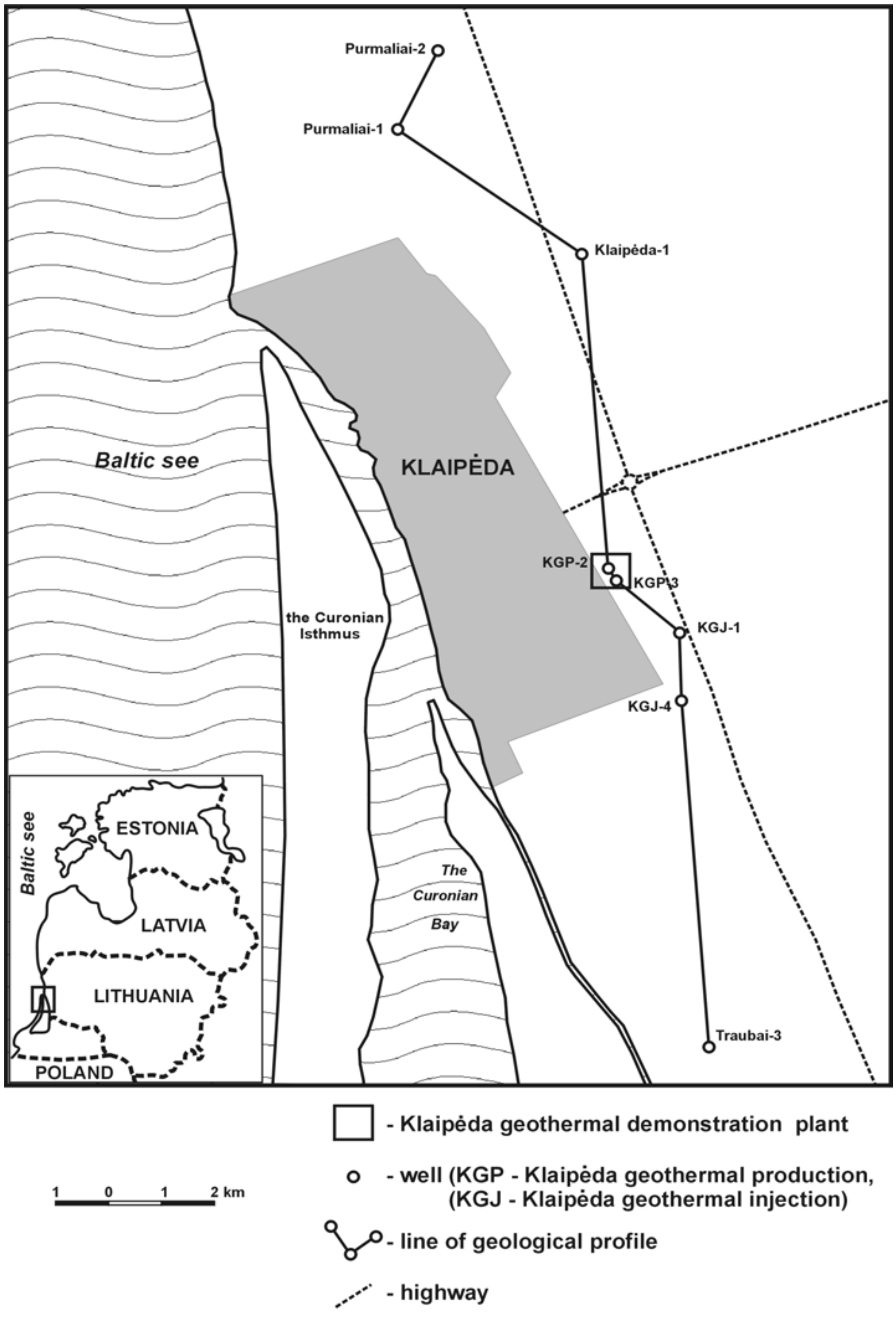

Fig. 1. Location map of Klaipeda geothermal demonstration plant

Collector qualities vary. The best filtration properties have weakly cemented, different grained sandstone, which permeability changed from 207 to 6295mD (average 2563mD), open porosity –from 20.1 to 31.2% (average 25%).

Thermal water (38°C, 92.8 g/l salinity) is extracted from clastic rocks (sandstone light gray, medium grained, some silt and clay) with the flow rate of 300 to 400m^3/h. After logging data 10m^3 rocks of aquifer content 1-3m^3 thermal water.

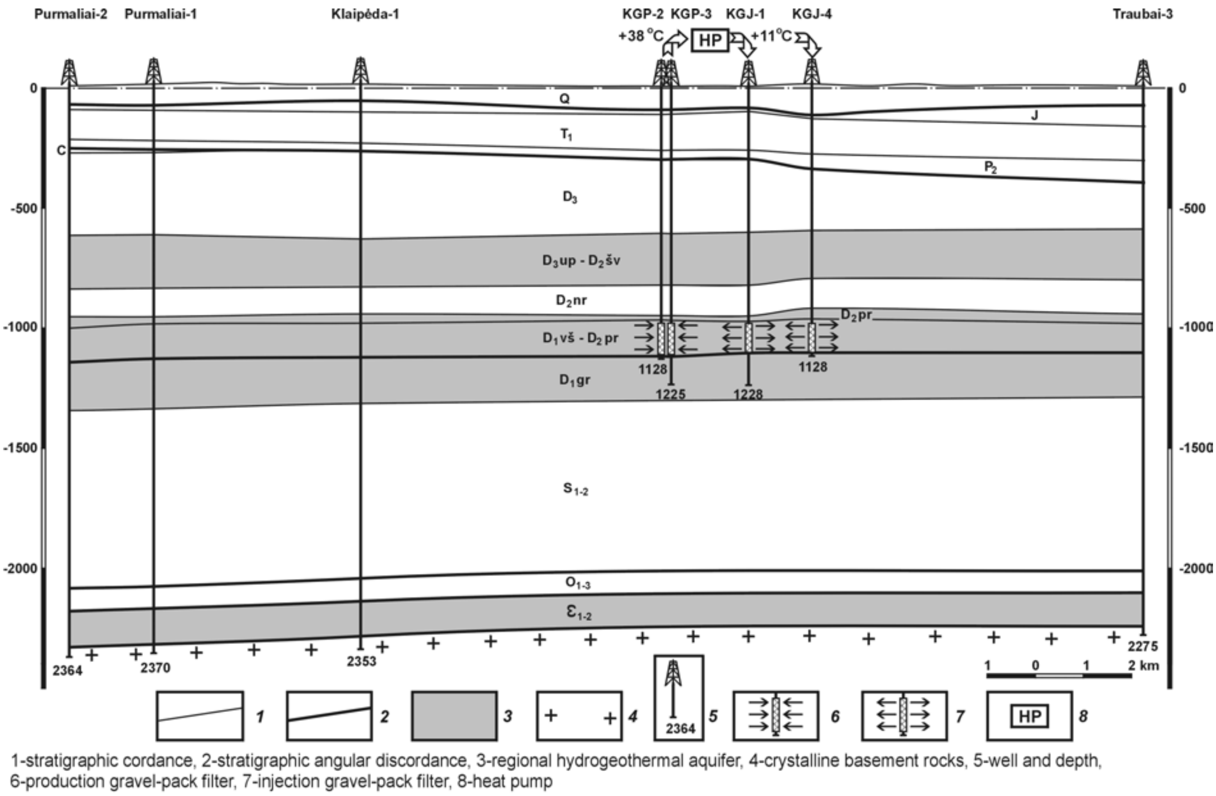

Fig. 2. Geological profile

Results

The construction of KGDP was to serve the following purposes: a) to develop the utilization of local geothermal resources, which could reduce the emission of gases causing the greenhouse effect, b) to demonstrate that the local geothermal resources could be used instead of imported fuel (oil, gas and coal), and c) to use the heat energy of geothermal water for the heating system of the premises, and for the production of hot water.

KGDP has two production (KGDP-2P, KGDP-3P) (Fig. 3) and two injection (KGDP-1I, KGDP-4I) (Fig. 4) wells. They are identical in construction. The working (filter) zone is over 100m, and filter diameter is $9^{5/8"}$. The depth of wells is 1128 to 1228m.

The geothermal water with the help of submersible pumps is extracted from the Devonian aquifer and via production wells, heat pumps and injection wells returned to the same aquifer. Low-temperature geothermal heat is extracted from geothermal water (38°C) using an absorption heat pump and transferred to district heating network of Klaipeda. Total thermal capacity of KGDP – 41MW: 17MW geothermal heat and 24MW heat from boilers (driving heat for the absorption heat pumps).

The configuration of the absorption heat pump comprises an evaporator, an absorber, a condenser and a working fluid generator (Fig. 5). The pump uses lithium bromide (LiBr) solution as the heat absorbent working fluid. The absorption heat pump is driven by 175°C hot water from the boiler, which is part of the Klaipeda Geothermal Demonstration Plant. The single-effect absorption heat pumps for Klaipeda Geothermal Demonstration Plant are tailor-made equipment in order to obtain optimum performance. 4 identical units are installed in Klaipeda Geothermal Demonstration Plant. Each unit consists of a serial connection of 2 groups of heat pumps, each group including 2 heat pumps connected in parallel. The district heating water is heated in the group 1 absorbers. It then enters the group 2 absorbers, goes into the group 1 condensers and exits through the group 2 condensers. The geothermal water is first cooled in the group 2 evaporators and then cooled to the exit temperature in the group 1 evaporators [4].

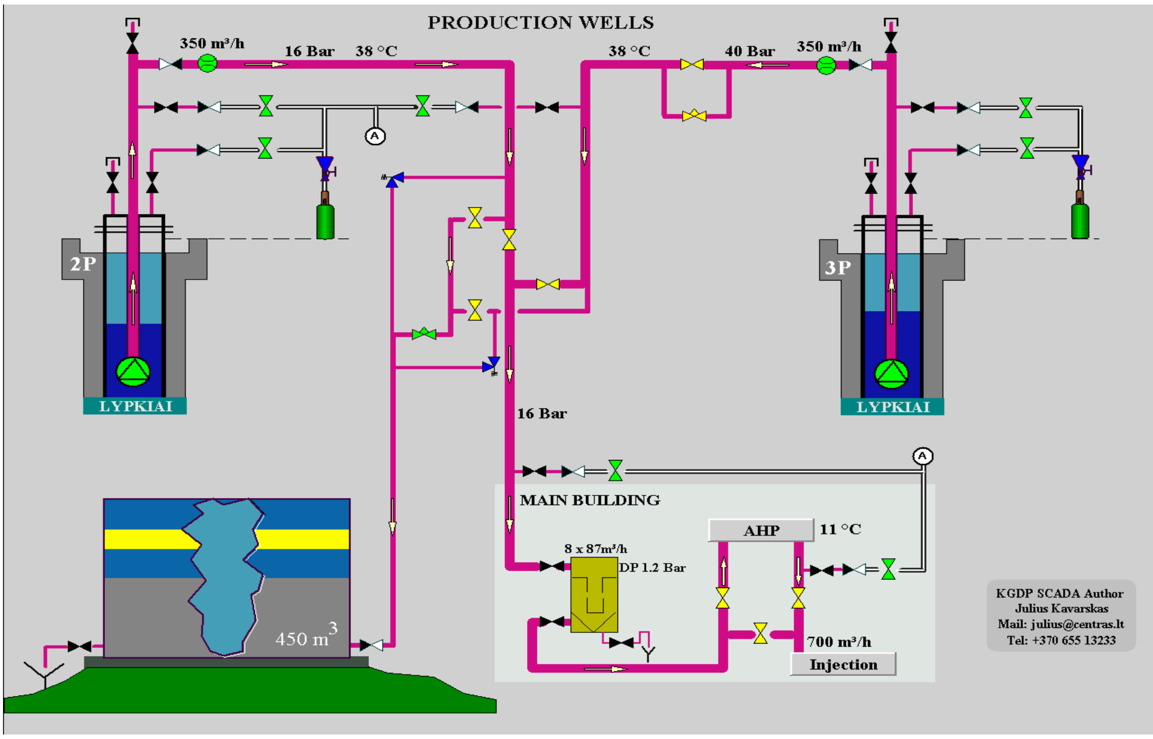

Fig. 3. Production wells

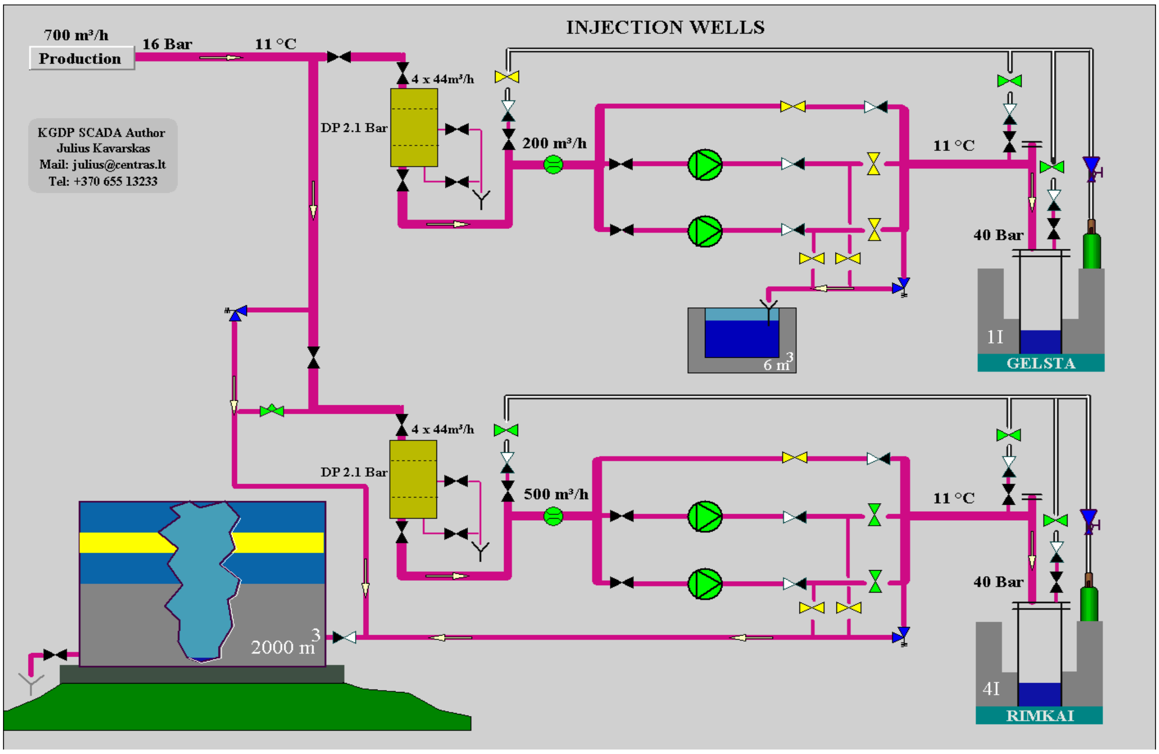

Fig. 4. Injection wells

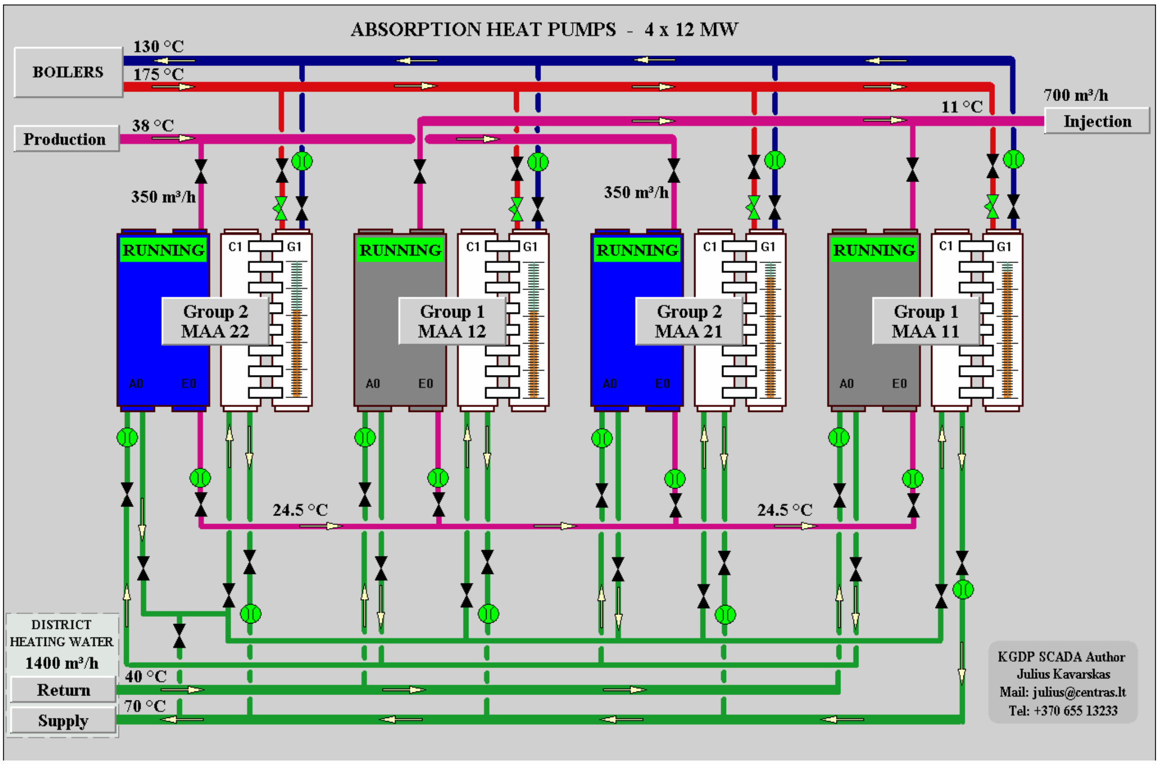

Fig. 5. Absorption heat pumps

The design procedures and material selection are made in order to provide a lifetime of at least 25 years.

The corrosion properties of geothermal water were investigated. The corrosion rate of the geothermal water has been measured to be 0.1 – 0.2mm per year in carbon steel. The conclusion was made that normal steel can be used with 5mm corrosion allowance and the moving parts such as balls in ball valves can be AISI 316. The carbon steel should, however not contain more than 0.02% of S. Special consideration taken to welds which can be corroded by the carbon dioxide. Precipitation problems have been not expected. Water with a high mineral content has more than 96% NaCl and CaCl. The pH – value is up to 6.3. One litre of geothermal water contains 160ml of dissolved gas. Approximately 94% of this gas is N_2.

During the project implementation it was found:
a) that producing well head water temperature is lower (38°C) rather than expected (42°C);
b) the injection capacity in well KGDP – 1I is insufficient for the injection of 600m^3/hour of geothermal water.

In order to achieve an annual heat production additional geothermal injection well KGDP – 4I was drilled.

The geothermal plant was erected next to the Eastern Boiler House owned by SPAB "Klaipedos energija". After detailed analysis the conclusion was made to put up three hot water boilers (16.2MW capacity each) at the geothermal plant, because the hot water boiler installed at Eastern Boiler House has no possibilities supply required quality driving heat (T = 175°C, p = 10Bar) for the absorption heat pumps.

In summer time the hot water consumption is not even, therefore the reservoir-accumulator (2000m^3) was established. The heat exchangers (2 ones, 16MW capacity each) (Fig. 6) are installed with aim to overcome reproaches for reliability of geothermal plant. Now even in case of accident when due to geothermal loop is not in operation – the heat would be supplied to district-heating network without a break.

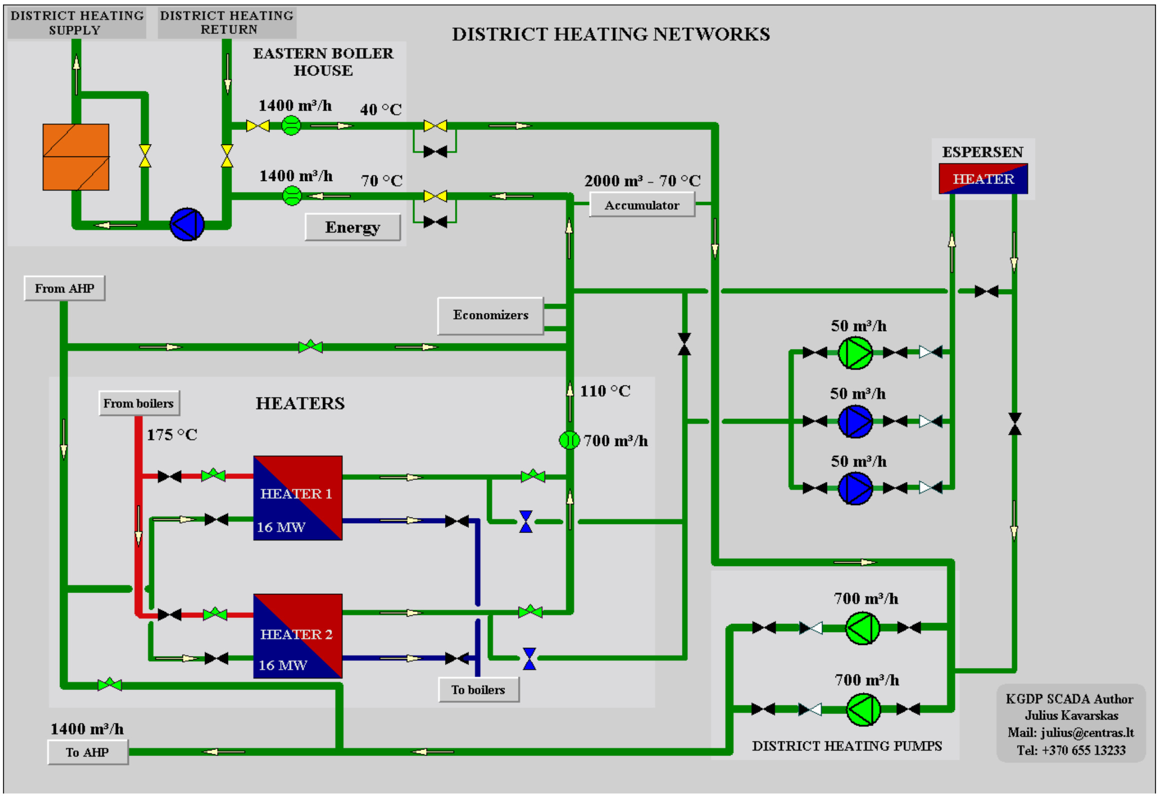

Fig. 6. Access to the district heating network

Setting in operation, adjustment

After flushing of geothermal loop at start-up in September 2001, it was fixed that injection capacities in well KGDP 1I and KGDP 4I are considerably lower than predicted. The problem is, that injection capacities have not been explored after injection wells have been drilled. Also the microbiological investigations have not been performed in regards H2S and hydrogen contains in wellheads; any measures have been undertaken in regards the constant pressure to be kept within system.

In October 2001, GTN Geothermie Neubranderburg GmbH inspected the 4I and 1I injection wells, as the injectivity was deteriorating rapidly. Since the inspection of the surface plant (water-chemical and microbiological investigations, oxygen measurements) did not indicate any reasons, a downhole inspection of the injection wells was carried out comprising:

- injection test with pressure build-up measurement,
- downhole video inspection,
- downhole solid sampling,
- gamma logging,
- flow metering.

After analysis, the causes are considered to be as follows:

- input of iron precipitations (coming from oxygen entry),

- input of redeposited clay from silty sections of the aquifer (clay destabilization).

In addition for the well KGDP II:

- unfavorable geological formation of the aquifer,
- unfavorable screen installation.

Proposals were elaborated regarding the improvement of the injectivity underlining that sustainable improvement and the designed capacity will be achievable at high expenditures only and with additional wells [5].

In March 2002 the clean up of the 4I and 1I injection wells has been performed by Halliburton company. The restitutes of gypsum, clay and ferrum oxides have been pumped out, but the test after the clean up showed that injection wells are still not able to reach full capacity of 700^3m/h.

The plant has been operating on constant capacity since the cleanup of injection wells. The heat demand from Klaipeda City has only been below half capacity during the summer period. The production has been based on flow from 2P only and injection into the two injection wells without use of injection pumps.

In October in line from well 3P huge amounts of gypsum crystals was identified. DONG has presented design for pressure expansion vessels for the two injection wells and implementation of inhibitor injection system.

Total amount of heat produced by KGDP in year 2002 was – 189000MWh.

Discussion

The economic viability of geothermal energy in Lithuania is sensitive to the quantity of heat extracted and the price at which it is sold.

The production costs for heat from a Klaipeda Geothermal Demonstration Plant is 0.047Lt/kWh, assuming a 15 year loan at 6 million USD and 300 MWh extracted annually from the geothermal water. While in 1999 production costs for heat from Klaipeda DH were - 0.06Lt/kWh (1EURO = 3.4528Lt).

Even it is possible for a Klaipeda type plant to pay off a 25 year loan at 20 million USD (total plant investment costs) assuming 500TJ extracted annually with heat production costs - 0.07Lt/kWh. In 1999 the average value of heat production costs in Lithuania were - 0.0825Lt/kWh.

Lithuanian practice shows, that for today the major challenges facing the geothermal heat industry are:

- obtaining access to the market,
- obtaining a profitable fixed minimum price for heat.

We can use German practice for solving such problems - the Act on Granting Priority to Renewable Energy Sources says: "Grid operators shall be obliged to connect to their grids electricity generation installations (geothermal), to purchase electricity available from these installations as a priority and to compensate the suppliers of this electricity (at least 17.5pf/kWh if the installation ... up to 20MW and at least 14.0 pf/kWh if installation ... over 20MW)".

Geothermal energy is a clean, proven and reliable resource for supplying the needs of a sustainable society and helping to improve the global environment. The environmental impact of geothermal energy is small as compared to that of hydrocarbons (especially CO_2 emission). Energy prices and environmental impacts are the two parameters that will have the largest influence on the competitive status of geothermal energy in the 21-st century.

New possibilities for geothermal energy development in Member States and Candidate Countries are given by European Commission in frames of the Sixth Framework Programme (FP6). The aim of Programme is to pave the way for the introduction of innovate and cost competitive renewable and energy efficiency technologies into the market. Project should focus on: *"Geothermal energy for heating and cooling employing innovate environmentally sustainable and cost competitive technologies, including ground coupled heat pumps". Geothermal energy for electricity generation, combined heat and power (CHP)…". "Innovative research into exploration, resource assessment and management techniques, cheaper and more advanced drilling and simulation technologies, and more efficient power cycles".*

New technologies, standardization and new grid management tools should facilitate the access of small self-producers to the grid, fuel flexibility ensures increased security in the decentralized energy market.

The geothermal plant (KGDP) is erected next to the free economical zone of Klaipeda City. The development in the free economical zone will result in sale of additional heat at a better price for "Geoterma". It is highly important that the geothermal plant can be run at full capacity. In spite of all mentioned problems Klaipeda Geothermal Demonstration Plant is reliable heat supplier capable to participate in competition with traditional heat suppliers.

Conclusions

1. The Baltic Geothermal Energy Project carried out in period 1992-1994 was accomplished – in year 2000 the geothermal plant in Klaipeda was built and started producing heat.
2. Step by step technical problems are under elimination and in year 2002 KGDP produced 189000MWh of heat.
3. In addition to technical – the problems faced with access to the market and obtaining a profitable fixed minimum price for heat must be solved.

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