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Geothermal Potential and First Achievements of its Utilization in Lithuania

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ABSTRACT

The territory of Lithuania is in the marginal area of the western part of the Precambrian East European platform. Main tectonic elements in Precambrian crystalline basement are the Baltic Syneclise and its slope, the Masurian-Belarusan Anteclise, and the Latvian Saddle. The western part of Lithuania is characterized by 40km depth, but central part - by 44-47km average depths of Mocho surface. It was also established that the specified large geoblocks in the structure have number of deep faults (penetrating as deep as mantle) with a significant subvertical amplitude of displacement in the deep strata, but it was insignificant on the surface. The increased geothermal parameters are typical in western part of Lithuania with heat flow about 100 mW/m^2.

The geothermal potential of Lithuania was estimated for three regional hydrogeothermal complexes: Cambrian (5.1x10^{18}J), Lower-Middle Devonian (5.0x10^{18}J), Middle-Upper Devonian 1.5x10^{18}J). Petrogeothermal resources were estimated down to 7km depth in Lithuania (7x10^{21}J).

Usage of geothermal resources for district heating started at 2000. The first geothermal demonstration plant in Lithuania was built in Klaipeda. Total thermal capacity of plant – 41MW. Low-temperature geothermal heat is extracted from geothermal water (38°C pumped from 1100 m depth) using absorption heat pump. Amount of heat produced by plant in year 2003 was – 215000 MWh.

In spite of technical problems Klaipeda Geothermal Demonstration Plant is reliable heat supplier capable to participate in competition with traditional heat suppliers.

Geothermal investigations were performed by the German company Geothermie Neubranderburg GmbH for sites of Vydmantai, Vilkaviskis and Silute.

Potential consumers of the Earth's thermal energy are several cities and towns (Palanga, Kretinga, Plunge, Gargzdai, Nida, Silale) and numerous settlements situated in area of the West Lithuanian Geothermal Field.

More than 200 systems of ground-source heat pumps are installed for heating at single family houses (total capacity - more than 3MW).

1. INTRODUCTION

Lithuania (population – 3.5 million, territory – 65300 km^2) since the first days of regained Independence in 1990 has been in transition to free market economy. During the last fourteen years great efforts were made to lay foundations for market economy: privatization of companies, liberalization of prices of almost all products and trade conditions.

Lithuania inherited powerful energy sector based on foreign primary energy resources.

Primary energy resources – crude oil, natural gas and nuclear fuel – are imported from Russia. Lithuania has no transmission lines from/to Western countries.

Currently Ignalina NPP with installed capacity of 3000MW produces over 85% of annual electricity production. First nuclear unit is to be closed in 2005, the second one – in 2009.

In year 2002 Gross inland consumption in Lithuania was 8.6 Mtoe: fossil fuel comprises 55.3%, the nuclear – 35.9%, renewable energy sources RES (wood wastes and firewood, hidro, geothermal, straw, biogas, solar) – 8.8%. (Energy, 2002) (Fig. 1).

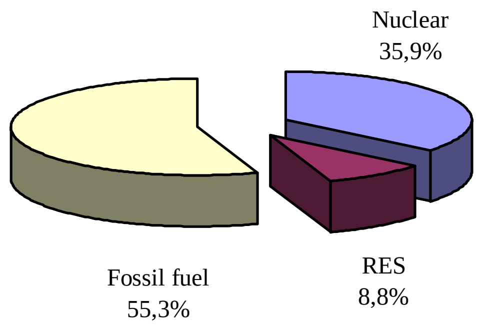

Figure 1: The structure of Gross Inland Consumption in year 2002.

Breakdown of RE projects by capacity implemented in period from 1990 to 2004 (Enhancement, 2003) is presented in Fig. 2.

Forest cover 1/3 of Lithuania's territory, so wood based boiler plants (app. 251MW) dominate among the RE projects. The second biggest part of implemented RE projects is geothermal (plant in Klaipeda – 18MW, total capacity 41MW) and the third – hydro-based power plants (small-hydro app. 15MW). Total capacity of hydro power installations in year 2002 was app. 916MW: Kruonis HPS-800MW, Kaunas HPP – 100.8MW, other HPP – 15MW). Construction of Kruonis Hydroelectric Pumped Storage Plant (HPS) takes period from 1992 to 1998.

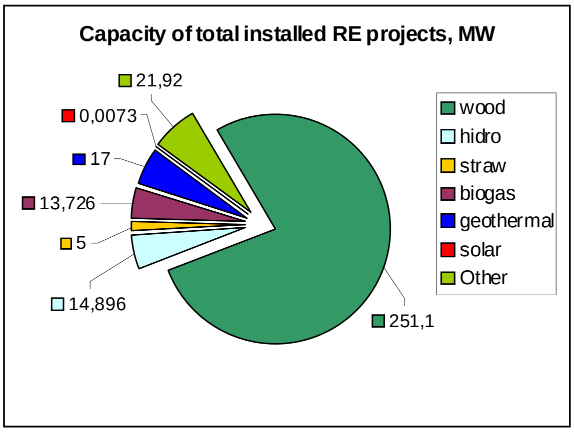

Figure 2: Breakdown of RE projects by capacity.

In 2004 Lithuania became Member of the EU and NATO.

The use of renewable energy sources is fundamental vector of energy policy for the future in Lithuania. The main document of energy policy: National Energy Strategy (2002), (National, 2002), National Energy Efficiency Programme (2001), (The National, 2001), Law on Energy (2002), (Low, 2002), Law on Electricity (2000), (Low, 2000), Law on Heat (2003), (Low, 2003) – are promoting consumption of indigenous and renewable energy resources.

The first geothermal investigations in Lithuania initiated in 1987-1989-s.

In 1992-1994-s Government of Denmark financed Baltic Geothermal Energy Project covering 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. On the basement of this project and other investigations Klaipeda Geothermal Demonstration Plant was engineered.

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.

UAB “Geoterma” is responsible for the new geothermal projects preparation and implementation in Lithuania also.

2. GEOLOGY BACKGROUND

The territory of Lithuania underwent two stages in its tectonic development – preplatform and platform (Geology, 1991). The Proterozoic crystalline basement was formed in the former, the sedimentary cover of the Late Proterozoic – Phanerozoic age in the latter. In the structure of the earth’s crust underneath the sedimentary cover (0.2-2.3km in thickness), granite (about 25km) and basaltic (about 20km) layers are distinguished. The earth’s crust is burdened by faults, intrusions, occasionally by effusive outpourings. The sedimentary cover is represented by all Phanerozoic systems. The thickness of sedimentary pile increases from 200m in southeastern Lithuania to 2.3km in the west. These overlay the crystalline basement of Early Precambrian consolidation. Summary geological section of sedimentary cover is represented in Figure 3. The sedimentary series on the eastern part of Lithuania begins with Vendian system. The sedimentary cover, filling all tectonic structures, as to the character of the occurring geological formations, their genesis and the rows of development in the vertical section, in the presence of large regional angular discrepancy, is divided into structural complexes, stages and sub stages. The following structural complexes were distinguished: Baikalian (Vendian – Lower Cambrian (Kotlin-Lontova)), Caledonian (Lower Cambrian (Lyviai) – Lower Devonian (Tilze), Hercynian (Lower Devonian – Lower Permian) and Alpine (Upper Permian – Quaternary)). The sedimentary cover according to geothermal energy is most importance. These series are formed from porous, fractured-porous and screening layers. Permeable layers are perspective as hydrothermal-bearing source. Summary permeable layers of Lithuania’s sedimentary cover are represented in map (Fig.4).

3. GEOTHERMAL RESOURCES AND POTENTIAL

Geothermal potential of Lithuania is rather high, the main economic prospects relating to the West Lithuanian geothermal anomaly. A temperature at the bottom of sedimentary cover exceeds 90°C. The aquifers defined in the sedimentary cover are potential sources for geothermal energy. They are conventionally grouped into several hydrogeothermal stages (permeable and screening beds).

The Lower Paleozoic – Upper Proterozoic hydrogeothermal stage (Baikalian and Caledonian structural complexes) is distributed over the whole Lithuanian territory. It comprises Cambrian-Vendian and Ordovician-Cambrian hydrogeothermal complexes. The former occurs in eastern Lithuania at the depths of 200-1000 m with temperatures ranging from 15 to 25°C. The Ordovician-Cambrian hydrogeothermal complex is characterized by highly variable temperatures trending westward mainly from 15 to 90°C due prominent difference in its depth ranging from few hundred meters in the east to more that 2km in the west.

Two wells were recently drilled in the western Lithuania with purpose to exploit geothermal energy from Cambrian succession. Cambrian is represented by quartz sandstones passing downward into dominating siltstone and claystone. That is the most prospective (high temperatures) although most problematic (extremely variable collector properties due to secondary quartz) succession. The thickness is about 150 m. The overlaying Ordovician succession is composed of limestone and marlstone showing rather poor reservoir properties, with exception of 1m thick layer of sandstone at the base that serves as a good collector.

The Middle-Lower Devonian hydrogeothermal complex is most prospective of the Paleozoic hydrogeological stage (Hercynian structural complex). Temperature increases to the west from 10 to 45°C, a thickness is about 400m. It is dominated by poorly cemented fine-grained sandstones. Two producing and two injecting wells of Klaipeda geothermal demonstration heat plant are drilled into this complex. Upward, the Upper-Middle Devonian hydrogeothermal complex (poorly cemented fine-grained sandstone, 10-35, 200m thick) and Permian hydrogeological horizon (carbonates, 10-30°C, 10-70m thick) are defined.

The Cainozoic-Mesozoic hydrogeological stage (Alpine structural complex) is restricted in the southern Lithuania. It is regarded as a prospective accumulator for storage of the surplus industrial energy.

In the deposits of the Quaternary are distinguished four intermorainic and one undermorainic water-bearing horizons. These deposits are prospective for heat pumps.

The geothermal potential of Lithuania was estimated for three regional hydrogeothermal complexes: Cambrian ($5.1x10^{18}$ J), Lower-Middle Devonian ($5.0x10^{18}$ J), Middle-Upper Devonian ($1.5x10^{18}$ J) (Fig. 5, 6,7). Petrogeothermal resources were estimated down to 7km depth in Lithuania ($7x10^{21}$ J) (Suveizdis et al., 1995), (Fig. 8).

4. GEOTHERMAL UTILIZATION

4.1 General targets for RES

The European Union has adapted on indicative target for renewable energy of 12% of gross domestic energy consumption and 22% of electricity consumption by 2010 (Directive 2001/77/EC).

Target 12% (RE) of gross domestic energy consumption for Lithuania is realistic, because in 2002 it was already 8.8%; target 22% (RE) of electricity consumption is too high. So, it was agreed with EU institutions that the growth for of "green electricity" in Lithuania will be from 3.7% (year 2002) to 7% (year 2010). This gap could be covered by installation of wind plants with total capacity of 170MW. (Table 1).

4.2 Vydmantai

In 1989 the first geothermal exploration well, Vydmantai–1 (2564m), was drilled and in 1993 injection well, Vydmantai–2, was completed. Hard mineralized (162g/l) underground water of Cambrian aquifer has flow rate up to $50m^3/h$ at temperature of 72^oC. These parameters are proper for the establishment the geothermal plant with power 7.5MW (2.0MW – geothermal part). (Table 2). In the meantime due to lack of money finish installation of geothermal plant and lack of consumers – the wells are shuted in.

4.3 Klaipeda geothermal demonstration plant (KGDP)

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 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.

Figure 9: View of KGDP.

The plant was built in 2000 and started producing heat.

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.

KGDP has two production (KGDP-2P, KGDP-3P) and two injection (KGDP-1I, KGDP-4I) wells. They are identical in construction. 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: 18MW geothermal heat and 23MW heat from boilers (driving heat for the absorption heat pumps). (Zinevicius et al., 2003)

The configuration of the absorption heat pump comprises an evaporator, an absorber, a condenser and a working fluid generator. The pump uses lithium bromide (LiBr) solution as the heat absorbent working fluid. The absorption heat pumps (4 ones, 4.5MW capacity each) are driven by hot water (175^oC, p = 10Bar) from three hot water boilers (16.2MW capacity each).

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) 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.

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.

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.

Figure 10: Absorption heat pump at KGDP.

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 2002 in line from well 3P (Denmark) 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.

In May 2004 the geothermal loop was cleaned up and plant started operation with inhibitor injection system. (Fig. 11)

Total amount of heat produced by KGDP grows from 103000MWh in year 2001 to 215000MWh in year 2003. (Fig. 12)

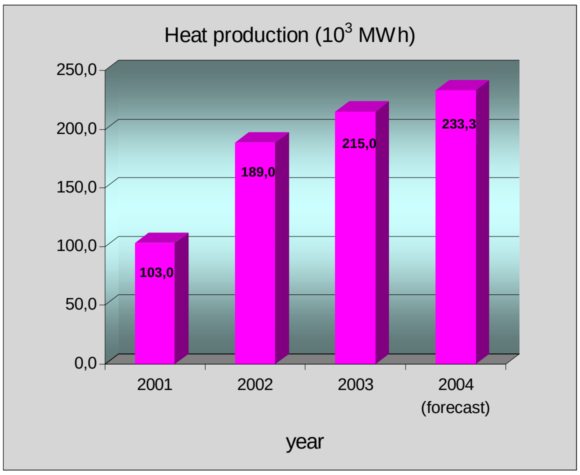

Figure 12: Heat production at KGDP.

4.4 Vilkaviskis

The study of the possibilities of thermal water utilization for balneological and energetic purposes on the site of Vilkaviskis has been prepared by Geothermie Neubrandenburg, Germany.

The plant in Vilkaviskis shall extract up to 6.1MW from up to 150 m^3/h geothermal water at 49°C (mineralization 127g/l) and supply 41000MWh/year to the district heating network of Vilkaviskis. Electrically driven compression heat pumps will be used. Total capacity of plant - 30.2MW.

The thermal water found on the Vilkaviskis site possess the quality of medicinal water and are, thus, very well suitable for balneological use. Another field of application of such waters are baths, the medical-therapeutic and recreational sectors. So, the development of the thermal brine may well be the starting point for the successful development of the municipality of Vilkaviskis as a spa and holiday resort.

4.5 Small - scale heat pumps

Since 1996 geothermal small-scale heat pump systems are under installation in Lithuania. Lithuania has an unlimited amount of low temperature (<20^{o}C) geothermal resources, lying at relatively shallow depths and its extraction is less complicated than for higher temperature. Total capacity of small geothermal heat pump installation in period from 1996 to 2000 – 0.39MW in period from 2001 to 2004 – 2.88MW. Private enterprises: “Alropa”, “Naujos idejos”, “Sanresta”, “Sildymo Technologiju Centras”, are very active in market for designing and installation. (Table 3, Table 4)

4.6 Personnel and Investments

In 1994 professional personnel allocated to geothermal activities was from Geology and Geography Institute, Lithuanian Energy Institute, Ministry of Economy, “Lietuvos energija” AB, Kaunas University of Technology, “Geotherma” UAB, “Minijos nafta” UAB, “Alropa” UAB, “N”, “S”, “STC” Danish companies (Table 5).

Investments in geothermal energy development are presented in Table 6. In period from 1995-1999 the main part of them, 19.3 million USD allocated to KGDP. In period from 2000 to 2004 the sum of 1.57 million USD to KGDP was allocated additional.

5. DISCUSSION

5.1 Legal basis

The legal basis of country's power sector and national electricity market is based on the Law on Energy (2002) and the Law on Electricity (2000). These acts have been fully harmonized with EU directives.

The **Law on Energy** defines five main objectives of the State in energy regulation:

1) Security of supply;
2) Energy efficiency;
3) Reduction of the negative environmental impact;
4) Promotion of competition;
5) Promotion of the local and renewable energy use.

The purchasing prices of **“green electricity”** are set by National Control Commission for Prices and Energy (NCC). RES-Electricity prices (Euro/MWh) for purchase by grid operators are: hydro power plants - 58.0, wind power plants - 63.8, power plants, using biofuel - 58.0, other power plants, using renewable or waste energy resources - price is set by separate NCC decision.

According to **Law on Heat**, State and municipalities shall encourage the purchase of heat fed into heat supply systems if produced from biofuel, renewable energy sources and geothermal energy (such original definition ! F.Z.).

(Chapter I, Article 1, Item 2)
The objectives of the Law:

1) To guarantee the reliable and high quality least-cost heat supply to consumers.

2) To legally establish the reasonable competition in the heat sector.
3) To defend the rights and legitimate interests of heat consumers.
4) To improve the efficiency of heat production, transmission and consumption.
5) To increase the utilization of local fuel, biomass and renewable energy resources in heat production;
6) To reduce the negative impact of heat energy industry on the environment.

(Chapter II, Article 4, Item 3)
The state (municipalities) shall promote the buying of heat produced from biomass, renewable sources of energy, waste incineration and geothermal energy for the heat supply systems. The buying of such heat shall be assigned to the public service obligations.

(Chapter III, Article 7, Item 4)
In preparation of the Municipal Heat Plan, all heat and gas undertakings servicing the territory of this municipality, other legal persons related to the heat sector as well as the organizations protecting the customer rights shall take part. The ecologically clean heat energy sources (electric, geothermal, etc.) shall be permitted in the whole territory of municipality.

The follow-up secondary act to Law on Heat, namely **Procedure of Purchase of Heat from Independent Producers to Heat Supply Systems (2003, July)** sets the rank (merit order) of heat to be purchased into DH systems. If the independent producers offer the same heat price, the heat supplier chooses the heat by following order:

1) from cogeneration units fuelled by renewable energy resources;
2) from non-cogeneration units using renewable energy resources or geothermal energy;
3) waste heat from industry;
4) from efficient cogeneration units;
5) from boiler-houses firing fossil fuel.

The minimum requirements for an independent heat producer to include in the share of his delivery is above 1% of peak demand in heat supply systems, and no less than 1MW. Nevertheless, the heat supply entity is entitled to derogate from this provision and to connect the installations of an independent producer below 1MW to a pipeline system and purchase heat from them.

5.2 The investment support

EC assistance funds are provided to Lithuania through three EU programmes - PHARE, SAPARD and ISPA. Each programme is managed by the relevant ministry, the overall coordination being performed by the Financial Assistance Department in the Ministry of Finance.

Municipalities have good opportunities to incorporate RES schemes into infrastructure development projects (heat supply, energy conservation in municipal buildings, etc.). If included to Special Governmental Programmes, those municipal projects are financed (granted) by so-called Special Donations from State Budget. Municipalities may approve own special programmes for promotion of RES and finance them from their own budget, but practically this opportunity is not financially viable. (Enchancement, 2003)

Private capital enterprises have rather limited possibilities of gaining subsidy support for own business projects in the RES field. As for the objective of energy production from RES, not above 30% of the project might be subsidized from investment programmes of state institutions, municipalities, state bodies (in pursuance with Law on Monitoring of State Aid to Undertakings, 18 May, 2000) if the energy production is intended only for purposes of pollution decrease, i.e. not for energy sale beyond their own consumption. If energy production (like green electricity) is intended for energy sale (own business), the subsidies are not allowed. Nevertheless, a company in the last case will be compensated later through the green electricity purchase tariff which is long-term and maintained by a public service obligation.

Private companies have certain possibilities to incorporate a RES-usage scheme into investment projects planned for the public sector by winning a tender for a technical project, e.g. if a project is to be implemented by ISPA implementing Agency, municipality, etc.

As for investment projects, National Energy Efficiency programme (2001-2005) is intended to finance mainly solar, wind, geothermal and other demonstrational projects. Financing possibilities under this measure are not firm (as funds should be attracted from State Budget, own sources private companies, EU and foreign assistance programmes).

Capital support is provided only for companies registered in Lithuania.

5.3 Future of Geothermal Energy – EU, Lithuania

The grow of geothermal energy use in EU is well in line with expectations of White Paper for period between 1995 and 2001. Future expectation is that the overall contribution of renewable energy to energy consumption in 2020 will be 20% (geothermal part – 0.8%). (Table 9) (Schaefer, 2004)

Table 9. Contribution of RES to total inland consumption – 2020 (Eurostat Convention)

	2000	Targets 2010	Targets 2020
Type of energy	% of total	% of total	% of total
1. Wind	0.13	0.91	2.4
2. Hydro	1.9	1.94	2.1
3. Photovoltaics		0.02	0.2
4. Biomass	3.73	7.96	13.0
5. Geothermal	**0.22**	**0.4**	**0.8**
6. STC	0.02	0.2	1.5
Total Renewable Energies	6.0	11.43	20.0

In Lithuania the targets for year 2010 are such: aprox. 12% in overall consumption and 2.3% for geothermal energy. (Table 10) (National, 2002)

It is very ambitions target for geothermal energy use in Lithuania because in 2004 it's share was approx. 1.6% and in year 2010 the geothermal production must be twice bigger.

Table 10. Possible energy production from indigenous and renewable resources in Lithuania thous. toe

Resources	2000	2010
Wood and wood waste	619.8	795
Peat	11.2	31
Straw	2.5	12
Biogas	1.7	12
Wind	-	13
Solar	0.001	0.2
Geothermal energy	**-**	**23**
Biofuel	-	64
Municipal waste	-	17
Hydro	29.2	40
TOTAL	659.9	1007
% in primary energy balance	9.0	12.0

CONCLUSIONS

1. The geothermal potential of Lithuania was estimated for three regional hydrogeothermal complexes: Cambrian ($5.1x10^{18}$ J), Lower-Middle Devonian ($5.0x10^{18}$ J), Middle-Upper Devonian ($1.5x10^{18}$ J). Petrogeothermal resources were estimated down to 7km depth in Lithuania ($7x10^{21}$ J).

2. The first geothermal investigations in Lithuania initiated in 1987-1989s.

In year 2000 Klaipeda Geothermal Demonstration Plant was built and started producing heat.

3. In spite of all technical problems in period from 2000 to 2004 - Klaipeda Geothermal Demonstration Plant is reliable heat supplier. The lessons learned will be useful for engineering of following geothermal plants in Lithuania.

4. In future geothermal development could be directed to: extension of KGDP by premises for bathing, therapeutic treatment, fish farming; bringing in exploitation of geothermal plant in Vydmantai; realization of project prepared for Vilkaviskis; preparation and implementation projects for Silute, Kretinga, Nida, Silale and other towns and numerous settlements situated in area of the West Lithuanian Geothermal Field. For these activities foreign investment and technology are required.

5. As the result of private activity – it is evident growth in number of small-scale geothermal heat pump installations in Lithuania: in year 2000 - 0.39 MW, in year 2004 - 3.27 MW.

6. External (in EU) and internal (in Lithuania) legal environment for the development of geothermal energy use is favorable.

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Table 1. Present and planned production of electricity.

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2004	-	-	2643	2521	914	742	3000	14014			6557	17277
Under construction in December 2004	-	-	-	-	-	-	-	-				
Funds committed, but not yet under construction in December 2004	-	-	-	-	-	-	-	-				
Total projected use by 2010									170 wind			

Table 2. Utilization of geothermal energy for direct heat (projects; not in operation).

Locality	Type[1)]	Maximum utilization					Capacity[3)] (MWt)	Annual Utilization		
		FlowRate (kg/s)	Temperature (°C)		Enthalpy (kJ/kg)			Ave.Flow (kg/s)	Energy[4)] (TJ/yr)	Capacity Factor[5)]
			Inlet	Outlet	Inlet	Outlet				
Vydmantai	H,G	12.9	72	35	-	-	2	7.1	34.6	0.55
TOTAL							2		34.6	0.55

[1)] H = Space heating & district heating (other than heat pumps); G = Greenhouse and soil heating
[3)] Capacity (MWt) = Max.flow rate (kg/s) [inlet temp. (°C) – outlet temp. (°C)] x 0.004184
[4)] Energy use (TJ/yr) = Ave. flow rate (kg/s) [inlet temp. (°C) – outlet temp. (°C)] x 0.1319
[5)] Capacity factor = [Annual energy use (TJ/yr) x 0.03171]/ Capacity (MWt).

Table 3. Geothermal (ground-source) heat pumps as of 31 December 2004.

Locality	Ground or water temp. (°C)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2)]	COP[3)]	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used (TJ/yr)
Klaipeda GDP	38	4500	4	W	1.78	6512	429
Vilnius	0	12	8	H	4	4000	1.037
Vilnius	0	10	7	H	4	4000	0.756
Kaunas	0	10	1	H	4	4000	0.108
Klaipeda	0	10	2	H	4	4000	0.216
Taurage	2	10	2	H	4.2	4000	0.219
Alytus	0	9	1	H	4	4000	0.097
Vilniaus reg.	0	18	1	H	3.4	2800	0.128
Vilniaus reg.	0	10.5	2	H	4.59	2700	0.160
Vilniaus reg.	0	18	8	H	4.42	2800	1.123
Vilniaus reg.	8	18	2	W	4.6	2700	0.273
Vilniaus reg.	8	25	2	W	4.8	2800	0.399
Vilniaus reg.	8	28	5	W	4.8	2800	1.117
Vilniaus reg.	8	38	1	W	4.8	3000	0.325
Vilniaus reg.	8	45	6	W	4.8	2900	2.231
Vilniaus reg.	0	45	3	H	4.4	2800	1.052
Vilniaus reg.	0	4.5	3	H	3.8	2700	0.097
Vilniaus reg.	0	6.0	2	H	4.2	2800	0.092
Vilniaus reg.	0	7.5	17	H	4.6	2800	1.006
Vilniaus reg.	0	10.5	23	H	4.6	2800	1.905
Vilniaus reg.	0	15.5	25	H	4.6	2800	3.057
Vilniaus reg.	8	15.5	5	W	5.4	2700	0.613
Vilniaus reg.	0	7.5	3	H	4.6	2800	0.177
Vilniaus reg.	2	10.5	4	V	4.4	2800	0.327
Vilniaus reg.	0	8	3	H	4.8	2800	0.192
Vilniaus reg.	2	8	3	V	4.7	2800	0.190
Vilniaus reg.	0	12	6	H	4.8	2800	0.575
Vilniaus reg.	0	16	3	H	4.8	3000	0.410
Bijutiskis	6	40	1	W	4	1800	0.194
Grigiskes	6	40	1	W	4.2	1800	0.197
Vilnius	4	10	4	H	4	1800	0.194
Vilnius	4	16	2	H	4	1800	0.156
Vilnius	4	20	2	H	4	1800	0.194
Kaunas	4	10	3	H	4	1800	0.146
Kaunas	4	16	3	H	4	1800	0.233
Kaunas	4	20	1	H	4	1800	0.097
Vilnius	7	42	1	W	3.5	4656	0.503
Vilnius	10	20	3	W	3.6	4656	0.726
Vilnius	10	6.7	4	W	3.5	4656	0.321
Vilnius	8	20	1	W	3.6	4656	0.242
Klaipeda	7	15.5	1	W	3.3	4656	0.181
Vilnius	7	8.4	1	W	3.5	4656	0.101
Kaisiadorys	7	42	1	W	3.5	4656	0.503
Vilnius	8	5.3	1	W	4.08	4656	0.067
Vilnius	9	20	2	W	3.84	4656	0.496
Vilnius	-1	19	2	H	3.51	4656	0.455
Vilnius	7	12.6	1	W	3.64	4656	0.153
Vilnius	8	24.6	1	W	3.86	4656	0.306
Vilnius	8	12.6	1	W	3.56	4656	0.152
Vilnius	-1	15	1	H	3.51	4656	0.180
Vilnius	7	42	1	W	3.64	4656	0.510
Vilnius	8	16.9	1	W	3.77	4656	0.208
Sum							453.40
In period till 2000:	Installed capacity – 0.39MW, number of units - 27						4.55
TOTAL							**457.95**

This table should separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used report thermal energy used (i.e. energy removed from the ground or water) and report to calculate carbon offsets.
Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps Report type of installation as follows: (TJ = 10^{12} J)
V = vertical ground coupled; H = horizontal ground coupled; W = water source (well or lake water); O = others (please describe)

Report the COP = (output thermal energy/input energy of compressor) for your climate
Report the equivalent full load operating hours per year, or = capacity factor x 8760
Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr
Note: please report all numbers to three significant figures

Table 4. Summary table of geothermal direct heat uses as of 31 December 2004.

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Subtotal			
Geothermal Heat Pumps:			
- small (total)	3.27	28.95	0.281
- big	18	429	0.756
TOTAL	21.27	457.95	

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001
[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154
[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year.
Note: please report all numbers to three significant figures.
[4] Other than heat pumps
[5] Includes drying or dehydration of grains, fruits and vegetables
[6] Excludes agricultural drying and dehydration
[7] Includes balneology

Table 5. Allocation of professional personnel to geothermal activities (Restricted to personnel with University degrees).

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2000	1	11	6	-	5	6
2001	1	12	6	-	5	6
2002	3	13	6	-	5	6
2003	3	13	6	-	5	8
2004	3	13	6	-	5	8
Total	11	62	30	-	25	34

Table 6. Total investments in geothermal in geothermal in (2004) US$.

Period	Research & Development Incl. Surface Explor. & Exploration Drilling Million US$	Field Development Including Production Drilling & Surface Equipment Million US$	Utilization		Funding Type	
			Direct Million US$	Electrical Million US$	Private %	Public %
1990-1994	2.03	-	-	-	-	100
1995-1999	0.035	19.23	19.3	-	0.3	99.7
2000-2004		1.03	2.97	-	45.6	54.4

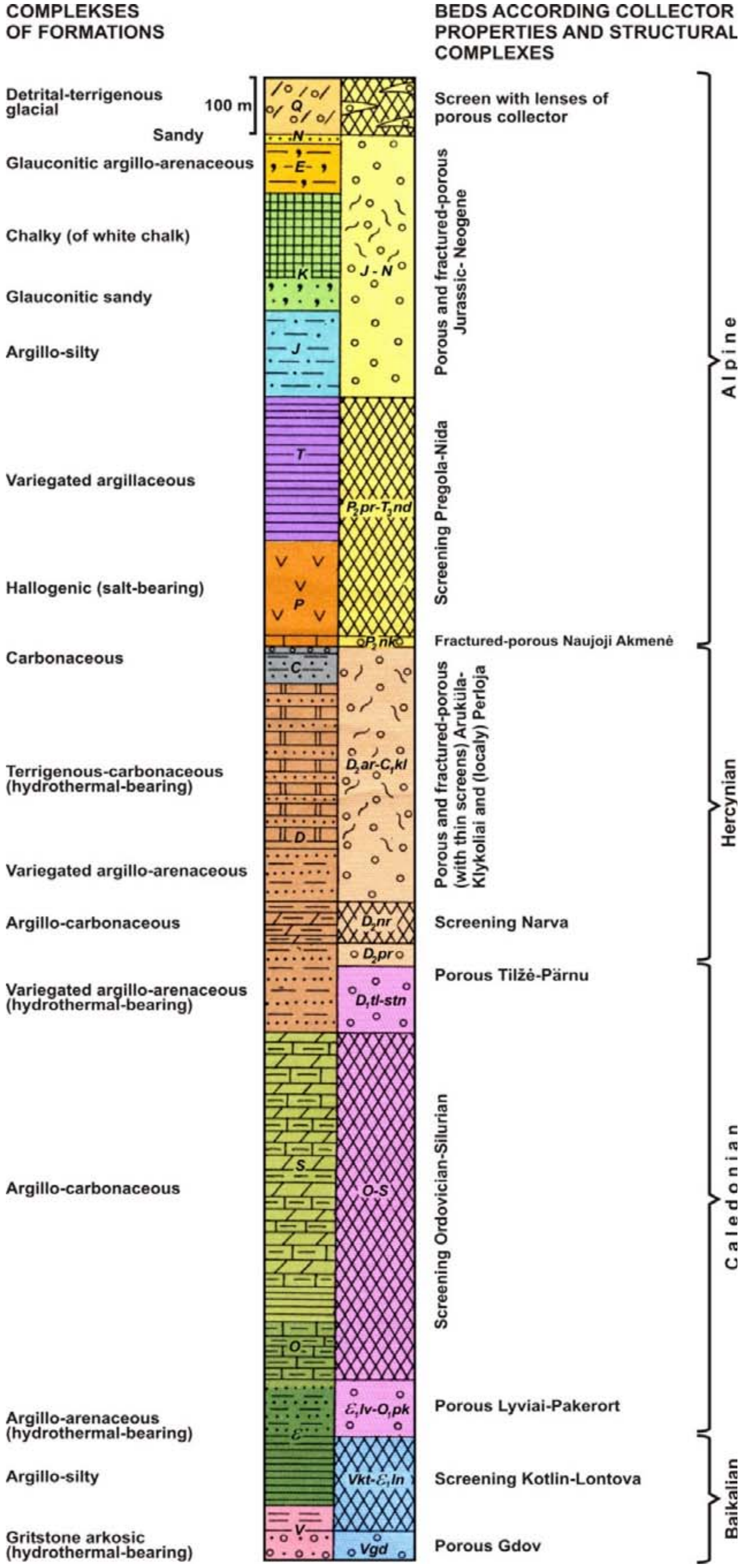
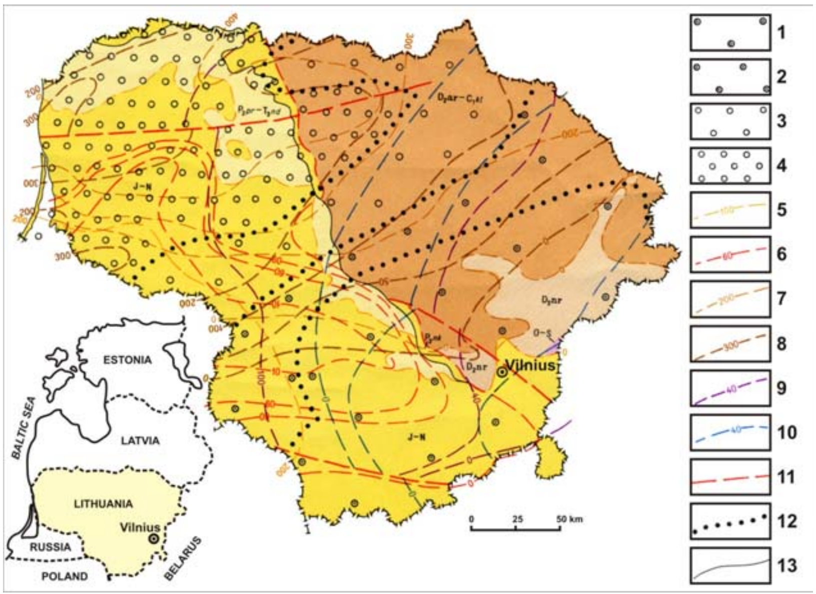
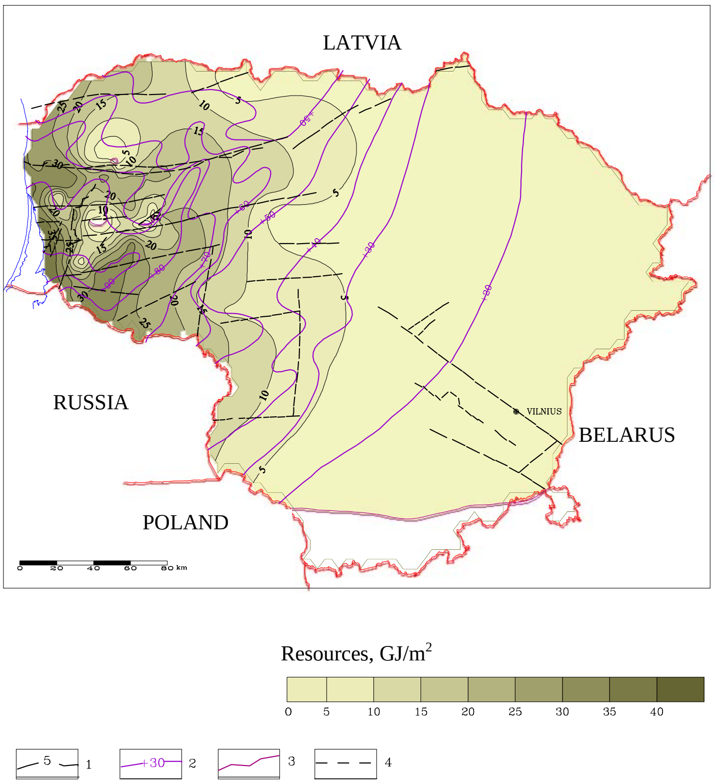


Figure 3: Summary geological formations section of sedimentary cover of Lithuania.



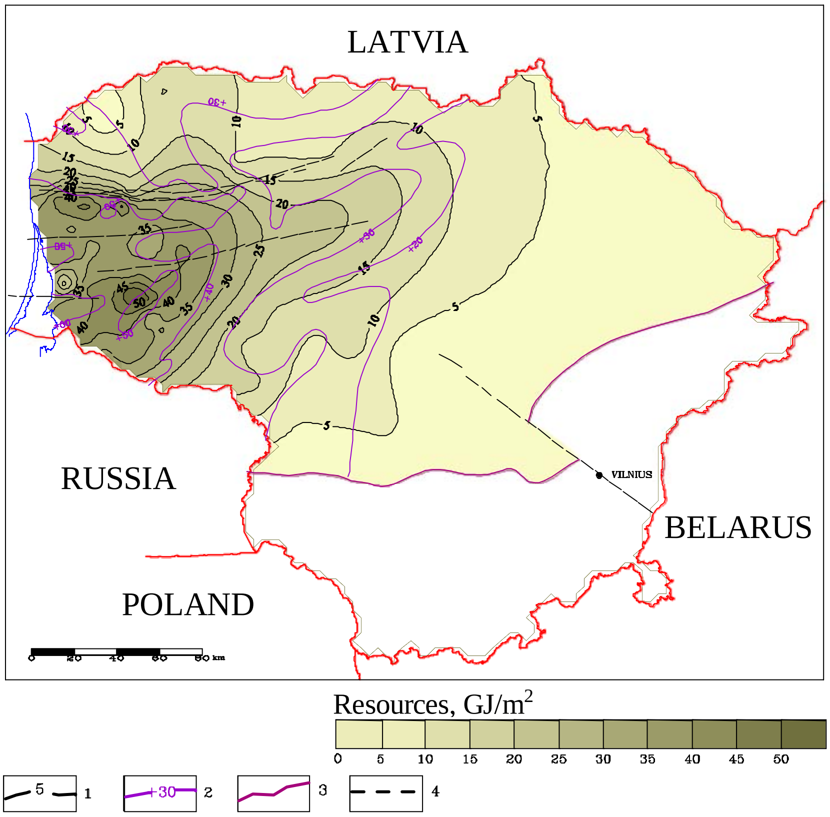
Total thickness, m:1– 0-200; 2 – 200-400; 3 – 400-600; 4 – >600. Isopachytes: 5–Jurassic-Neogene (J-N); 6–Upper Permian (P2nk); 7–Middle-Devonian-Lower Carboniferous (D2ar-C1kl); 8–Lower Devonian-Middle Devonian (D1tl-D2pr); 9–Lower Cambrian-Lower Ordovician; 10–Vendian. 11–faults; 12–bondaries of zonation; 13–geologic boundaries.

Figure 4: Map of development of the main permeable beds in the sedimentary cover of Lithuania.



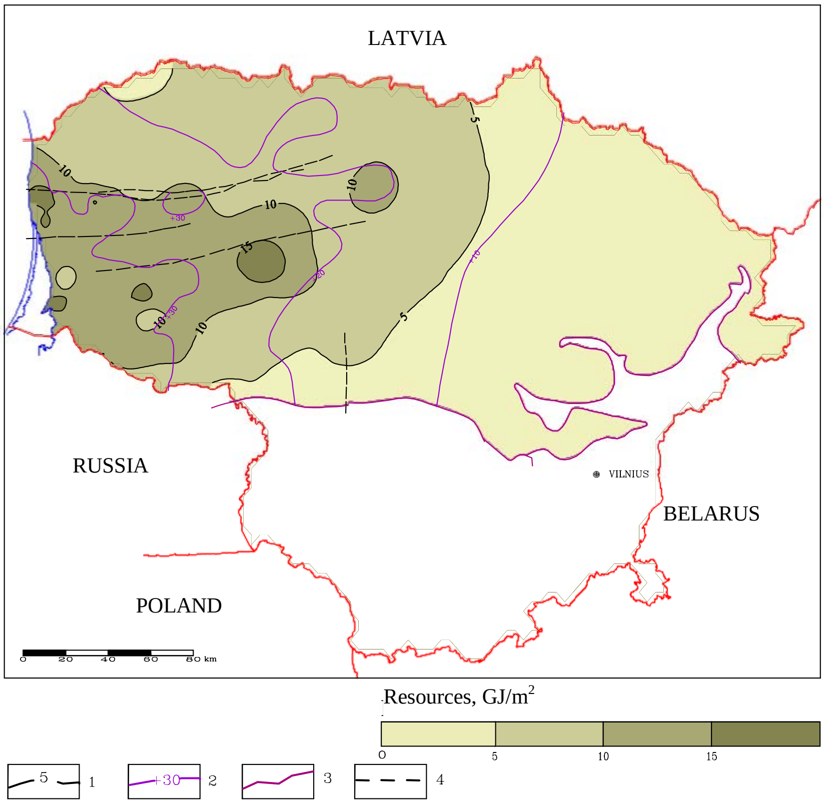
1 – isolines of resources density; 2 – hydroisotherms of the top of O–Є complex; 3 – present border of Cambrian rocks spreading; 4 – tectonic faults.

Figure 5: Geothermal resources density and temperature map of Ordovician-Cambrian hydrogeothermal complex.



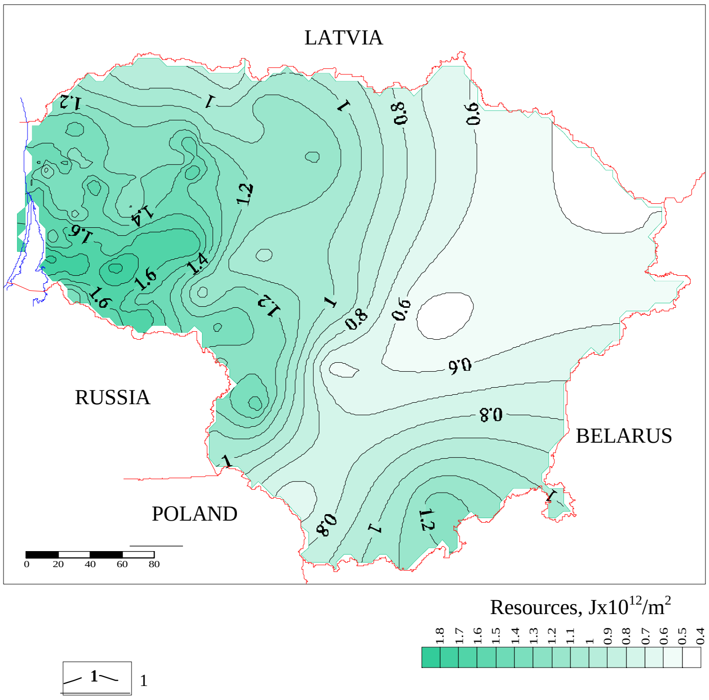
1 – isolines of resources density; 2 – hydroisotherms of the bottom of D2pr–D1tl complex; 3 – present border of D2pr–D1tl rocks spreading; 4 – tectonic faults.

Figure 6: Geothermal resources density and temperature map of Middle–Lower Devonian hydrogeothermal complex.



1 – isolines of resources density; 2 – hydroisotherms of the bottom of D3sv–D2up complex; 3 – present border of D3sv–D2up rocks spreading; 4 – tectonic faults.

Figure 7: Geothermal resources density and temperature map of Upper–Middle Devonian hydrogeothermal complex.



1 – isolines of resources density;

Figure 8: Map of petrogeothermal resources density (resource base) of Lithuania down to 7 km.

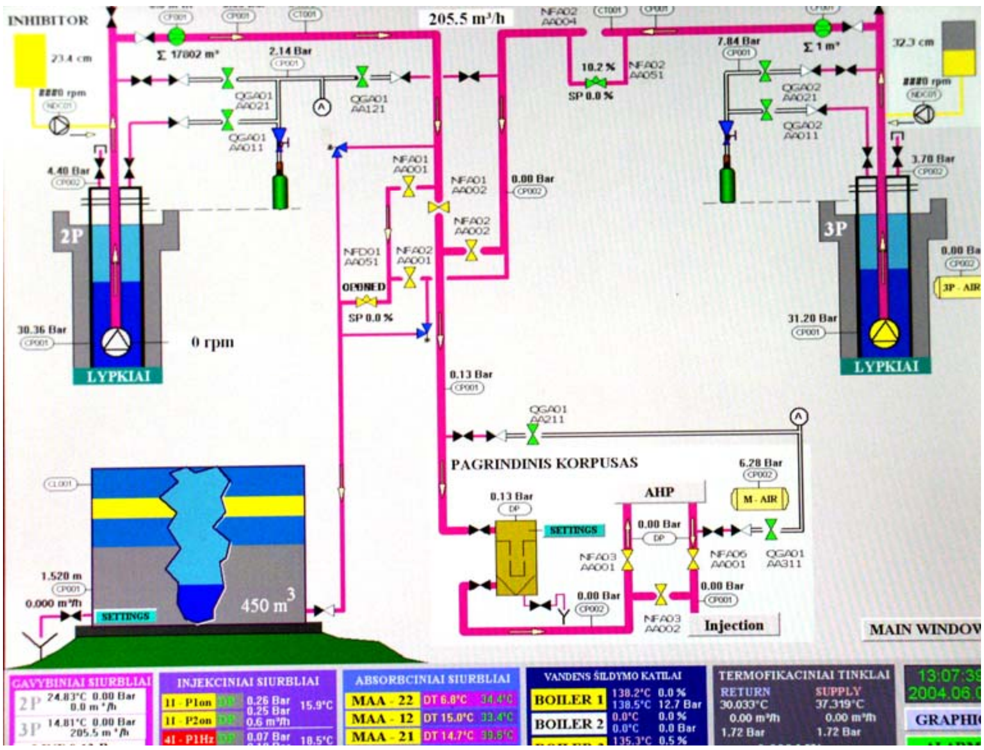


Figure 11: Inhibitors injection system in KGDP.