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Potential of geothermal energy and possibilities of its employment in Lithuania

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ABSTRACT

Lithuania is a country with an area of 65 300 sq **km** and 3 71 million population (1998) The average yearly, January and July temperatures are 6.7°C, –4.9°C, and 17°C, correspondingly Space heating of houses is therefore needful from October to April The annual final energy consumption **in** Lithuarua **is** 51 5 GJ per capita (1997) Lithuania **is** located at the western margin of the East European Preriphean Craton with a high potential of geothermal energy

KEYWORDS

Geothermal resources, hydrogeothermal complex, Devonian, Cambrian, Lithuania

Introduction

During last years significant positive changes continue to take place in the economy and in its main branch – energy sector of the country. Thus, the annual increase of the General Domestic Product (GDP) rose from 3% to 6% in 1995-1997. While economy growth rates are high, final energy demand in the economy of the country decreases constantly. It diminished by 5% in 1995-1997, under prevailing influence of economy restructuring.

Positive changes continue **in** management of energy sector in its restructuring and privatization. Thus, in 1997 district heating facilities and some central heating plants were transferred from Joint Stock Company Lithuanian Energy ownership to city municipalities.

Optimal conditions for utilization of the geothermal energy are found to be in the western regions of Lithuania in the coastal area of the Baltic Sea. These conditions can be characterized by three basic parameters: geothermal gradient, heat flow density and resources density. In West Lithuania maximum values of geothermal gradient exceed 5°C per 100 m and heat flow density reaches >90 mW/m^2. The resources density is greatly varying.

In the area of the West Lithuanian Geothermal Field several towns and numerous settlements are situated. They are potential consumers of the Earth's energy.

In West Lithuania hot groundwater can be used for municipal heating systems from three hydrogeothermal complexes: i.e. Upper and Middle Devonian, Middle and Lower Devonian and Cambrian. Moreover, heat can be extracted from hot waterless rocks of crystalline basement called "the petrogeothermal massif' (SUVEIZDIS at al. **1993;** SUVEIZDIS et al. 1995, JUODKAZIS et al. 1997).

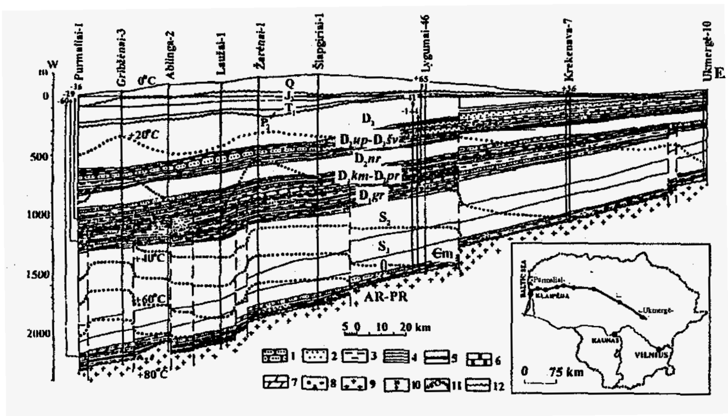

Figure 1 :Hydrogeothermal profile going from the well Purmaliai-1 to Ukmerge-1
1-sandstone; 2-sand; 3-aleurolite; 4-argillite; 5-ferruginous aleurolite; 6-dolomite 7-marl; 8-breccia: 9-rocks of crystalline basement; 10-piezometric level; 11-geoisotherm; 12-stratigraphic discordant

Potential geothermal resources

The country is rich in geothermal energy of low enthalpy. **A** temperature at the bottom of sedimentary cover exceeds +90°C in West Lithuania. The aquifers defined in the sedimentary cover are potential sources for geothermal energy. There are three hydrogeothermal complexes in the Baltic artesian basin: Upper/Middle Devonian – nearest to the surface, Middle/Lower Devonian – below the latter, and Cambrian – the deepest one.

Hydrogeological stratification data show that there are Upper/Middle Devonian, Middle/Lower Devonian and Ordovician/Cambrian water-bearing complexes. These complexes are separated from each other by practically impermeable aquicludes and make up independent, hydraulically separate aquifers. Therefore, composition and temperature of heat carrier (groundwater), as well as thermal resources are evaluated without taking into account hydrodynamic interaction of the above mentioned systems. Such interaction takes place only in the zones of tectonic fractures (fig.1).

The Upper/Middle Devonian water-bearing hydrogeothermal complex

The Upper/Middle Devonian hydrogeothermal complex (U/MDC) is composed of similar terrigenous deposits: sand, weakly cemented sandstone, aleurolite and clay.

Their total thickness ranges from 170 to 200 m. The occurrence of this complex is different, with the nearest distance to the surface in East Lithuania it is deepening south-westwards from –100 to –600 m (absolute height). The profile is slightly complicated by largest tectonic fractures. The complex is most greatly affected tectonically in the southern part of Lithuania, where its thickness decreases and rocks are wedging out.

The porosity makes up from 17.7 to 30.0%, the permeability ranges from 435 to 2895 mD.

The highest temperature is +35.5°C at the roof and +37°C at the foot. The U/MDC is a constituent part **of** the Baltic artesian basin; therefore groundwater is confined here. In Stoniškiai well hydraulic test was done in the perforated column in the range from 645 to 680 m. After the perforation, water fountain sprang from the well and reached 14 m height over the well opening. The discharge was 864 cub. m/d. Water is of calcium chloride type with excreting gases. Water mineralization is 27.3 g/l, specific weight 1.02 g/cm^3, temperature +30°C. Contents of dissolved salts (in %) are as follows: NaCl 8.6, $CaCl_2$ 8.4, $MgCl_2$ 1.1, $CaSO_4$ 11.3, NaBr 0.2, $Ca(HCO_3)$ 0.4.

The Middle/Lower Devonian water-bearing hydrogeothermal complex

The Middle/Lower Devonian complex (MLDC) is stratigraphically rather large in size. The thickness of this hydrogeothermal complex in West Lithuania exceeds 400 m **in** some places. However, usually, the thickness varies from the 200 to 300 m. MLDC is composed of similar terrigenous deposits: sandstone, aleurolite and argillite. This complex is affected by tectonics: there is a large number of tectonic fractures cutting the complex or complicating it by flexures.

The depths of occurrence in Central and West Lithuania are from 200 to 500 and from 600 to 900 m below sea level, correspondingly.

Collecting features of rocks are investigated only in the western part of Lithuania, whereas the eastern part remains unexplored, although the latter is characteristic of higher sand content in the sections. The porosity makes up 8 to 30%; the permeability is 145 to 1000mD. The discharge was 807 to 1226 m^3/d.

The wells having temperature measurements with one of the roof exceeding +20°C have been analysed. In the wells drilled in the maritime area (near to the Baltic Sea); the roof temperature exceeds +40°C, and at the foot of Lower Devonian it even exceeds +50°C. The highest temperatures were found from +46.5°C at the roof and +57°C at the foot.

Water mineralization is varying in the lower part of the complex from 10.8 g/l and 11.1 g/l to 109.8 g/l and 110 g/l. In the upper part it ranges from 6.6 g/l to 85.4 g/l.

Water of this complex is of calcium chloride type.

The Cambrian water-bearing hydrogeothermal complex

The Middle and Lower Cambrian complex is reaching 40 m in the eastern part and 170 m in the western part.

In West Lithuania this hydrogeothermal complex consists of rocks belonging to the Deimena series and Kybartai horizon of Middle Cambrian, with lower occurring layers of Virbalis and Gege of Lower Cambrian. All their sections are composed of sandy and aleuritic deposits. In Central and East Lithuania its upper part becomes thinner and total thickness smaller.

Occurrence depth ranges from –600 m in the east to –2300 m in the west. Conditions of occurrence are complicated by tectonic fractures, mainly normal faults. Only in the western part, the thrust faults are found, resulting repetition of the Cambrian section in the well. Quartz sandstone with scarce aleurolite or aleurolitic clay interlayers prevail in the section of the Deimena series. Eastwards and northwards, the quartzification disappears.

Open porosity increases westwards from 6.5% to 19.6%. Low values of mean porosity (10%) are thought to be related less to primary sedimentation conditions, hut more to diagenesis causing sandstone quartzification, which is especially often in the upper part of the Deimena series – the oil-bearing horizon. Maximum permeability is determined to be 1100 mD. In all other cases, it varies from 3.5 to 380 mD

Water discharges obtained during hydraulic tests in South and Central Lithuania are rather high. Lower discharges were obtained in West Lithuania, where the results were obtained from oil-prospecting wells investigated for one or two ranges of Cambrian. As for the thermal resources, all the efficient ranges of Cambrian can be used.

Temperature was measured only as part of geological studies. The best results were obtained in West Lithuania. The Cambrian roof temperature reached +99.4°C (2301 m). The entrails with temperatures over +80°C were determined in the Kuršiai depression – on the Baltic Sea coast.

In general, Cambrian water mineralization varies from 109 to 203 g/l.

Heat flow density

Data available show a wide range of heat flow from <40 to >90 mW/m^2 (ZUI & URBAN 1986). West Lithuanian geothermal anomaly is characterised by highest heat flow from 60 to >90 mW/m^2 (fig.2).

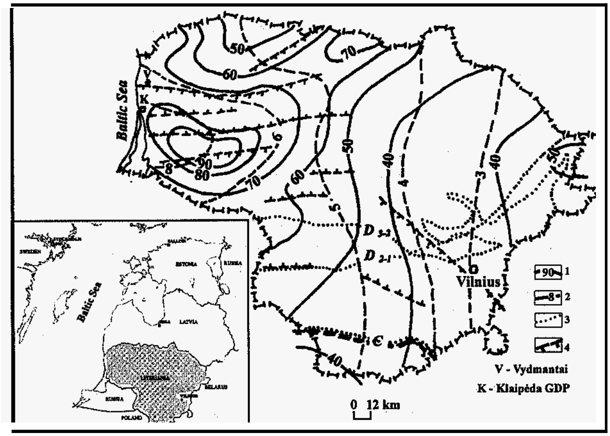

Figure 2 : Heat flow and prognostic petrogeothermal resources of Lithuania 1-heat flow density (mW/m^2), 2-resources density (tCF/m^2); 3-area extent line of the complex; 4-fractures

Thermal resources	Density of resources, CF*t/m^2	Area, km^2	Quantity of resources, million. tons CF*
Hydrogeothermal	<0.2 - >2.0	42444	26.9x10^3
Petrogeothermal	<3.0 - >8.0	65300	298.5x10^3

Direct use of geothermal energy

Geothermal water in a temperature range of 25°C to 50°C can be used in district heating systems with such main equipment as primary heat exchanger, heat pump, and boiler plant **for** any additional heating.

In 1989 the drilling of the first geothermal well Vydmantai-1 (the deepest one in Lithuania, its depth is 2564 m) for installation of experimental geothermal circulation system, using hot water from the Cambrian hydrogeothermal complex, was started. In 1993 the drilling of the injection well Vydmantai-2 was finished. The productive Cambrian horizon was tested. The temperature of water was ~+74°C. A technical – economic estimate for both Cambrian and Devonian aquifer systems has also been prepared. Reservoir properties were rather problematic. The wells were closed because of lack of investments. According to the estimation by the German company Geothermie Neubrandenburg GmbH, 2.3 mln. USD must be invested for the establishment of this 7.5 *MW* plant (2.0 *MW* – geothermal part). In the meantime the municipality of Kretinga district and company UAB Vydmantu Šiluma took an interest in these wells; it is now making efforts to find financing and start operation of the plant.

When Baltic geothermal project financed by Danish Environmental Protection Agency (DEPA) was finished, the city of Klaipeda was selected for construction of geothermal demonstration plant (KGDP) (Tab.2).

Locality	Type[1]	Maximum utilization					Capacity[2]	Annual Utilization		
		FlowRate (kg/s)	Temperature (°C)		Enthalpy (kJ/kg)			Ave.Flow	Energy[3]	Capacity
			Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[4]
Klaipeda	H	185	38	11	-	-	20.9	154	550	0.83
TOTAL							22.9		585	0.81

The KGDP is built by company UAB Geoterma (Vilnius) under assistance of Dansk Olie & Naturgas A/S in co-operation with Houe & Olsen, PGI and Lithuanian experts. The plant comprises a geothermal loop with four 1.2 km deep wells already drilled to Devonian and a heat pump plant with absorption heat pumps driven by steam from boilers (MAHLER 1998). In 2000 the plant will supply heat to the district heating network of Klaipeda.

This project is financed by Global Environmental Protection Fund (non-repayable loan 6.9 mln. USD), Danish Government (2.5 mln. USD), ES PHARE (0.1 mln. USD), the Government of Lithuania (2.6 mln. USD) and the World Bank (loan 5.9 mln.USD). It will reduce annual CO_2 emissions by an estimated 56 000 tons, moreover, it will significantly reduce SO_2 and NO, emissions too.

The market economy opened paths to private initiative and brought innovations into the sector of energetic. In Vilnius and Klaipeda cities already some autonomous geothermal systems function in private sector (Tab.3). Here groundwater of low temperature (+8 to +12°C) from the depths of 30-60 m, or ground heat (~0°C) is used with temperature risen to the needs of consumer (+40 to +55°C) by means of heat pumps. The individual geothermal system is installed in Vilnius for the first time in 1996.

Table 3: Geothermal (ground-source) heat pumps (in operation)

Locality	Ground or water temp. (°C)	Typical Heat Pump Rating or Capacity (kW)	Numbe of Units	Type of installation[1)]	COP[2)]	Equivalent Full Load Hr/Year[3)]	Thermal Energy Used (TJ/yr= 10^{12}J/yr)[4)]
Klaipeda"A"	8	12	1	W	3.3	3694	0.111
Klaipeda"B"	0	12	1	H	3.3	4148	0.125
Klaipeda"R"	8	43.1	4	W	4.2	1330	0.157
Vilnius"I"	12	15	1	W	3.3	4187	0.158
Vilnius"L"	8	15	1	W	3.3	3756	0.141
Vilnius"Y"	8	17	1	W	3.2	2034	0.086
TOTAL		141.1	9				0.778

1) H = horizontal ground coupled W = water source (well or lake water)

2) Coefficient of performance

3) Report the equivalent full load operatmg hours per year, or = capacity factor x 8760

4) Thermal energy (kJ/yr = flow rate in loop (l/s) [(inlet temp (°C) – outlet temp. (°C)] x 0 1319 or = rated output energy (kJ/hr) x [(COP – 1)/COP] x equivalent full load hours/yr

Exploration activities

The expedient investigations of geothermal energy assigned to its use for heating purposes began in 1987. In the Institute of Geology the geologic and technical-economic conditions of the Cambrian and Devonian aquifers, as well as a reservoir in the crystalline basement, were evaluated for beating of seven towns in Western Lithuania. In 1990 the geologic and technical-economic conditions of beating of Palanga town, taking hot water from an artificial reservoir installed in the rocks of crystalline basement at a depth of 4.5 km, were evaluated (DYADKIN 1992).

The Danish Company Petroleum Geology Investigators in 1992 began the initial stage studies according to the Baltic geothermal project on the possibility of using geothermal energy in the towns of Latvia and Lithuania.

In 1995 the German Company Geothermie Neubrandenburg GmbH started implementation of three projects: Vydmantai, Vilkaviškis spa and Šilute. In the site of Vilkaviškis, the expected thermal water temperature from Cambrian system in a depth 1200 m is 47°C, with the rate of delivery of 100 m^3/h and mineralisation of 127 g/l. The capacity of plant is 30.2 MW (geothermal part 6.1 MW), the costs of heat generation equal to 0.021 USD/kWh.

In 1996 the GFZ Potsdam checked up the technical condition of Vydmantai wells, measured temperature, and sampled deep Cambrian water. The GFZ Potsdam together with partners from Germany, Lithuania and Holland prepared the project for reviving of the Vydmantai object.

In the field of geothermal investigations the general methods of geologic, laboratory, geophysics and of mathematical modelling were applied.

The works, mentioned above, were not assigned to geothermal investigations.

At present in the Institute of Geology only one scientific research associate is financed from the State budget. The State Science and Studies Foundation also gives a support to geothermal investigations. This financing does not allow to carry out any field and laboratory studies. In 1991 in Lithuania the Geoterma State Enterprise with 6 employees supported by the State was established. Realization of geothermal projects is the main field of the Geoterma activity.

Future activities

On the base of geothermal potential in Lithuania, in our opinion, the heat pumps are highly prospective; the individual and centralized consumers may install them to take heat from shallow aquifers or solid rocks.

The Geological Survey of Norway together with the Geological Survey of Lithuania and other institutions are planning realization of such demonstration projects in the future, under the financial support by the Government of Norway. Denmark and Germany has already given the financial-technical support for geothermal investigations in Lithuania.

In 1995 the Institute of Geology together with the Mining Institute from Sankt Petersburg have assessed possibility to provide Klaipeda city with electric energy to be taken from Hot Dry Rock (depth 4.1 km, temperature 145°C, discharge 100 kg/s). It is the project, we ought to return to and suggest to international experts to evaluate it.

To expand use of geothermal energy in Lithuania, much must be done at the governmental level, e.g.: the price of electric energy to users of geothermal heat pump should be reduced, favorable credits for purchase of heat pumps and other energy efficient equipment given, some taxes diminished.

The geothermal investigations will reach highest level and become more active, when the Klaipeda geothermal demonstration project begins its functioning.

Sustainable energy policy

The potential integration of Lithuania into EU, joining the nature protection programmes and the market economy opened ways for investigations and use of sustainable energy, including the geothermal one. In the Programme (LITHUANIAN MINISTRY OF ENERGY 1996) the sustainable energy should make up 17.7% in the total energy balance of Lithuania.

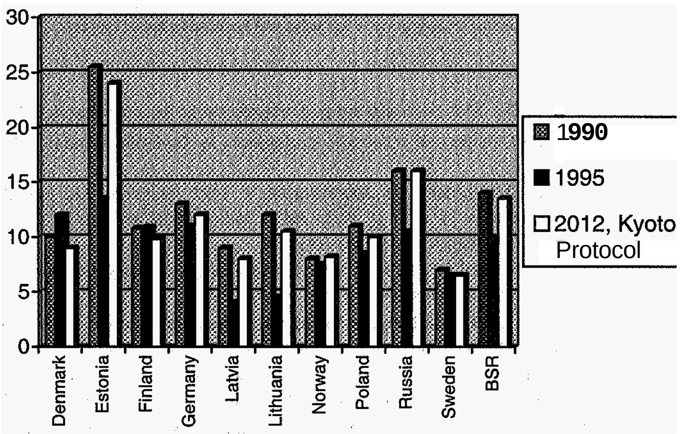

Figure 3: Emission of CO_2 per capita (ton CO_2/capita) in the Baltic Sea Region

Lithuania is quite clean country (fig.3), but according to the Kyoto Protocol it had agreed to reduce emission of greenhouse gases by 8% during the period from 2008 to **2012** (on average) compared to the 1990 level (BALTIC **21-ENERGY** 1998).

This decision gives good possibilities of geothermal energy in Lithuania.

Conclusions

The potential **of** geothermal energy in Lithuania stored in sedimentary strata and crystalline basement indicates its exceptional geologic situation in the East European Craton. In connection with it, the experimental systems of closed circulation (Klaipeda and others) are created; the low temperature geothermal energy is started to be used by applying heat pumps. In perspective for more successful solution of economy problems, the wider use of geothermal energy is possible.

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