

## Lithuania – Geothermal Energy Country Update

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### ABSTRACT

Lithuania is situated in the eastern part of the Baltic sedimentary basin overlying the western margin of the East European Craton of the Early Precambrian consolidation. The basin contains all Phanerozoic systems. The thickness of the sedimentary pile is 200 m in southeast Lithuania and 2300 m in west Lithuania.

The new maps of the potential of the major aquifers were compiled for Lithuania. The maps are prepared for applied use and indicate the heat energy capacity of the duplet of wells (MW). They are based on the detailed assessment of the reservoir properties and temperatures of the aquifers. The highest potential was estimated for the Lower Devonian aquifer. Its capacity is in the range of 2-10 MW (wells duplet) in west Lithuania. The average depth of the aquifer is 1 km. The Cambrian aquifer has lower capacity, the geothermal potential of wells duplet is in the range of 1.5-3.5 MW, the depth ranging from 1.5 to 2 km. Also the possibilities of electricity production using HDR are investigated.

Klaipeda Geothermal Demonstration Plant was built in 2000 and started producing heat. On June 2004 State Commission confirmed it's capacity of 35 MW (geothermal part 13,6 MW). Due to decrease of injecting capacity in wells the plant was stopped for repair in 2007. Now plant is on operation again. Since 1996 geothermal small-scale heat pump systems for heating at single-family houses are under installation in Lithuania (total capacity more than 30 MW).

### 1. INTRODUCTION

Lithuania's gross domestic product (GDP) was positive till year 2009 (7,8% in 2005; 7,8% in 2006; 8,9% in 2007; 3,0% in 2008).

In year 2006 contribution of RES and indigenous resources to Primary energy balance was 11,4%, natural gas-28,5%, imported oil and oil products – 29,1%, nuclear fuel – 25,8%, local oil – 2,1%, coal – 3,0%. (Fig.1) (National, 2008).

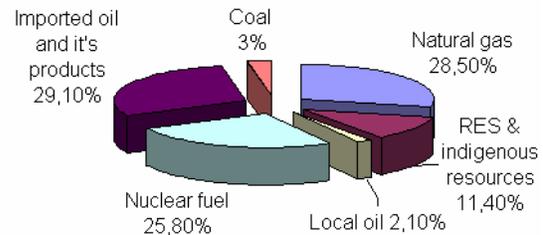


Figure 1: The structure of Primary energy balance in year 2006.

### 2. GEOLOGICAL SETTING AND GEOTHERMAL POTENTIAL

Lithuania is situated in the eastern part of the Baltic sedimentary basin overlying the western margin of the East European Craton of the Early Precambrian consolidation (Fig.2).

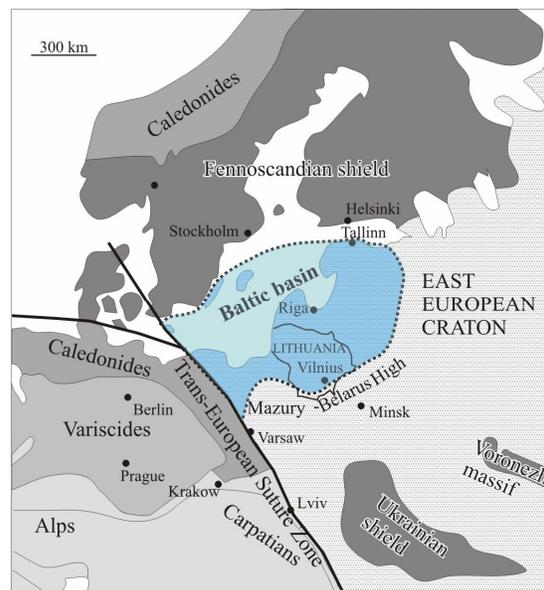


Figure 2: Geological setting of Baltic sedimentary basin.

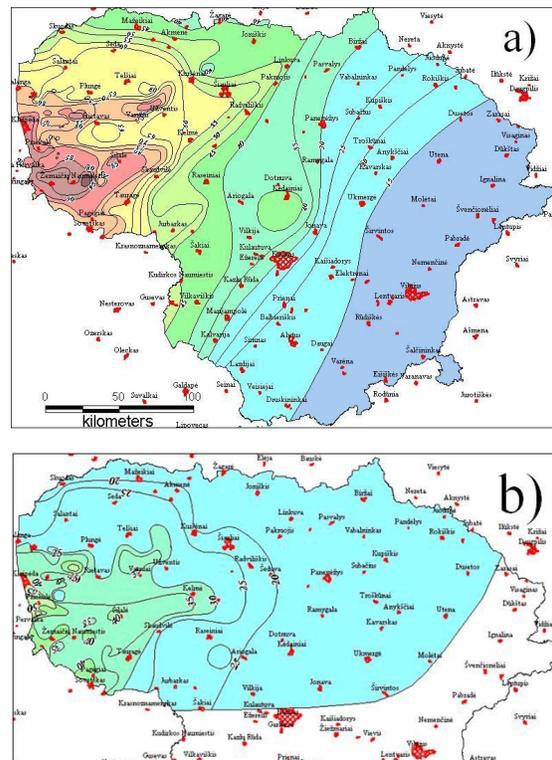
The basin contains a number of potential geothermal aquifers. The Cambrian aquifer is composed of quartz sandstones with rare siltstones, and shales. The thickness of the Cambrian aquifer is up to 60-80 m. The Cambrian is overlain by a 800-1000 m thick Ordovician-Silurian shaly-carbonaceous aquitard. The composition of Devonian sediments, reaching 1100 m in thickness, is variable, the marly/carbonaceous packages alternating with sandy packages. The major aquifers are the Lower Devonian and Middle Devonian sandstones of up to respectively 160 m and 220 m thick. They are composed of quartz and –feldspar-quartz sandstones with subordinate shales and siltstones. Those aquifers can be used for the district heating. The other aquifers are of much smaller thickness and are of low geothermal potential. They can be used for only ground heat pumps.

### 2.1. Parameters of major geothermal aquifers

Cambrian sandstones show regional trend of decreasing of porosity and permeability to the west that associates with increasing burial depth. A gradual decrease of the porosity from average 25% to 16% is reported at depths interval of 400-1800 m. At depths greater than about 1800 m a sharp reduction of pore space from 16% to average 5% is identified. The gas permeability at depths of 400-1800 m is around 0.5-1 D. It sharply decreases from 10-1 D to 10<sup>-5</sup> D below the depth of 1800 m. The decrease in the reservoir properties to the west is basically controlled by increasing late diagenetic quartz cementation. The water salinity ranges from 0,5 g/l in southeasternmost Lithuania to 200 g/l in west Lithuania. Due to considerable changes in depth, the temperature of the aquifer changes from 15°C in the east to 70-90°C in west Lithuania (Fig.3). A prospective area for district heating, exceeding 30°C, encompasses central and west Lithuania.

The Lower Devonian geothermal aquifer is composed of quartz and quartz with feldspar fine-grained sandstones. They contain siltstone and shaly layers that compose 30-40% of the succession. The average porosity of sandstones is 26%, the permeability is in the range of 0.5-4 D. The salinity of the formation water ranges from 0.2-0.5 g/l in the shallow basin periphery in the east to 40-90 g/l in deep part of the basin. Temperatures exceeding 30°C are encountered in west Lithuania. The maximum temperature is 45°C.

The Middle Devonian geothermal aquifer has similar parameters. It is composed of quartz and quartz with feldspar fine-grained sandstones with subordinate siltstone and shaly layers that compose 30-40% of the succession. The average porosity of sandstones is 28%, the permeability is in the range of 0.5-4 D. The salinity of the formation water changes from 0.2-0.5 g/l in the east to 10-20 g/l in west Lithuania. Temperatures exceeding 30°C are distributed in only westernmost Lithuania. The maximum temperature is 32°C.



**Figure 3: Temperatures of Cambrian (a) and Lower Devonian (b) aquifers. Contour lines show temperature °C.**

### 2.2. Re-evaluation of geothermal potential of west Lithuania

As mentioned above, the western part of Lithuania is characterized by anomalous heat flow that is the most intense in a whole East European craton. It provides favorable conditions for utilization of the earth's heat for district heating. So far only one geothermal district heating station of Klaipeda is operating in Lithuania.

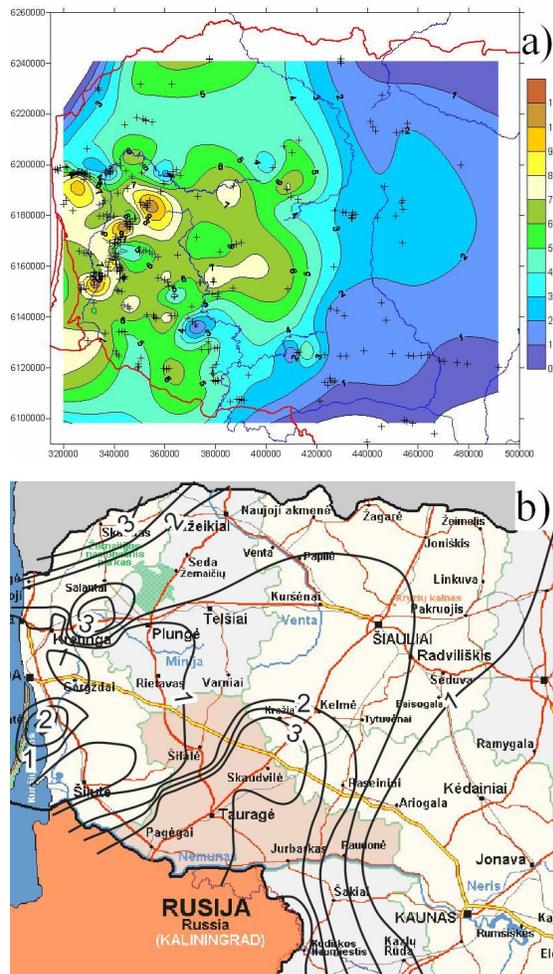
Three large geothermal aquifers are defined in the sedimentary section of west and middle Lithuania. The Cambrian lower aquifer occurs at the depth of about 2 km in west Lithuania. The temperature ranges from 70°C to 90°C. The thickness is of 50-70 m. It is composed of quartz sandstones. Due to intense diagenetic quartz cementation the reservoir properties are rather poor. Accordingly, the well production ranges from 20 to 80 m<sup>3</sup>/h.

The Lower Devonian geothermal aquifer is of about 1 km deep, the temperature ranges from 30°C to 45°C. The thickness is 100-150 m. The aquifer is composed of friable sandstone that has high reservoir properties resulting in large production of wells exceeding 250 m<sup>3</sup>/h.

The Middle Devonian geothermal aquifer is similar in terms of composition and productivity to the Lower Devonian sandstones, except the lower temperature in the range of 23-30°C.

A new approach was accepted to calculate the potential of geothermal aquifers (Fig.4). Instead of calculating the theoretical geothermal recourses of an aquifer, that is difficult to understand to decision makers and engineers, the energy potential of a well doublet was calculated for different sites. For that the reservoir properties (porosity and

permeability), effective thickness, temperatures were derived from deep wells and were converted to capacity of thermal energy (MW) of a hypothetical well doublet. This kind of maps is easy to accept by energy engineers and decision makers that do not have any special knowledge in thermal energy thus facilitating the public acceptance of geothermal energy for district heating.



**Figure 4: Geothermal potential of Lower Devonian (a) and Cambrian (b) aquifers calculated for one duplet of wells (contour lines show MW of thermal energy) assuming injection water temperature 11°C.**

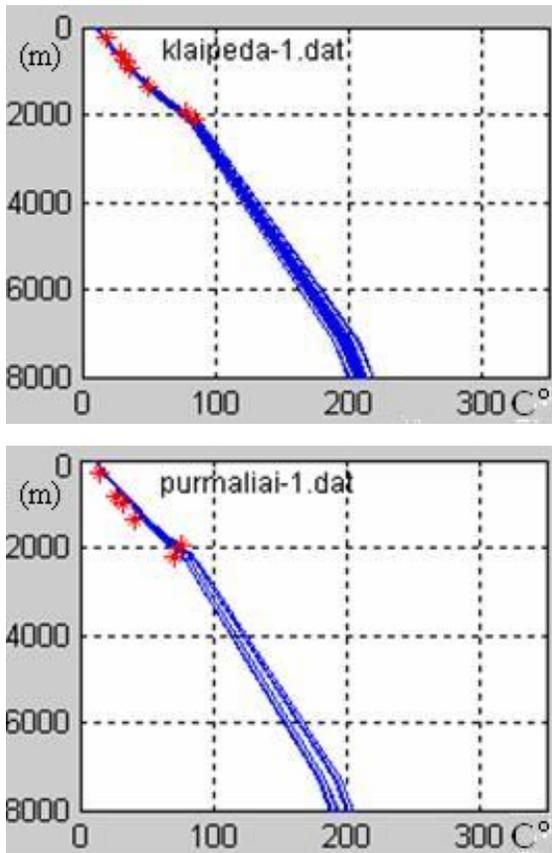
### 2.3. Opportunity study of EGS/HDR systems in Lithuania.

Lithuania is situated in the western periphery of the East European craton overlain by Baltic sedimentary basin. The heat flow ranges systematically increases from 38 mW/m<sup>2</sup> in the east to 90 mW/m<sup>2</sup> and more in the west. Accordingly the most favourable conditions for utilisation of the geothermal energy are related to the western part of the country. Besides to high potential for district heating by utilising the geothermal aquifers, the possibility of energy production from the crystalline basement rocks was considered. The basement is covered by 2 km thick sediments in prospective area of west Lithuania. The previous studies revealed that the main reason of elevated heat flow in western part of Lithuania is related to increased heat production of the basement lithologies. The basement is dominated by Palaeoproterozoic granulites. A number of Mesoproterozoic

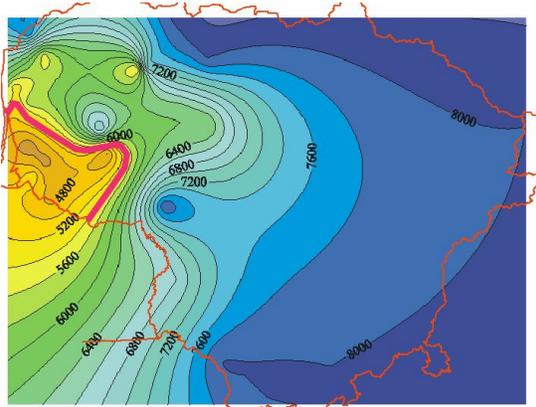
granitoid intrusions were identified. They were established in the cratonic setting about 1.5 Ga. A specific feature of those bodies is a high heat production in the range of 4-18  $\mu\text{W}/\text{m}^3$ . As a consequence, the most intense heat flow anomalies are confined to hot granite intrusions. Those are viewed as the potential targets for EGS/HDR systems for production of electric energy combined with a district heating. The analysis was focussed on (1) specification of the geothermal parameters of Mesoproterozoic granulites; (2) recognition of deep geometry of intrusions; (3) evaluation of effectiveness of 3D seismic technique in detecting fractured zones as the potential features for establishment of the engineered reservoir; (4) modelling the temperature distribution in west Lithuania; (5) identification of potential zones with respect with recent tectonic stress; (6) preliminary economical evaluation of EGS/HDR power stations.

The deep geometry of intrusions was defined from magnetic and gravity fields by using 2.75-D modelling approach. It was indicated that, for example, the largest Zemaiciu Naumiestis intrusion is as thick as 4 km, the smaller ones are somewhat thinner. An effectiveness of 3-D seismics was proved for identification and characterisation of zones of increased fracturing. Based on modelling of horizontal shift of GPS stations the distribution of the horizontal stresses was studied. It is rather variable in west Lithuania as the regional stress field is seemingly disturbed by large-scale faults causing a rotation of the stress field. Accordingly, the selection of most prospective structures for EGS/HDR systems is rather complicated, the strike of prospective fault zones ranging from roughly W-E to N-S. The temperature distribution in the basement was modelled and based on geothermal data from deep oil exploration wells that provided information on temperature distribution in sedimentary cover, geothermal gradient, and drill cores of the crystalline basement. The latter were important for measuring the heat production and thermal conductivity that are essential parameters for consistent modelling. A map of depths of isotherm 150°C was the basic for identification of the most prospective areas for geothermal energy production. A prospective area was considered to have 150°C temperature in the depth interval of 4-5 km (Fig.5, Fig.6). That favourably conditions were defined in southwest and westernmost Lithuania.

A conclusion is drawn that the development of EGS/HDR geothermal systems have certain prospects in Lithuania. The technique needs however improvement, as the geological conditions are somewhat worse compared to for example Soutz site located in the graben that is more intensely tectonised. On the other hand the geological conditions are compatible to Middle Australia, the high heat flow of which is related to fertile basement lithologies, similar to Lithuania.



**Figure 5: Temperature distribution in Klaipeda area, west Lithuania, measured (red stars) and modelled (blue lines). Prospective temperature 150°C is modelled at depths of about 5 km.**



**Figure 6: Depths of 150°C isotherm in Lithuania. The prospective HDR/EGS area is marked by pink line.**

### 3. GEOTHERMAL UTILIZATION

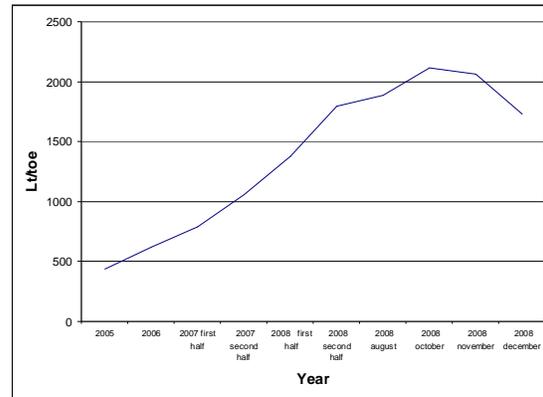
#### 3.1. Klaipeda geothermal demonstration plant (KGDP).

In June 2004 the State Commission confirmed a plant capacity of 35 MW<sub>t</sub> (geothermal part - 13,6 MW<sub>t</sub> ).

The operation of plant is as follows: the geothermal water is extracted from the Devonian aquifer with submersible pumps in the production wells, passed through heat pumps and returned via injection wells to the same aquifer. Low-

temperature geothermal heat is extracted from the geothermal water (38°C) using an absorption heat pump and is transferred to the Klaipeda district heating network.

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 x 4,5 MW<sub>t</sub> capacity) are driven by hot water (175°C, 10 bar) from three hot water boilers (16,2 MW<sub>t</sub> each). The natural gas is used as a fuel for mentioned boilers (Fig.7). (In detail the Klaipeda geothermal demonstration plant was described in paper (Zinevicius et al.,2003)).



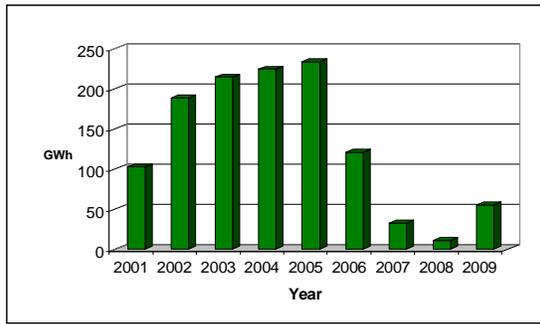
**Figure 7: Natural gas price in district heating sector**

The economical sustainability of KGDP is very sensitive to the price of heat supplied by the plant. The price till year 2007 was low and did not comply with the price agreed when the project was initiated. Due to financial and technical problems (one by one – three heat pumps got out of order) in July 2007 KGDP operation was stopped. Thanks to President of Lithuania Valdas Adamkus – Government allocated 12,9 million Lt for: the repayment of debts regenerative activities in plant and covering World Bank loan with interest.

The Investment Programme was prepared with aim to reach the capacity of 35 MW and to produce more than 200 000 MWh/year by implementing such main measures:

1. Repair of heat pumps (as leakages in generators of two heat pumps and condenser of one heat pump were defined).
2. Increase injection capacities in well KGDP II and KGDP 4I (because injection rate fell from 350m<sup>3</sup>/h to 140 m<sup>3</sup>/h).

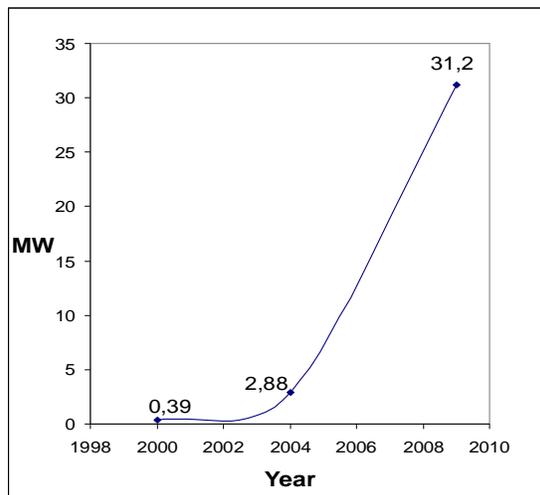
KGDP resumed activity in November 2008 and step by step increasing production in parallel with regenerative activities (Fig.8). For the end of June, 2009 we have all three heat pumps renovated and ready for operation; well KGDP 4I is cleaned with chemicals and it's injection capacities are increased from 110m<sup>3</sup>/h to 180 m<sup>3</sup>/h; well KGDP II is still under renovation – side offset is drilled.



**Figure 8: Heat production**

**3.2. Small-scale heat pumps.**

Very evident growth in number of geothermal small-scale heat pump systems installation in Lithuania is presented in Fig. 9. Without any support – near 3000 units were installed in period from 2005 to 2009 (Fig.9). Private enterprises most active in this field are: IĮ „Sanresta“, UAB „Naujos idėjos“, UAB „Donasta“, UAB „Ekokodas“, UAB „Vilpra“, UAB „Geoterminis šildymas“, UAB „Alropa“, UAB „Ardega“, UAB „EES“, IĮ „Bremena“, UAB „Ogeo“, UAB „Ekomatrica“, UAB „Kauno hidrologija“, UAB „Šilumos mašinos“.



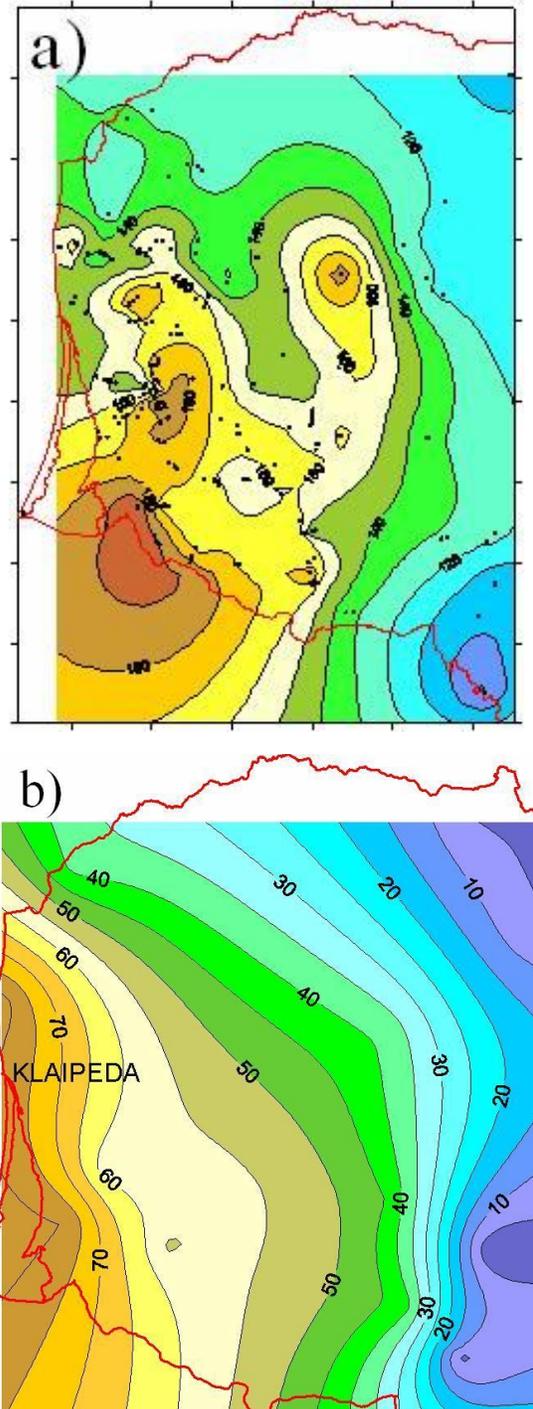
**Figure 9: Total capacity of geothermal small-scale heat pump systems.**

It is very difficult to collect exact information from enterprises. Some of them indicating only total capacity of heat pumps installed. Also we haven't national registration system for that purpose.

**3.3. Alternative utilization of geothermal energy.**

So far, only one district heating station and a number of ground source heat pumps are used in Lithuania despite of high geothermal potential of the country. Some alternative application of this kind of energy was considered in some research projects targeted at evaluation of possibility to use geothermal water for balneology and fish farming. For this reason the inventory of temperature distribution and chemical composition was performed for Lithuania (Fig.3, Fig.10). It is stated that good prospects for fish farming exist in Lithuania, mainly due to high salinity of even shallow

aquifers. Yet, the utilization of numerous old oil exploration and exploitation wells could be of economic value for extraction of hot water (70-90°C) to heat fish ponds. A further economic-technical evaluation is required in the future.



**Figure 10: Salinity of Cambrian (a) and Lower Devonian (b) aquifers, g/l, west Lithuania.**

#### 4. DISCUSSION.

##### 4.1. Legal Basic.

The main legal acts are:

1. Low on Energy (2002),
2. National Energy Strategy (2007),
3. National Energy Efficiency Programme for 2006-2010 (2006).

**The Law on Energy** is in details described in previous WGC paper (Zinevicius et al., 2005).

*The National Energy Strategy (NES) defines the main targets set by the State and directions for their implementation until 2025. The main attention was paid to energy security which covers the totality of conditions ensuring the diversity of traditional and renewable primary sources of energy, diversity and security of energy supply. It is fixed that the share of renewable energy resources in national balance of primary energy reached in 2005 - 8,7%, in 2010 objective is to increase the share up to 12% and in 2025- at least up to 20%.*

*About 75% of residential buildings in Lithuania's town are supplied with heat from district heating systems. Gas accounts for approximately 75% in the production of district heating and, after decommissioning of the Ignalina NPP, up to 75% - in generation of electricity. So the task "to ensure that the share of the natural gas used for the generation of energy would not exceed 30% in Lithuania's annual fuel balance" could be reached more widely using renewable energy resources and indigenous fuel when producing heat and electricity.*

*National Energy Efficiency Programme (NEEP) is updated every five years. In NEEP general political condition is indicated: Lithuania has signed the Kyoto Protocol and assumed the commitment to reduce greenhouse gas emissions by 8% in the period from 2008 to 2012 (compared with 1990 as the base year).*

*The main problems in renewable energy resources sector are indicated: lack of experience of Lithuanian producers of manufacturing the equipment that uses renewable energy resources; large investment in renewable energy plants; municipalities have limited investment capacity for contributing to project financing; rare use of renewable energy resources in buildings; poor state support for the implementation of projects related to renewable resources; feed-in tariffs are introduced on the buying of electricity produced from renewables but in general tax policy does not stimulate the use of renewables.*

*In same time the consumption of energy produced from renewable energy resources in 2004 and the economic potential for its consumption by types of energy resources (TWh a year) are as follows: wood – 8,03/9,8; straw - 0,05/3,59; biogas and landfill gas - 0,02/0,4; hydro energy - 0,42/1,5; solar and geothermal energy - 0,02/2,1; wind energy – 0,00/0,85; biofuels - 0,01/2,25. The use of renewable energy resources accounted for 8,55 TWh of energy consumed in 2004, and the economic potential for using such energy is targeted at the annual amount of 11,9 TWh in 2010 and 14,3 TWh in 2020.*

The Low on RES is under preparation and will be ready in autumn 2009.

##### 4.2. Future of Geothermal Energy in Lithuania

European Union set task for Lithuania to reach share of RES in final energy consumption – 23% in year 2020 (in year 2005 we had 15%). Prognosis on geothermal energy development in Lithuania is presented in Table 5.

Table 5. Consumption and prognosis of indigenous and renewable energy resources, thous. toe (National, 2008).

Type of sources	Year		
	2006	2010	2025
Firewood and wood	728,2	795	1015
Agriculture waste	1,7	25	120
Biogas	2	10	20
Sprout		20	70
Wind	1,2	35	90
Hydro	34,2	40	45
Bio fuel	20,9	115	450
Municipal waste		25	120
Geothermal & Solar	1,7	10	45
Other	0,1	12	80
<b>Total,</b>	<b>790</b>	<b>1090</b>	<b>2055</b>
<b>% in Primary energy balance</b>	<b>9,2</b>	<b>12,6</b>	<b>19,6</b>

#### CONCLUSIONS.

1. Geothermal potential of West Lithuania is re-evaluated – the new maps indicating use and indicate the heat capacity of the duplet of wells (MW) are prepared for applied.
2. After one year gap Klaipeda Geothermal Demonstration plant restarted it's operation and step by step increasing production in parallel with regenerative activities.
3. Sudden growth of geothermal small-scale heat pump systems installations was fixed in period from 2004 to 2009 – installed capacity increased 10 times.
4. The Low on RES is under preparation. Hopefully it will create good conditions not only for electricity but also for heat producers.
5. More tight international cooperation of geothermal experts is necessary to solve complicated problems of injection, corrosion, microbiological investigations.

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