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Geothermal Energy Use, Country Update for Lithuania

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ABSTRACT

Deep wells in Lithuania were drilled in the 20th century. As established by numerous deep drillings, there are huge resources of mineral water in the entire territory of the country. The Cambrian sandy aquifer is the most extensive saline aquifer: salinity increases from 0.5 g/l to 200 g/l with increasing depths and temperature from +15^{o}C to +95^{o}C. The second Lower Devonian aquifer contains salinity from 0.5 g/l to 95 g/l and temperatures from +10^{o}C to +45^{o}C. The third Middle Devonian geothermal aquifer has water with a saline content of up to 45 g/l and temperatures from +8^{o}C to +35^{o}C. All mentioned aquifers have a potential in geothermal balneology and the first steps in this direction are already completed.

Data on the operation of the Klaipeda Geothermal Demonstration Plant (KGDP) and the installed capacity of ground-source heat pump systems are presented in this paper.

Two case studies are discussed – one already implemented, the second as a possibility for the future:

first, An industrial building built according to BREEAM standards;

second, A combination of water-power plant with heat pump.

1. INTRODUCTION

Lithuania has a long history of air temperature measurements. During 240 years of observations local changes correspond to the global climate warming trend (Climate 2013) (Fig. 1).

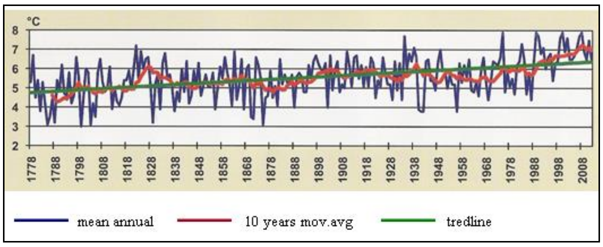

Figure 1: Average annual temperature in Vilnius, 1778-2008.

Directive 2009/28/EC on the promotion of the use of energy from renewable sources sets a binding target for Lithuania to achieve that by 2020 the share of RES in the final energy consumption is no less than 23%. The requirements of the Directive have been transposed into the National Strategy for Development RES (approved on June 21, 2010) and the Law of the Republic of Lithuania on Energy from Renewable Sources (approved on May 12, 2011) (see Zinevicius et al. 2013).

The Paris Agreement (Paris 2015) aims to strengthen the global response to the threat of climate change (Article 2 (a)):

Holding the increase in the global average temperature to well below 2^{o}C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5^{o}C above pre-industrial levels, recognising that this would significantly reduce the risks and impacts of climate change.

The strategic goal of Lithuania's climate change mitigation policy is to make sure that the growth of the country's economy is much faster than the increase of greenhouse gas (GHG) emissions. In the vision of the climate change management policy until 2050 it is foreseen that renewable energy sources will be used in all sectors of the domestic economy: energy, industry, transport, agriculture, etc. The national strategy for climate change management policy (National 2012) states GHG emission reduction by 40% in 2030, 60% in 2040 and 80% in 2050 as compared to the levels in 1990 (Fig. 2)

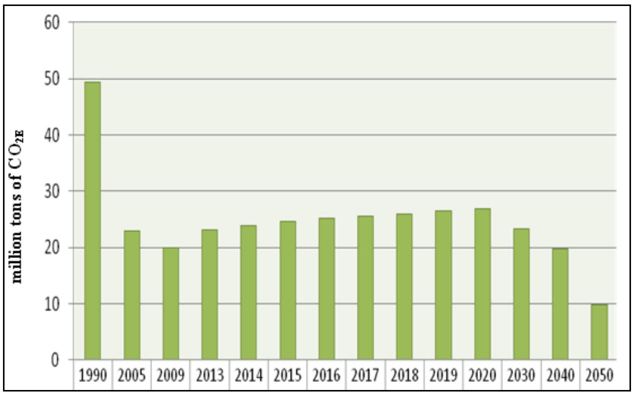

Figure 2: Factual levels of Lithuania's GHG emissions and indicative goals in 2050.

2. GEOTHERMAL BALNEOLOGY

There are several mineral water SPA resorts in Lithuania dating back to the 18th and 19th centuries (Birstonas, Druskininkai, Likenai) (Fig. 3), (National SPA Association, 2011). The Druskininkai mineral water resort is the oldest and was established in Lithuania in 1794. These resorts are based on mineral water springs that are related to upward water flow along the regional-scale faults dissecting the sedimentary cover of the Baltic sedimentary basin. The deep wells were drilled in the 20th century to expand mineral water supplies at these sites.

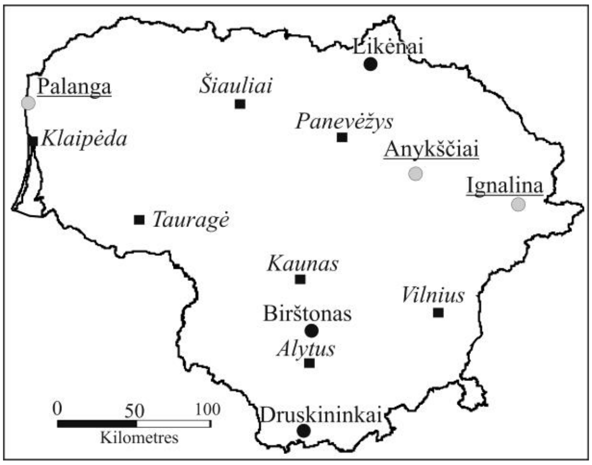

Figure 3: Geothermal balneological SPA centres established in 2014-2015 in Lithuania (Palanga, Anyksciai, Ignalina underlined). Traditional mineral water spring SPA centres are indicated (Druskininkai, Birstonas, Likenai). The main cities are shown (Vilnius, Kaunas, Klaipeda, Alytus, Panevezys, Siauliai).

Until recently, these traditional mineral water spring SPA centres remained the only ones operating in Lithuania. There are huge resources of mineral water throughout the entire territory of Lithuania, however, as discovered by numerous deep drilling operations in the country.

The Cambrian sandy aquifer is the most extensive saline aquifer in Lithuania (Fig. 4) (Sliaupa 2002). The salinity increases from 0.5 g/l in SE Lithuania to 200 g/l in SW Lithuania that correlates with the increasing depths of the aquifer from 400 m to 2,300 m. The increasing salinity associates with the increasing temperature from +15^{o}C to +95^{o}C. The thickness of the aquifer is of the order of 15-75 m, increasing to the west. The heat energy potential of the model well is about 0.5-2 MW_{th}.

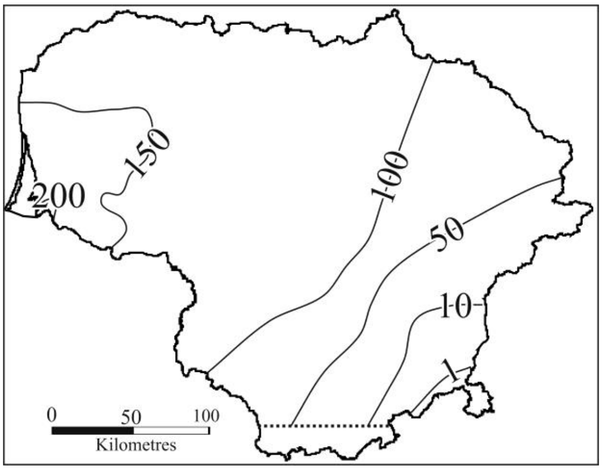

Figure 4: Salinity of the Cambrian aquifer (g/l).

The second potential geothermal balneological aquifer is related to the Lower Devonian (Kemeri Regional Stage) sandy package of a thickness of 50-180 m (Sliaupa 2002). It contains shaly and silty interlayers averaging 35% of the section. The depths range from 300 m to 1,100 m. The variations in depth are closely related to salinity changes from 0.5 g/l to 95 g/l (Fig. 5). The temperature is increasing to the west from +10^{o}C to +45^{o}C. The average water discharge of a model well is evaluated at about 600 m^3/h within the prospective area, and the heat energy potential is about 4-10 MW_{th}.

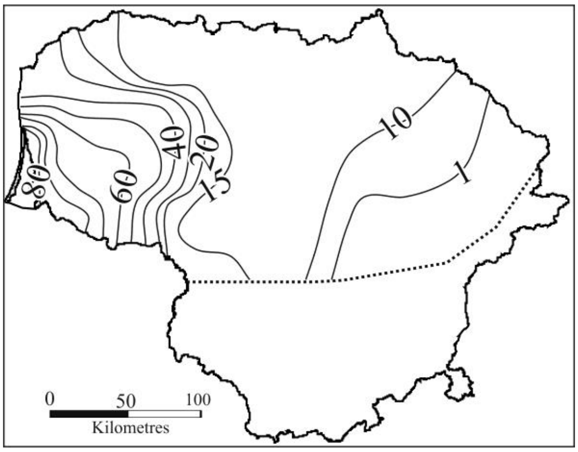

Figure 5: Salinity of the Lower Devonian (Kemeri RSt) aquifer (g/l).

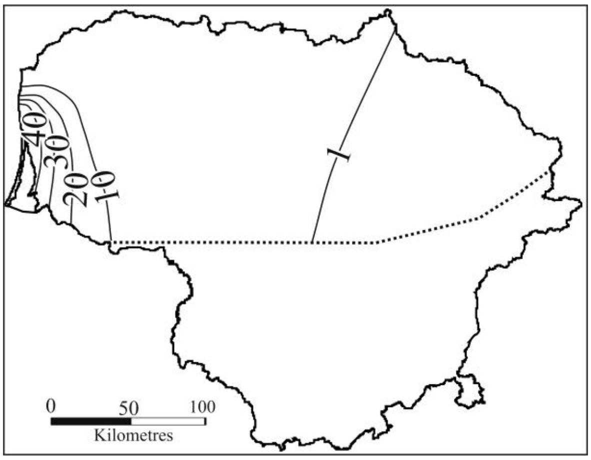

Figure 6: Salinity of the Middle Devonian (Šventoji-Upninkai RSts) aquifer (g/l).

The Middle Devonian (Sventoji-Upninkai RSts) is the third prospective geothermal balneological aquifer distributed in the northern half of Lithuania (Fig. 6) (Sliaupa 2002). It is composed of loosely cemented sandstone and sand with shale and siltstone interlayers (average net-to-gross 0.65). The water is of low salinity in most Lithuania and is extensively exploited as a source of potable water in the eastern half of the country. The salinity sharply increases to 10-45 g/l in the westernmost part of Lithuania. The temperatures range from 8+^{o}C to +35^{o}C. This aquifer is therefore not considered a prospective body for district heating, but has a high potential in geothermal balneology in the westernmost part of Lithuania. The average drilling well water discharge is evaluated at about 1,000 m^3/h within the prospective area. The heat energy potential of the model well is about 3-7 MW_{th}.

The chemical composition of the mineral water of the aforementioned aquifers is dominated by Cl and Na (Table 1). The highest sulphur content is defined in the Lower Devonian aquifer that is related to the partial cementation of the aquifer sandstone by gypsum. The Cambrian saline water contains high amounts of Ca and Mg. It is also notable for its high Br concentration.

The large resources of hot saline water inspired the establishment of the new SPA facilities in Lithuania. The Ignalina and Anyksciai SPA centres utilise the Cambrian saline water (TDS 40 g/l) that is exploited by a renovated old deep well since 2014 in the eastern part of Lithuania. Similarly, the Palanga (Zybininkai) SPA centre reopened two old oil exploration wells at the Lower Devonian aquifer level in 2015 in the westernmost part of Lithuania.

These initiatives indicate an increasing interest in the SPA centres in the deep geothermal aquifers. It is remarkable that they are related to the very different geological conditions of the easternmost and westernmost parts of Lithuania. At this stage, only mineral water is exploited for balneological purposes. There are, however, new initiatives of the combined utilisation of the geothermal and saline water potential in the western part of Lithuania as it is characterised by excellent geological conditions for this type of combination (SPA Vilnius Anyksciai for example).

A substantial contribution to balneotherapy using high mineralisation geothermal water was carried out at the Klaipeda Seamen Health Care Center. Certificated geothermal water - naturally warm (+34.6^{o}C on average), mineralised (108 g/l) from Geoterma 2P borehole (1,135 m depth, lower Devonian layer) of the Klaipeda Geothermal Demonstration Plant - was successful used during the clinical trial (Rapoliene et al. 2015).

Table 1: Chemical composition of mineral water of the Cambrian, Lower Devonian, and Middle Devonian aquifers. Palanga site (westernmost Lithuania, see Fig. 3 for location).

Aquifer index	depth, m	salinity, mg/l	Cl, mg/l	SO_4, mg/l	HCO_3, mg/l	Na+K, mg/l	Ca, mg/l	Mg, mg/l
Cm	2171	133000	83337	370	73	34000	17586	4496
D1km	1124	82109	49850	1601	146	2400	7311	2596
D2sv-up	682	30060	18055	234	91	91	91	91

3. GEOTHERMAL UTILIZATION

3.1. Klaipeda Geothermal Demonstration Plant (KGDJ)

The absorption heat pumps use the lithium bromide (LiBr) solution. Low-temperature geothermal heat is extracted from the geothermal water of the Devonian aquifer. Plant capacity is confirmed by the State Commision – 35 MW_t (geothermal part – 13,6 MW_t). (In detail the operation of the Klaipeda Geothermal Demonstration Plant was described in papers (Zinevicius et al. 2003 and Zinevicius and Sliaupa 2010)).

The heat production of KGDP in the period 2001-2015 is presented in Fig. 7.

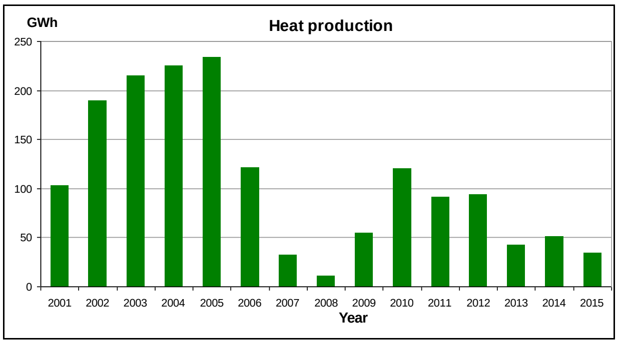

Figure 7. Heat production.

3.2. Small-scale ground source heat pump installation

The number of small-scale ground source heat pump systems in Lithuania is growing. Today we have almost 6,400 installations thanks to such private enterprises as: UAB Ekoklima, UAB Naujos Idejos, UAB Tenko Baltic, UAB EES, UAB Vilpra, UAB Ekokodas, UAB Steltronika, UAB Geoterminis Sildymas, UAB Atsinaujinanti Energetika, UAB Melkerlita, UAB Ardega, UAB Bremena, UAB Kauno Hidrogeologija and UAB Konkretus. The total installed capacity is more than 82 MW (Fig. 8).

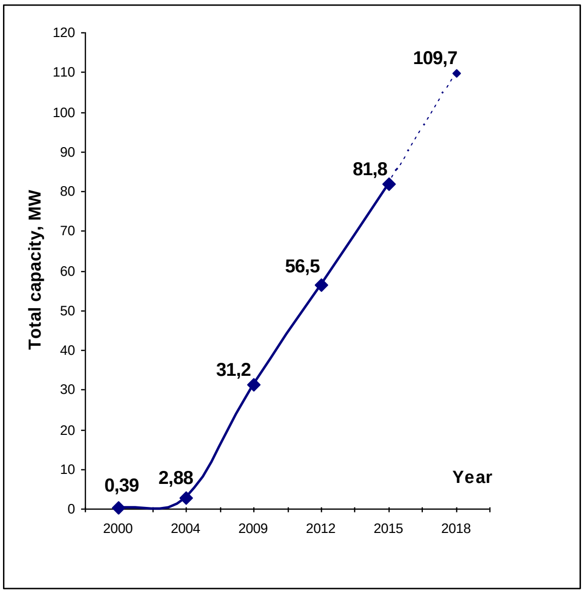

Figure 8. Total capacity of small-scale GSHP systems.

4. GOOD PRACTICE EXAMPLES

4.1. First industrial building built according to BREEAM standards

The biological wastewater treatment equipment-producing company August & Co set a goal to build the first industrial building according to BREEAM (Building Research Establishment Environmental Assessment Method) standards. This ambitious goal was successfully reached, and today the factory building is energy effective and has a mostly tight (h<0.14 1/h) structure and in Lithuania achieved the A+ energy efficiency class.

For the purposes of BREEAM system construction, costs increase by about 30% because the building must meet the energy requirements of the class, but these investments pay off. Under this system, certified sites usually have a quarter increase in labour productivity and production volumes, considerably lower energy consumption and greatly reduced emissions. According to the design and construction of the August & Co building, special attention was paid to the tightness and energy performance guarantee. The BREEAM requirements, carefully select and energy sources, some of which are renewable, such as the August & Co factory installed geothermal heating system. This ensures independence from District or Gas Heating and helps significantly reduce energy costs. It is estimated that by setting the heating system, up to 40% reduction of carbon dioxide (CO_2) emissions.

A geothermal boiler room and floor heating in the building was installed by UAB Donasta, who have considerable geothermal experience in similar industrial facilities (the company installed a 240 kW heat pump hot water system in SPA Vilnius Druskininkai, 5,300 m^2, a 140 kW Würth logistics terminal in Ukmerge, a 740 kW 46,000 m^2 Sanitex stock in Riga, a 160 kW 4,200 m^2 UVS Group building in Vilnius and a 210 kW in SPA Vilnius Anyksciai et al.).

Approximately 4,600 m^2 of floor heating was installed in the August & Co factory, 110 kW cascade of two pcs Stiebel Eltron WPF 52 heat pump with drilled 12 geothermal probes (‘U‘ pipe, 140 m deep). The geothermal plant is designed to heat and cool the premises, heat hot water and in the winter time to supply the required heat to recuperative ventilation devices. The project was optimised in order to maintain a lower temperature for heat pumps (supply temperature should be less than +30°C) and high annual coefficient of performance (SPF>5).

The modern factory building is a high-functioning technological object with its own heating, ventilation, cooling, lighting and other comfortable working environments for creating systems. The industrial and warehouse floor heating solution is the most desirable, with the trends of the energy performance and renewable geothermal energy. Heating the floor not only provides an enjoyable, healthy and quiet working system, but also an energy cost saving solution, which is important for a successful business. The heat in the August & Co plant is really needed because plastic products during processing work require higher ambient temperatures.

It was necessary to install the building's energy holding separate accounting systems, monitoring devices that are needed for energy cost savings and monitoring.

Figure 9: General view.

Figure 10: Heat substation.

4.2. Combination of water–power plant with heat pump is an excellent heat producing unit for space heating.

A heat pump plant using the low potential heat of soil, water or air is one of the advanced renewable energy techniques. The combination of this plant with a water-power plant ensures a low heat price due to high COP and a low off-peak electricity price. An additional hot water reservoir is needed as well as a huge heat exchanger for heat extraction from full water flow behind the hydro turbine (Fig. 11).

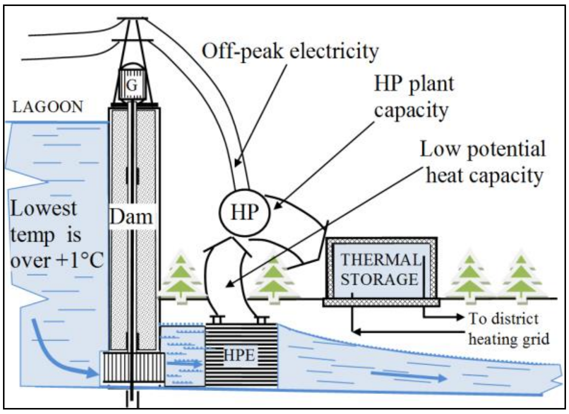

Figure 11: Scheme of combined heat pump and water-power plant.

Usually, the water-power plant has a custom-made dam of a certain height, so a large area lagoon forms in the flatlands with a considerable shallow geothermal heat capacity. For example, the geothermal heat capacity of the Kaunas Lagoon is over 2,000 MW, more than enough for the purposes of heating the city using heat pump technology. Geothermal heat increases water temperature, thus even during the coldest winter period it is at least +1ºC (Fig. 12).

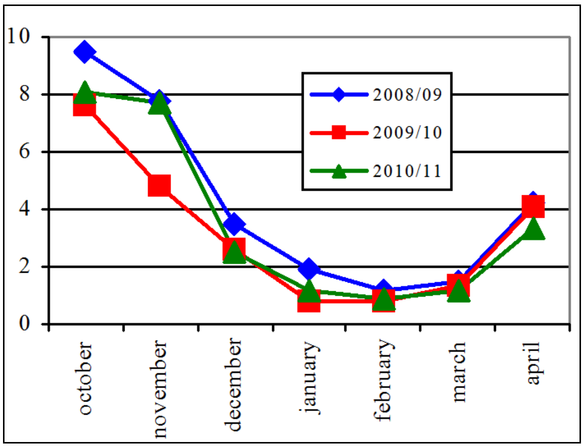

Figure 12: Kaunas Lagoon water temperature.

The relatively high COP of the heat pump plant is due to:

a) The very effective heat transfer between water and the heat pump evaporator (HPE, Figs. 11, 12);

b) The high efficiency of the compressor because of its high capacity;
c) The counter-flow condenser, which guarantees a more complete heat exchange between grid water and working fluid (Fig. 13).

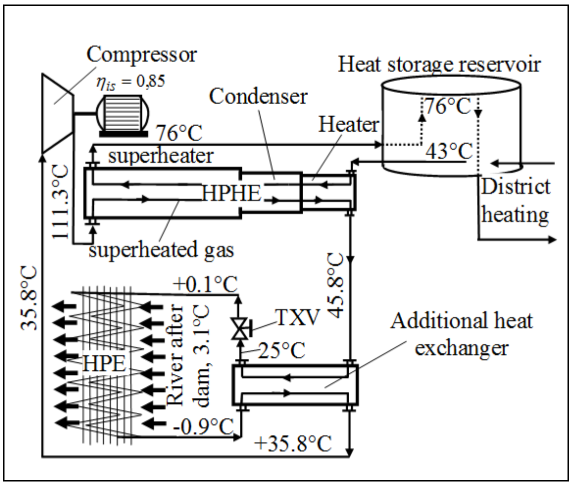

Figure 13: Scheme of heat pump plant.

A capacity of max 40 MW (off-peak electricity) can be used for the heat pump in the Kaunas plant case. A capacity of 146 MW of the high pressure heat exchanger (HPHE) is achieved using heat pump technology. The condenser is a complex heat exchanger, which extracts only 53% of heat from the condensing of working fluid. The remaining 28% of the heat is received from the superheated vapour and 19% from sub-cooled liquid refrigerant. The Coefficient of Performance (COP) of the heat pump is 3.65 at the lowest water temperature of +1°C (Dagilis 2014). The heat capacity of the heat pump evaporator (HPE) and additional heat exchanger (AHE) are 84 MW and 22 MW respectively.

The use of off-peak electricity increases the economic effectiveness of a combined plant because the electricity price is almost half compared to the average cost. Therefore, the energy component cost of produced heat is only €0.007/kWh that makes the economic operation of the above-mentioned unit very effective. The investment costs (Arsalis 2008) (Sayyaadi 2012) are high enough (see the table below).

However, the payback period is only three years when the construction time is not included. The short payback time is determined by the low cost of produced heat. It is assumed that income from heat selling is received when the price is in order of that which is received by heat producing plants fuelled by wood chips. This price is low today in Lithuania, not overstepping €0.03/kWh. Meanwhile, the cost of the heat produced in the presented combined plant is around €0.01/kWh. It is a big difference that mainly determines the short time for payback of investment.

Table 2: Investment costs of a heat pump plant.

	Characteristic	Cost by author (Arsalis 2008) mill. USD	Cost by author (Sayyaadi 2012) mill. USD	Taken cost mill. USD
Compressor	40 MW	1.87		1.9
Superheater of the HPHE	10,090 m^2	1.1	1.1	1.1
Condenser of the HPHE	3,570 m^2	0.49	0.44	0.49
Heater of the HPHE	2,850 m^2	0.41	0.4	0.4
Additional heat exchanger	6,020 m^2	0.74	0.68	0.74
Evaporator, HPE (copper)	16,000 m^2			3.3
Reservoir for heat storage	20,000 m^3			2.7
Engineering, procurement, Construction management service	US\$360/kW_{POWER}			14.4
Balance of the plant	US\$50/kW_{POWER}			2
Owner's costs	US\$60/kW_{POWER}			2.4
All costs				29.4

5. CONCLUSIONS

1) Cambrian Lower Devonian and Middle Devonian hydrogeothermal resources could be used for geothermal balneology. The first steps are already completed.

2) The Klaipeda Geothermal Plant is struggling for its place in the market.

3) The total capacity of installed ground source heat pump reached 82 MW_t.

4) The installed heat pump lead-up to first constructed industrial building according to BREEM standards.

5) The combination of a water-power plant with a heat pump could be an excellent heat producing unit for space heating.

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Tables C-G

Table C: Present and planned geothermal District Heating (DH) plants and other direct uses, total numbers.

	Geothermal DH plants		Geothermal heat in agriculture and industry		Geothermal heat for individual buildings		Geothermal heat in balneology and other	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2015	35	34	-	-	81.8	193		
Under constru-ction end 2015								
Total projected by 2018					109.7	250		
Total expected by 2020								

Table D1: Existing geothermal District Heating (DH) plants, individual sites.

Locality	Plant Name	Year commis-sioned	CHP **	Cooling ***	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2015 produc-tion * (GW_{th}/y)	Geoth. share in total prod. (%)
Klaipeda	Klaipeda Geothermal Demonstration Plant	2004	N	N, RI	13.6	35	34	26.5
Total					**13.6**	**35**	**34**	**26.5**

Table E: Shallow geothermal energy, ground source heat pumps (GSHP).

	Geothermal Heat Pumps (GSHP), total			New (additional) GSHP in 2015 *		
	Number	Capacity (MW_{th})	Production (GWh_{th}/yr)	Number	Capacity (MW_{th})	Share in new constr. (%)
In operation end of 2015 *	6,396	81.8	193			
Projected total by 2018	8,689	109.7	250			

Table F: Investment and employment in geothermal energy.

	in 2015		Expected in 2018	
	Expenditures (million €)	Personnel (number)	Expenditures (million €)	Personnel (number)
Geothermal electric power	-	-	-	-
Geothermal direct uses	0.08	14	0.5	16
Shallow geothermal	5.82*	105		
Total	**5.9**	**119**		

* estimated

Table G: Incentives, Information, Education.

	Geothermal el. power	Geothermal direct uses	Shallow geothermal
Financial Incentives – R&D	-	DIS (€210,000, EU projects)	-
Financial Incentives – Investment	-	-	DIS (%)
Financial Incentives – Operation/Production	-	-	-
Information activities – promotion for the public	No	Yes	Yes
Information activities – geological information	No	Yes	Yes
Education/Training – Academic	Yes	Yes	Yes
Education/Training – Vocational	No	No	No

Key for financial incentives:

DIS	Direct investment support	FIT	Feed-in tariff	-A	Add to FIT or FIP on case the amount is determined by auctioning
LIL	Low-interest loans	FIP	Feed-in premium		
RC	Risk coverage	REQ	Renewable Energy Quota	O	Other (please explain)