Proceedings World Geothermal Congress 2000
Kyushu - Tohoku, Japan, May 28 - June 10, 2000

INCORPORATION OF GEOTHERMAL HEAT SOURCES IN LATVIAN HEAT SUPPLY SYSTEMS

Edvins Eihmanis
Riga Technical University, 20 Azenes St., Riga LV 1019, P.O. Box 227, Latvia

Key Words: geothermal resources, low enthalpy water, heat consumers characteristics, technological schemes

ABSTRACT

The main objective of this study is a comprehensive evaluation of the geothermal potential of Latvia and the solution of practical problems in conjunction with the incorporation of geothermal plants into the existing heat supply systems.

The Latvian geothermal resources are concentrated in the Lower Devonian (D1km) and Cambrian (Cm2dm) aquifers in the form of low enthalpy water. Noteworthy heat power could be obtained from the water of the Cambrian aquifers, located in the area of 12,000 km^2 in the Central and south-western parts of Latvia at the depth 1,350-1,730 m. During the recent years, the economically usable heat resources were evaluated, reaching the total of 36exp18 J.

The geothermal plants in Latvia are feasible only using the systems of thermal water circulation with reinjection in combination with the heat pump technology and peak load boiler plants. Taking into consideration the existing fuel and energy prices in Latvia and the tendencies of their changes in the near future, it was concluded, based on calculations, that the above geothermal plants can have the pay-back time of up to 8-10 years, if the following conditions are fulfilled:

- there should be certain heat consumption in the summer, at least 25-30% of the winter peak load;
- there should be a district heat supply system in good working condition;
- the total heat consumption (the winter base load) should be at least 3.5-4.0 MW.

After the analysis of heat demand volume and dynamics for different consumers in the geothermal zone, complying with the above conditions, we have come to the conclusion that bigger cities are more suitable for the use of geothermal water for district heating and hot water supply: Liepaja (population 98,000), Jurmala (60,000), Jelgava (71,000) and Dobele (16,000). There are no suitable consumers in the rural areas, and such consumers are unlikely to appear in the near future, except in the virgin coastal areas suitable for the establishment of spas, where ecologically friendly geothermal plants could be used for the heat supply. The schemes most suitable for current conditions, have been selected. The computer modelling of the working conditions is carried out with the objective to optimise the compatibility of the construction and technological parameters of the proposed plant equipment in order to minimise the operation costs. This work is still in progress, although the power of the main items of basic equipment, the interrelation between them and the limiting values of the work regimes have already been determined.

1. INTRODUCTION

Speaking realistically about the use of geothermal energy in Latvia during the next 20-30 years, we mean the use of the earth heat in the form of thermal water with the temperature 25-60ºC, using Lindal’s diagram (Lindal, 1973), predominantly, for balneological purposes, fish farming and growing of vegetables in greenhouses.

Previous studies and economic evaluations were aimed at the use of thermal water in the heating and domestic hot water supply using the base load regime. The use of geothermal water is made simpler and more effective by the recent tendency to make use of the heating system radiators with lower temperatures, with those of the heat carrier being 55º/40 ºC, as well as floor heating systems with the temperature 35º/25 ºC.

2. LATVIAN GEOLOGICAL FEATURES AND RESOURCES OF THERMAL WATER

Geographically, Latvia is a small country, its area being 64,500 km^2 and population ca 2.4 million. Geologically, though, it is quite diverse. Latvia is located in the western part of the East European Platform, thus determining an almost horizontal occurrence of sediment layers (Brangulis J. et al.,1998). The geological features have resulted from the non-uniform character of the directions and amplitudes of the crustal tectonic movements. The pre-Baikalian tectonic cycles have influenced the structure of the crystalline basement only, while, during the following cycles, the sedimentary cover with various structural stages was formed.

In the top crystalline basement, there are three most important structural tectonic features: a part of the Baltic Syneclise is situated in the western part of the country, while the Latvian saddle occupies the north-eastern and eastern parts of Latvia, bordering the southern flank of the Baltic Shield in the north of Latvia. In general, the top basement subsides in the southwestern direction from 350-m (SL) in the Northeast to 1,900 m in the southwest (Barta Trough). Against the background of these regional features, numerous lesser tectonic features are observed. Numerous local highs, associated with tectonic faults, are located in western Latvia.

The Proterozoic and Palaeozoic sedimentary rocks are predominant in Latvia: the Vendian complex with the thickness > 100 m in eastern Latvia, the thickness of the Cambrian complex varies from 22 m in central Latvia to 100 m in eastern Latvia and 220 m in western Latvia. The Vendian and Cambrian rocks are overlain by the Ordovician and Silurian clayey carbonate formations; their thickness varies from a few tens of metres in the north-east of the country to 800 m in the coastal zone of the Baltic Sea. The Pre-Quaternary surface is formed by terrigenous and carbonate rocks of different age, up to 900 m thick. The Carboniferous and Permian deposits occur only in the south-western part of Latvia. Deposits belonging to other geological periods are absent in Latvia, except the Quaternary sedimentary cover (its thickness varies from a few metres to 200-300 m) formed as a result of several Pleistocene glaciations, overlying the older bedrock.

Against the above geological background, two zones of geothermal anomalies were discovered and studied. They occur in central and South-western Latvia (Fig. 1). If the average heat flow at the earth surface in Latvia is 55-58 mW/m^2, it reaches 82 mW/m^2 in the Nidasciems area in the South-western anomaly and 87 mW/m^2 in Eleja in the Central Latvian anomaly. The geological sections of the above anomalous zones are shown in Fig. 2 and Fig.3. The existing geothermal heat resources in the anomalous zones, calculated based on the methods developed by Muffler and Cataldi (1978) and McOuat (1993) are shown in Table 1.

3. THE EXISTING ECONOMIC AND HEAT SUPPLY SITUATION IN THE LATVIAN GEOTHERMAL ANOMALOUS ZONES.

Some relatively big cities: Liepaja (population 98,000), Jelgava (71,000), Jurmala (60,000), Dobele (16,000) and several smaller towns and villages are located within the two above-mentioned geothermal anomalous zones. The population density in the rural areas is, in general, quite low and, at the moment, there are no heat consumers with the demand at least 3-4 MW.

During the last 10 years, important qualitative and structural changes have taken place both in the Latvian energy sphere and in the heat supply, due to the restoration of the Latvian independence and the change in the economic system. After a considerable fall in the heat consumption during 1991-95 (ca 1.7 times), the situation became more stable, and there is a slow rise in consumption which, based on forecasts, will continue (Phare TA Programme for Latvian Energy 96-1021.06). The structure and dynamics of the heat consumption in the biggest consumer in the geothermal zone (Liepaja) are shown in Fig. 4.

The share of the alternative energy sources (resources) in the total energy supply is, at the moment, less than 0.1% (provided by windmills in the Baltic coastal zone). According to the above Phare programme, geothermal energy is also considered an alternative energy resource. The use of geothermal energy in the anomalous geothermal areas could cover up to 18-20% of the forecast heat demand, contributing in the diminishing environmental contamination and complying with the requirements of the EU directives and the Kyoto Protocol.

It follows from the above that, at present, it is feasible to build geothermal plants only in the biggest Latvian cities with the existing district heating systems with the capacity of at least 4-5 MW and, secondly, in the coastal zone (Fig. 1) with well preserved natural conditions, if spa complexes develop there with the heat consumption of at least 3-4 MW. The use of geothermal plants in such areas will help to preserve the environment.

4. PROPOSED TYPES OF GEOTHERMAL PLANTS FOR LATVIA AND TECHNOLOGICAL SOLUTIONS

Since the water temperature even in the Cm2dm zone does not exceed 40-54 °C, it is necessary to include both heat pumps and boiler plants in the geothermal plant equipment, in order to cover the peak load during winter when the temperature is -20 °C and lower. Under our conditions, only geothermal water circulation systems with reinjection can be used, primarily, due to the high salt content (predominantly, Na^+, K^+, $Ca2^+$, $Mg2^+$, Br^-, J^-, the total salinity reaching 120 g/l) and in order to preserve the general water balance in the aquifers.

Such a technology poses certain requirements regarding the aquifers: the transmissivity should be at least 40-60 Dm for the 25 MW plants and 20-30 Dm for the 5-8 MW plants. The distance between the production and injection wells should be at least 600-800 m. The aquifer conditions in the above-mentioned cities comply with these requirements, especially in Liepaja with the net aquifer thickness of ca 200 m.

One of the most suitable technologies is shown in Fig. 5. The geothermal water feed from one or several wells is recognised as 25, 50 and 100 m^3/h with the temperature 52 °C and 44 °C for the Central and South-western anomalies, correspondingly. The return water in the heating networks with the temperature 25-60 °C, depending on the season, undergoes, first of all, cooling in the HP (absorption or compression)evaporator, then is warmed in the geothermal heater until the temperature of 50 °C or 42 °C is reached, depending on the temperature of geothermal water. Further heating occurs in the HP and, if the temperature of outside air is below -8 ^oC, in the boiler plant as well.

Analysing this technological option, the following functional dependences were observed: $Q_{evap}=f(T2)$; $Q_{cond}=f(T2)$; $Q_{geoth}/N_{comp}=f(T2)$; $Q_{geoth}/Q_{cond}=f(T2)$; $Q_{total}=f(T2)$, their mutual interrelations were already calculated as well.
Here:
Q_{evap} – evaporator power, kW;
Q_{cond} – condenser power, kW;
Q_{geoth} – heat obtained from geothermal water, kW;
N_{comp} – energy consumed by the HP compressor or HP absorption generator, kW;
$Q_{total} = Q_{geoth} + Q_{cond}$.

The dependence $Q_{total}/N_{comp} = f(T2)$ is shown in Fig. 6. Of course, the lower T2 and T22 are, the fuller is the use of geothermal heat, the lesser heat power of the plant and the smaller is the volume of the heat carrier circulating in the heating network. It follows from the above that the geothermal water heat is used to cover the so-called base load, that is why it is important to preserve the heat consumption during the warm season as well, i.e. there should be domestic hot water consumption of at least 25-30% of the nominal load.

The target is that, based on the meteorological information regarding the duration of different outside air temperatures during the year, and determining the time period when the system operates at a certain T2 ($T2=f(t_{ext})$), to calculate the total yearly energy consumption by the HP and the boiler plant, using different operation regimes, to optimise the

Q_{geoth}/N_{comp} ratio, aiming at minimum operation costs during the year. This phase is going on in compliance with the experts of the Nordic Energy Research Council.

Based on the obtained results, the parameters of a proposed geothermal plants in Liepaja and Dobele have been calculated with the heat production of 4 and 8 MW, correspondingly (Table 2).

5. CONCLUSIONS

The analysis of the Latvian geothermal resources and technologies for their utilisation has proven the viability of their direct use for heating and hot water supply in Latvia.

The main obstacle for the initiation of the practical use of the geothermal heat is in the funding, since geothermal plants require higher initial investments than the traditional heat production technologies which can pay off only if the geothermal plants are maximally used in the base load regime. In order to transfer the geothermal energy related activities into the implementation phase, it is necessary to solve the financial problems, involving the Latvian energy supply companies, local banks and foreign companies with the experience in the implementation of geothermal projects.

ACKNOWLEDGEMENTS

Since 1992, all the Latvian activities in the sphere of geothermal energy have taken place with the active financial and scientific support of foreign institutions.

That is why the author would like to express his sincere gratitude to the following companies and persons: DONG, Denmark (Dr. Allan Mahler), Petroleum Geology Investigators ApS, Denmark (Mr. Lars Tallbacka), Geotherma Neubrandenburg GmbH, Germany (Dr. Peter Seibt and Dr. Herbert Schneider) and Geo Forschungs Zentrum Potsdam, Germany (Dr. Ernst Huenges and Mr. Peer Hoth).

REFERENCES

Lindal,B. (1973). Industrial and other applications of geothermal energy. In: Geothermal Energy (ed.H.C.H. Armstead), Earth Sci., v.12, UNESCO, Paris, pp. 135-148.

Brangulis, A.J., Kurss, V., Micans, J., and Stinkulis, G. (1998).Geology of Latvia. Geology Map at the scale 1:500 000 and description of Pre-Quarternary deposit. Geological Survey, ed. Micans J. 70 pp.

Tallbacka, L., (Project Manager) Eihmanis,E., Freimanis, A. and Radeckas, B. (1994). *Baltic Geothermal Energy Project. Feasibility Study.* Final Report, Copenhagen. 35 pp.

Muffler, L.J.P. and Cataldi, R. (1978). Methods for regional assesment of geothermal resources. Geothermics, 7(2-4), pp. 35-89, 131-207.

MCOuat, J.F. (1993). Reserves. Requirements for global reserve standarts and practices. Engineering and Mining Journal, 194 (8), pp.3-30.

Phare TA Programme for Latvian Energy 96-1021.06. (1997). 127 pp.

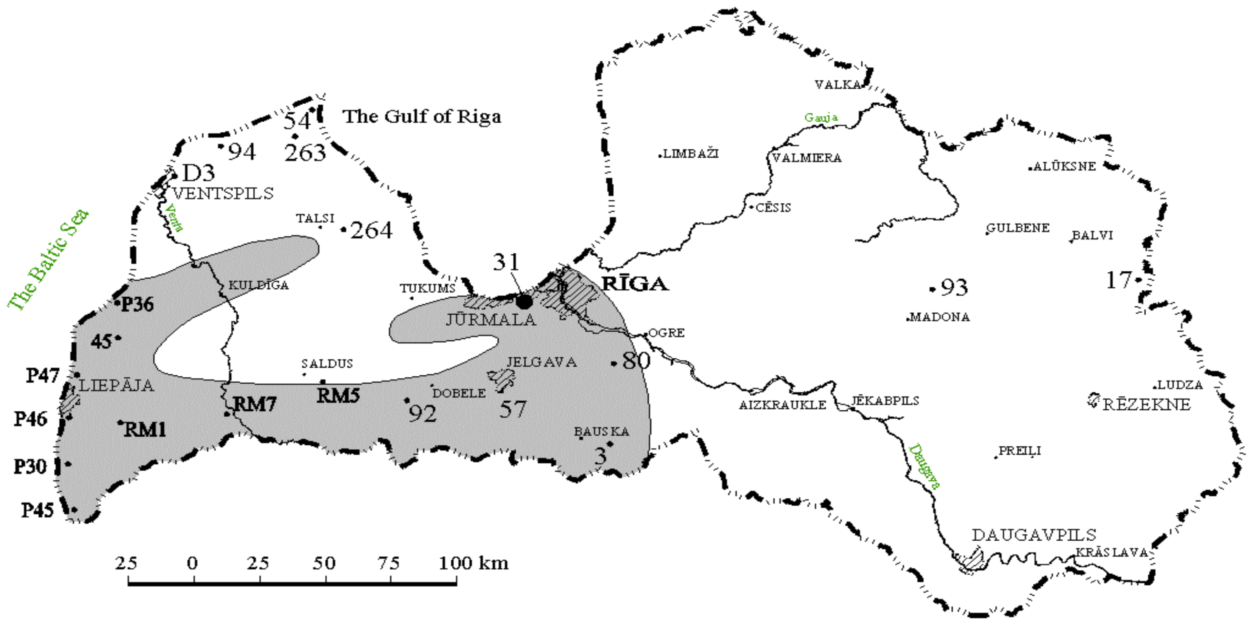
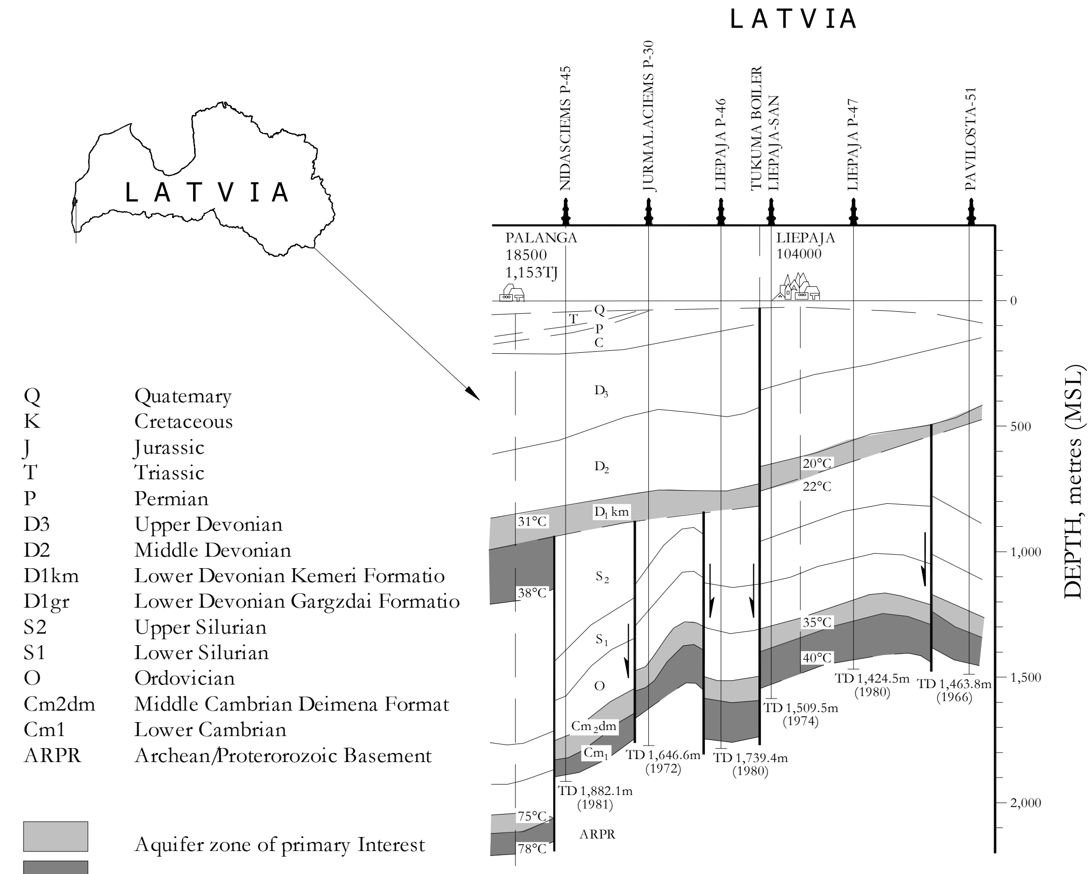


Figure 1. Zones of the geothermal anomalies



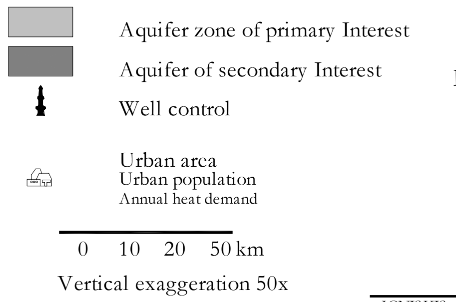


Figure 2. Cross section of the South-western Anomaly

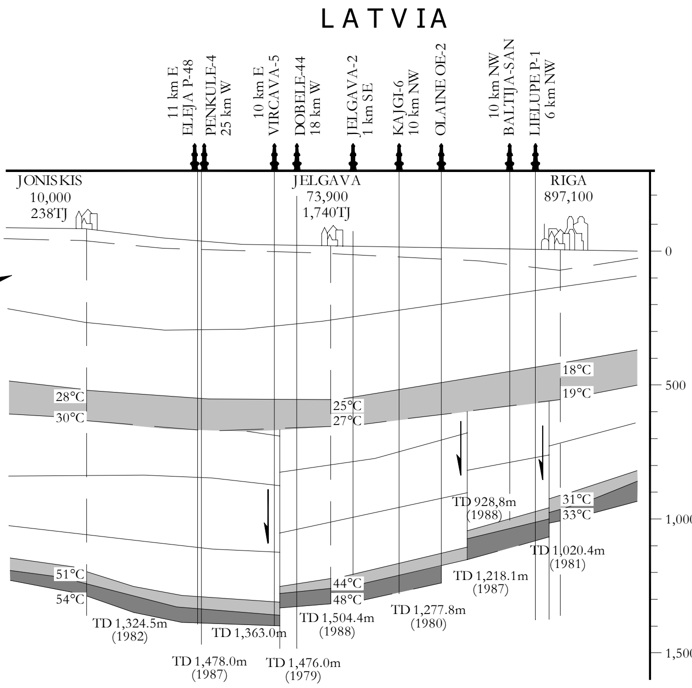


Figure 3. Cross section of the Central Anomaly

Table 1. Geothermal heat-in-place

Aquifer	Geotherma l area 25 °C, km^2	Gross aquifer rock volume, $*10^9$ m^3	Net aquifer rock volume, $*10^9$ m^3	Water volume, $*10^9$ m^3	Average aquifer temperature,°C	Technical heat resource, $*10^{18}$ J	Economi-cal heat resource, $*10^{18}$ J
D1km	1,000	150	99	23	29	5.4	3.4
Cm2dm	12,00-	1,260	604	85	44	46.4	35.4

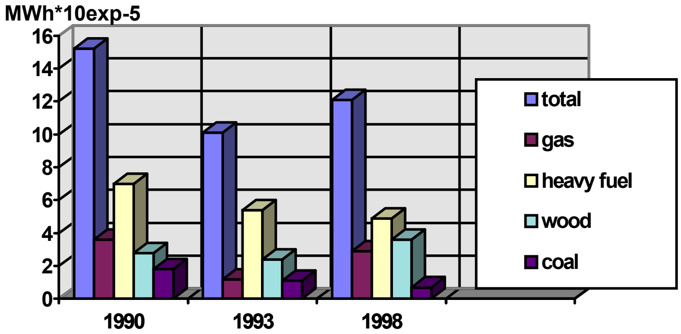


Figure 4. Heat consumptioin and this structure in Liepaja

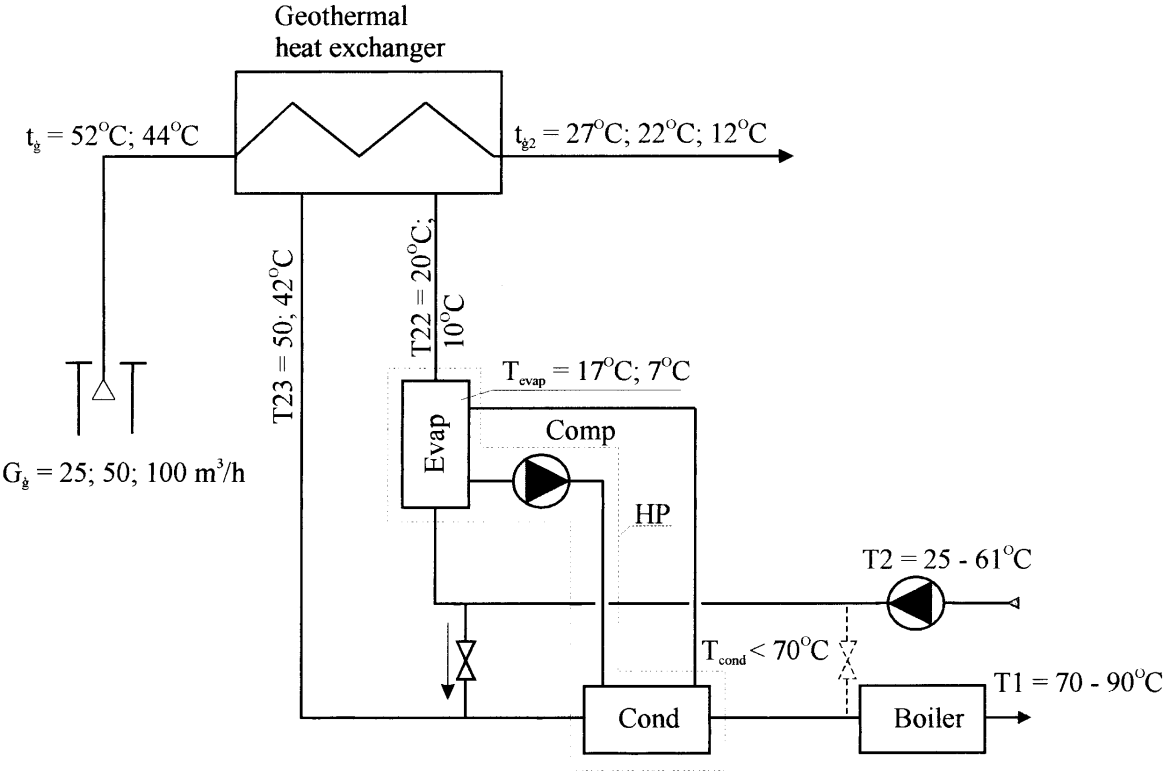


Figure 5. Sample of the suitable tecnologycal schemes of geothermal plant

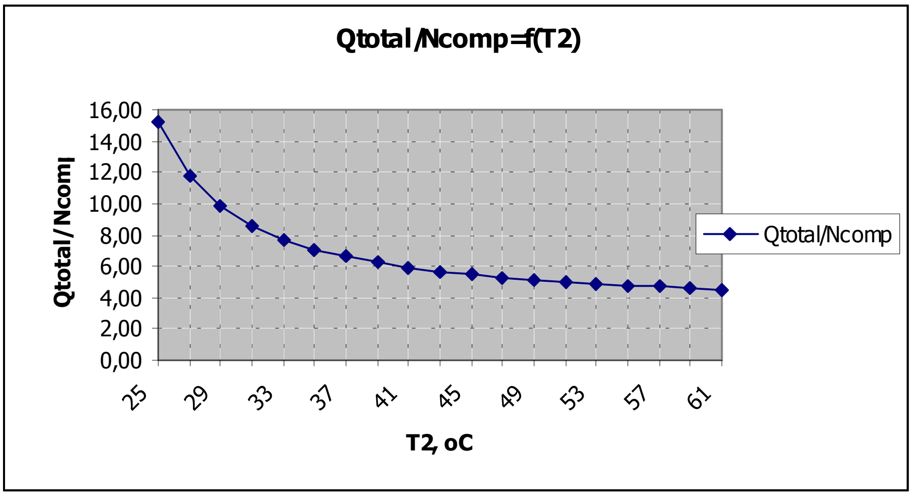


Figure 6. $Q_{total} / N_{comp} = f(T2)$

Table 2. Basic parameters of geothermal plants

Parameters	JELGAVA	LIEPAJA
Depth interval, m	1260 - 1325	1490 -1730
Static levet, m	-15	-13
Porosity, %	16	18
Permeability, mD	140	550
Temperature, °C	42	38-42
Volume of circulating water, m^3	100	200
Geothermal heat power, MW	4	8
Temperature of re-injecting water, °C	12	12
Produced annual heat energy, MWh/year	33,500	65,000
Heat energy produced directly from thermal water, MWh/year	19,950	42,600
Expenditure of energy of heat pumps, MWh/year	5,350	8,910
Heat pumps energy coversion coefficient	4,4	4.0
Number of hours per year of full capacity operation	6,030	6,350
Planned direct investment in average European prices, mio of USD	4.4	5.6