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Comparative Economic Analyses of the Utilization, of Geothermal Resources (Cambrian Deposit) in Latvia

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1. PRIMARY POWER RESOURCES AND THEIR POTENTIAL IN LATVIA

Latvia's consumption of primary power resources in the year 2007 was 193.6 PJ, which was ensured by local power resources and stream of primary resources from abroad. Solid fuel, petroleum products and electric energy are imported from a few countries and delivery regions, excluding natural gas, which is imported from only one country – Russia. Allocation of streams of resources draws attention to Latvia's relatively high dependence on imports – local resources supply only 36% of total consumption.

Latvia's potential of primary power resources consists of:

1.1 Biomass

1.1.1 Wood

Latvia is one of the most woody countries in Europe – on average 1.23 ha of wood per one inhabitant, which is 4.5 times more than in Europe on average.

Total wood volume in Latvia is 578 millions of cubic meters (in 2004). It has noticeably enlarged during post-war period as a result of increase of forest stand productivity and expanded areas (scrubby farmlands), as well as under influence of age structure. An average wood volume is m3/ha.

Average increase of wood per year is evaluated to the tune of 16.5 millions of cubic meters or 6.2 m3/ha a year. Large segment of this increase are bushes and wood of little value, which is not temporarily used.

Wood is the most significant local fuel in Latvia. Proportion of wood in Latvia's balance of primary power resources on 2004 was 30% of the total consumption of power resources. Wood is used in unitary, local and individual heat supply. Since mid-nineties fuel wood is exported also to several European countries and volume of wood export has an increasing trend.

1.1.2 Biogas

Biogas is coal gas, generated by the anaerobic fermentation of organic matter under anaerobic conditions and consists of on average 60-75% marsh gas (natural gas) and 25-40% CO_2 (carbon dioxide). Total production capacity of electric power production machine, which burns biogas, at present is 7.5 MW.

In accordance with data of estimation, executed in 2004, about volume of biomass resources, which can be used for biogas production, it is possible to extract about 290 millions of cubic meters of biogas, which is equivalent with approximately 5 PJ of power. Evaluating technical and organizing possibilities, total potential of biogas output per year is evaluated as 121 millions of cubic meters, from which around 2 PJ of power can be extracted.

Straws and by-products of agricultural production

In Latvia up to now straws extracted in the result of agro activity have not been taken as potentially significant kind of fuel. In Latvia only one boiler house, which uses straws as fuel, functions successfully. In Latvia total surplus of straws per year is evaluated within 150 and 570 thousands of tons (total economically accessible potential is about 2.2 PJ).

While production volumes of bio diesel increases, also big amount of by-products from rape processing appears, which are different organic matters (glycerine, fatty acids, hydrocarbons) with big heating capacity. Around 1400 tons per month of such mixtures of by-products of bio diesel production with other kinds of biomass is possible to use as fuel.

1.1.3 Biofuel

More widely-known kinds of biofuel are bioethanol and bio diesel as well as pure seed oil is used as motor fuel. At present there are three bio diesel manufacturing enterprises, which capacity is around 10000 t a year and 1 bioethanol manufacturing enterprise, which capacity is 9600 t a year in Latvia.

1.1.4 Hydroelectricity

The main Latvia's hydroelectricity's source Daugava is already largely used with set-up cascade of hydroelectric power station Daugava (hydroelectric power station Ķegums, hydroelectric power station Pļaviņas and hydroelectric power station Rīga). Electric energy is produced also in 149 small hydroelectric power stations.

Hydroelectric power resources of small rivers are between 150 and 300 GWh of electric power a year. Practically usable potential is significantly smaller, because demands of nature and landscapes' preservation impose certain restrictions on utilization of hydroelectric power. There are imposed restrictions on construction of small hydroelectric power stations on rivers significant for migration of fish species.

Output can be increased also in present small hydroelectric power stations by accordingly updating them. Their output of electric power could be increased by 10-20%, taking into account present financial and technical possibilities of hydroelectric power stations to implement new technologies.

1.1.5 Wind Power

In Latvia at present are set-up wind generators with total capacity 26.9 MW. Allocation of wind energy resources in Latvia is really irregular. There are marked areas with different annual average intervals of strength of wind – between 3.5 m/s till even more than 5.0 m/s in Latvia's wind atlas. An average theoretical potential per year is between 250 and 1250 millions of kWh.

To increase the potential of renewable power, set-up of wind generators in the sea is possible. Nevertheless, expenses of equipment and set up for such technological solution are higher.

1.1.6 Solar Energy

Solar radiance in Latvia has quite low intensity. Total amount of solar energy is 1109 kWh/m2 a year. Period of solar energy utilization is from April's last decade till September's first decade. During this period (approximately 1800 hours) it is possible to use solar energy, setting up solar collectors.

1.1.7 Oil in Latvia's Territory

Reposing on geological research about oil accessibility in Eastern part of the Baltic sea and Western part of Latvia's land territory, potential oil resources under Latvia's jurisdiction are evaluated up to 250 million barrels or 33-35 million tons. It will be possible to evaluate practical potential of oil output only after expansion of research and extractive works in land and the sea as well.

1.1.8 Household Waste

As amounts of household wasteare increasing, it can also give some input to total structure of primary resources. Waste as a kind of power resources can be used for burning and biogas extraction. Utilization of this resource is connected with improvement of waste management logistics and usage of modern burning technologies, which ensure standards of environmental protection. Evaluated usable potential is approximately 4.5 PJ.

1.1.9 Geothermal Energy

In general from the point of view of utilization of geothermal energy territory of 12,000 km2 is perspective. The main potential of geothermal waters is situated in Latvia's East-western part and is in depth of 1300 – 1800 meters.

1.1.10 Peat

Peat is singular, geologically new organic formation, which has developed from plants died off in too wet and oxygen poor environment and is usable as fuel. There is gathered information about 6.8 thousands swamps in Latvia, in which peat resources reach 1.5 milliards of tons. Peat resources usable in power industry are evaluated to the tune of 230.4 millions of tons or approximately 2387 PJ.

2. PRIMARY POWER RESOURCE UTILIZATION

Strategy of delivery and utilization of primary power resources is important element of state infrastructure and environmental policy as well as significant factor for economic competitiveness and development in the future. Phase and speed of economic development determine demand of power, but at the same time situation of power supply system, effectiveness of its operation and supply security determine possibilities of economic development and competitiveness.

Latvia's consumption of primary resources is ensured by local and renewable (wood, peat, straws, hydroelectricity resources, wind, biomass and biofuel) and imported power resources (oil products, natural gas, coal etc.). Latvia, in common with many other European Union countries, is dependent on import of primary resources. Nevertheless, Latvia's dependence has decreased within last 15 years from 86% (year 1990) to $64 (year 2004), mainly due to increase of utilization of wood resources.

Total consumption of power resources in Latvia has experienced significant changes within last 19 years. Since 2001 it has become stable within 180 PJ and within last couple years high GDP growth rate has caused also a little increase in it.

Approximately 45% of the total consumption of primary power resources are utilized in transformation sector for producing electric power and thermal energy. More than 20% of the total consumption of primary power resources consists of fuel necessary for transport sector. That draws attention to the sector's significant influence on structure of primary resources and increase of role dependency on import.

At present renewable resources occupy an important place in Latvia's balance of primary power resources. Main resources, which are widely utilized, are wood and hydroelectricity resources, less – also wind power, straws and biogas. Proportion of renewable resources in supply of power resources has increased from 28% (year 1996) to 36% (year 2007). Nevertheless, there still exist undigested potential, which effective utilization can make a contribution to diminishing of Latvia's dependency on imported primary resources. Geothermal energy is one of such resources.

3. GEOTHERMAL PILOT PROJECT "ELEJA"

In Latvia geothermal waters are with low enthalpy, that is why its utilization has to be economically substantiated and realizing geothermal power projects possibly larger amount of potential of geothermal power has to be used.

To evaluate utilization possibilities of geothermal energy in Latvia, a pilot project in Eleja rural municipality had been started. Option of Eleja rural was determined by geothermal potential of water as we can see in figure 5.

Utilization of geothermal energy in Eleja is possible in a few ways:

- Heat supply and cooling, including also district heating;
- Swimming pools, baths, saunas and balneology;
- Agriculture;
- Aquaculture;
- Production.

There are not big heat energy consumers in Eleja, besides the whole rural municipality is extended in large area. Basic load for construction of geothermal station and executing calculations will be carried out by renovated Eleja palace's manor houses, involving also other consumers of heat energy and developing district heating.

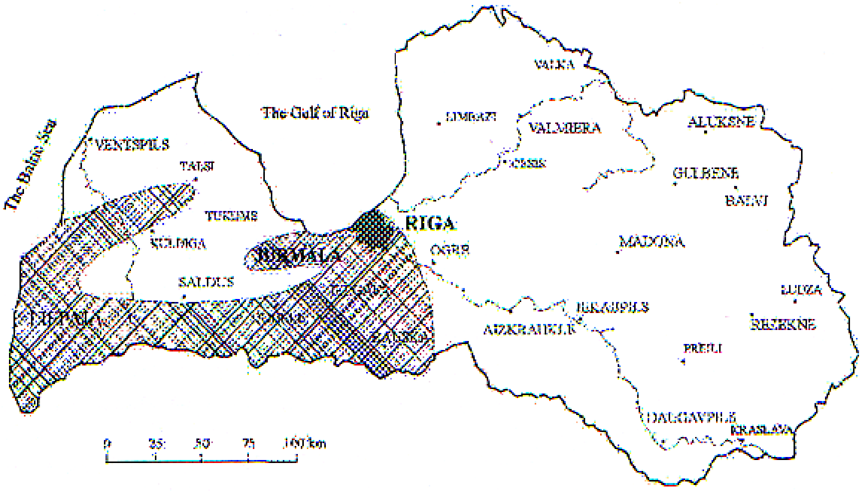


Figure 1: Potential of geothermal energy in Latvia.

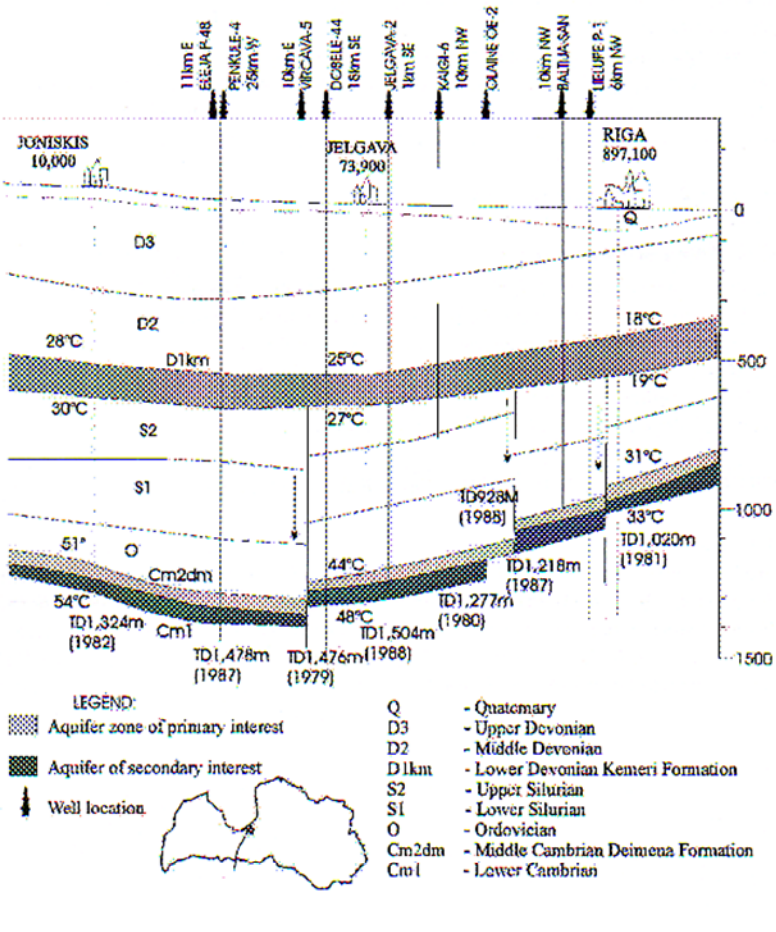


Figure 2: Geothermal energy anomaly in Latvia.

Evaluation of heat energy loads was divided in following way:

- Variable of minimal or basic heat energy loads; (500 kW)
- Variable of average heat energy loads; (2200 kW)
- Variable of maximal heat energy loads. (3250 kW)

Basing on these data utilization of geothermal energy in Eleja rural municipality could be developed in three different ways:

- Utilizing geothermal water from 200 – 250 metres deep port, ensuring heat supply with heat pumps per separate consumers (basic variable of heat energy loads) (GEO-1). Necessary investments – 290’000 euros.
- Utilizing geothermal water from 500 – 650 metres deep port, constructing centralized heat supply

system and with heat pumps ensuring common heat supply for a few buildings, recreation centre with a pool, hospital and fishpond (middle variable of heat supply loads) (GEO-2); Necessary investments – 900,000 euros.

- Utilizing geothermal water from 1200 – 1350 metres deep port, constructing cascade type heat supply and ensuring centralized heat supply for a few buildings, pools, hospitals and fishponds (maximal variable of heat supply slots) (GEO-3). Necessary investments – 2,500,000 euros.

Evaluating technological solutions in Eleja rural municipality utilizing geothermal energy technologically – economic aspects were taken into account. Technical solutions were made basing on qualities of accessible geothermal resources, mainly on chemical structure, temperature and pressure of geothermal water.

There are a few different economic aspects of utilization of geothermal energy and fossil fuel in heat supply systems. In utilization of fossil fuel is comparatively more expensive, besides for utilization of geothermal energy bigger capital investments are necessary. Utilization of geothermal energy is economically more profitable, if potential of geothermal water us used as much as possible.

Developing utilization of geothermal energy following economic circumstances has to be taken into account:

- Large proportion of investments in geothermal energy systems construction consists of drilling works, which expenses are quite high in comparison with costs of steam-shop construction.

- For geothermal energy systems major proportion of maintenance expenses consists of water pumping expenditures, but for geothermal water with lower enthalpy potential major part of expenditures consists of electric power expenditures necessary for operation of heat pumps.

To execute necessary evaluation of power resources in Eleja rural municipality ENEP model was used. ENRP (Energy and Power Evaluation Program) MS Windows model is processed ENEP model's DOS version, which was worked out by Argonne National Laboratory – ANL supported by USA Department of Energy and International Atomic Energy Agency - IAEA.

The central requirement of a comprehensive energy analysis is the evaluation of alternative configurations of the energy system that will balance energy supply and demand. The BALANCE module of ENPEP for Windows is designed to provide the planner with this capability. BALANCE uses a non-linear, equilibrium approach to determine the energy supply and demand balance. For its simulation, the Model uses an energy network that is designed to trace the flow of energy from primary resource (e.g., crude oil, coal) through to final energy demand (i.e., diesel, fuel oil) and/or useful energy demand (i.e., residential hot water, industrial process steam). Demand is sensitive to the prices of alternatives. Supply price is sensitive to the quantity demanded. BALANCE seeks to find the intersection of the supply and demand curves as illustrated by Image 1.6. In its operation, BALANCE simultaneously tries to find the intersection for all energy supply forms and all energy uses that are included in the energy network. The equilibrium is reached when the model finds a set of prices and quantities that satisfy all relevant equations and inequalities. The simulation time step is one year for up to 75 years. However, the Model is typically used to analyze a 20 to 30-year forecast period.

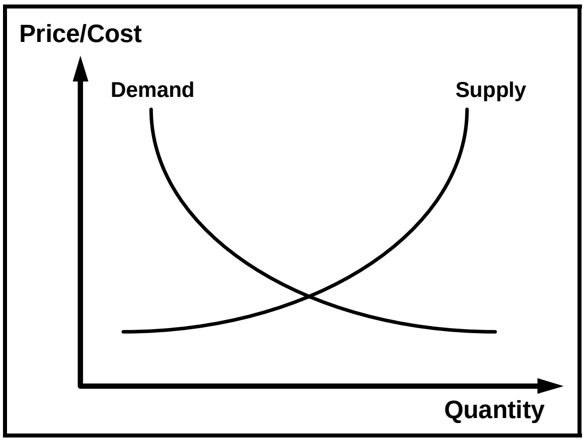


Figure 3: BALANCE Supply and Demand Curves.

The energy network represents all energy production, conversion, transport, distribution, and utilization activities in a country or region, as well as the flows of energy and fuels among those activities. The energy network is constructed with a set of submodels or building blocks, called nodes (see Image 1.4. for available node types and their symbols). The nodes of the network represent energy activities or processes, such as geothermal energy. The user connects the nodes with a set of links. The links represent energy and fuel flows and associated costs among the specific energy activities. Links convey this information (i.e., price and quantity) from one node to another. The energy network is developed by defining the energy flows among the different types of nodes for a given base year. All sectors of the energy supply and demand system are included in a typical BALANCE analysis.

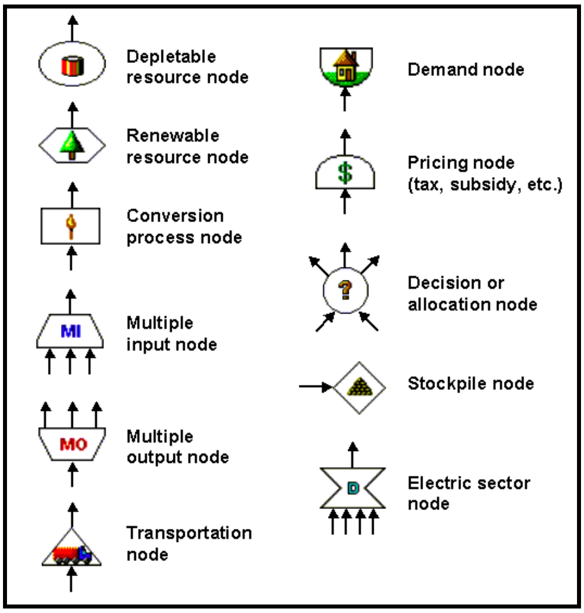


Figure 4: BALANCE Nodes

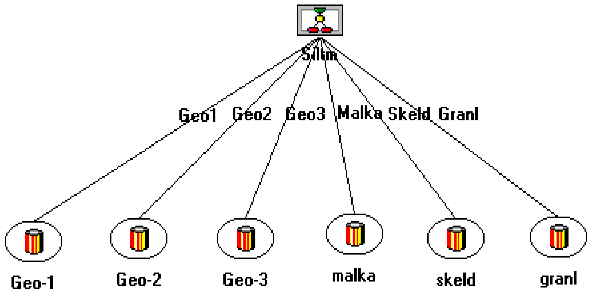


Figure 5: Renewable energy sector. In ENPEP model was included tree geothermal energy variants GEO-1, GEO-2, GEO-3 and wood, pellets and wood chips.

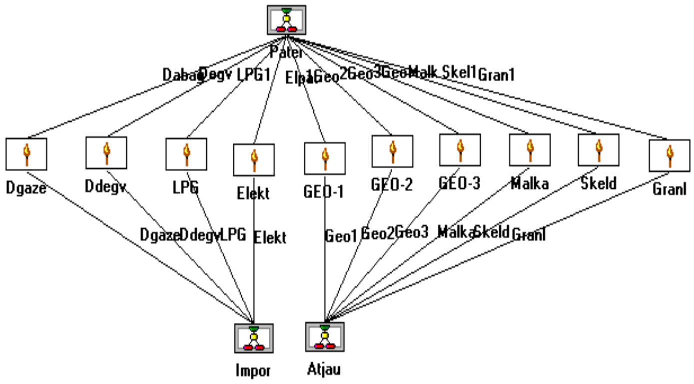


Figure 6: Heat supply sectors were modeled to imply all energy conversion processes, included price of technology, maintenance; efficiency and life cycle.

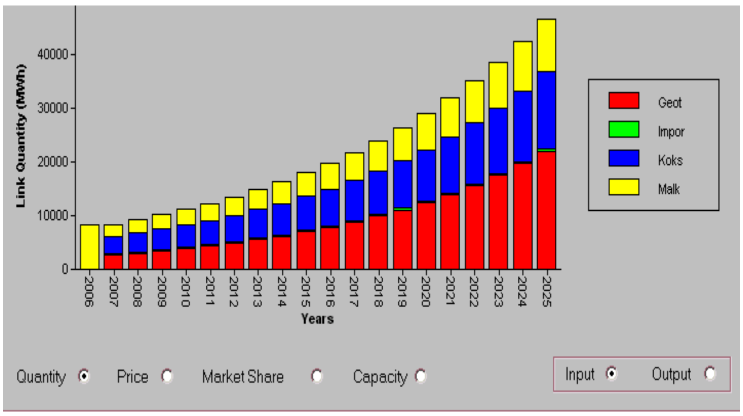


Figure 7: Heat supply demand analysis results of ENPEP model, in first year's model choice wood and geothermal energy, but after increase of energy demand model choice more and more geothermal energy. Imported energy resources model were choice very small part.

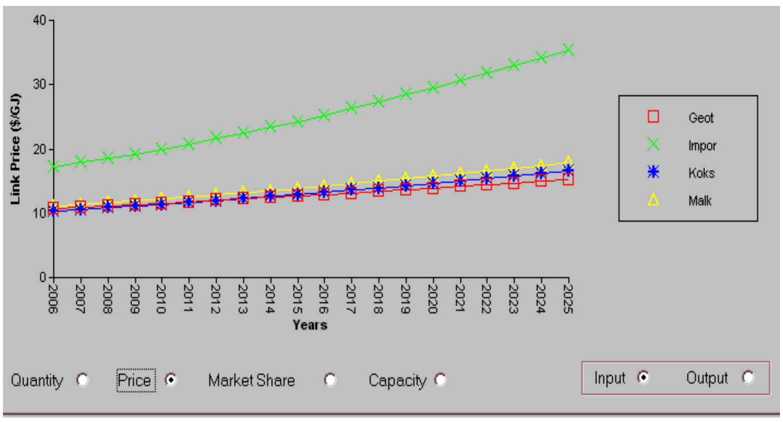


Figure 8: Comparison of singular heat energy expenses.

Singular expenses per one heat energy unit determine most gainful version of heat energy production, depending on kind of utilized power resources. Highest heat energy expenses are for imported kinds of fuel, which include – natural gas, derv, liquefied gas and electric power resources.

Besides expenses of geothermal energy only during first years are a little higher than expenses of utilization of firewood, nevertheless, along with increase of demand of heat energy and in the course of time expenses of geothermal energy is the most gainful version.

Increase of geothermal energy, which little by little covers proportion of firewood, is obvious by division of market shares.

During the project using results of ENEP models expenses of heat energy were compared depending on project time period and demanded amount of heat energy.

Singular heat energy expenses include expenditures of power resources, capital investments, equipment operation and maintenance, including also personnel salaries.

Evaluating the findings the lowest heat energy expenses are for utilization of firewood, nevertheless, if capacity increases up to 2 MW heat energy price for firewood almost equalizes with technological solutions GEO-2 and GEO-3 of geothermal energy utilization. If heat energy capacity increases, starting from 2 MW the most profitable version is utilization of geothermal energy and starting from 2.5 MW the cheapest version is utilization of geothermal energy GEO-3 technical version.

The next evaluation of heat energy expenses is depending on project time period, during which cover of in projected, invested investments are planned. At 1 MW heat energy load geothermal energy starts to compete with firewood resources only starting from 20 years and within 25 years period GEO-2 technical version is the most profitable with heat energy price 17.30 LVL/MWh.

At 1.5 MW heat energy load total singular heat energy expenses are lower than at version of 1 MW load, nevertheless, in common with previous graph, geothermal energy GEO-2 technical version is the most gainful within 25 years long period.

As it is seem by executed analyses utilization of geothermal energy in the Republic of Latvia is economically profitable.

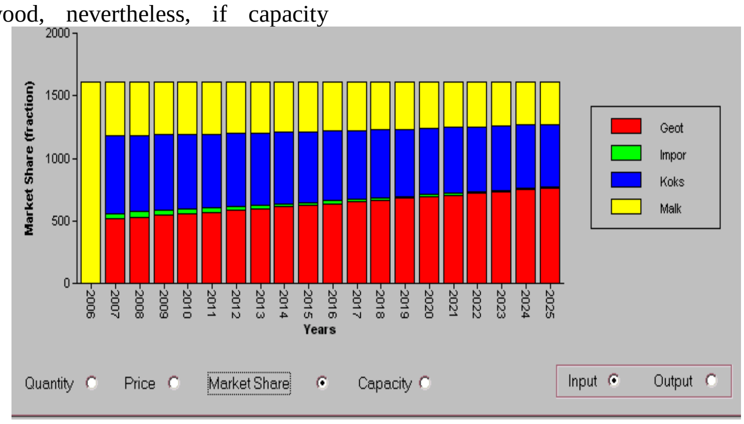
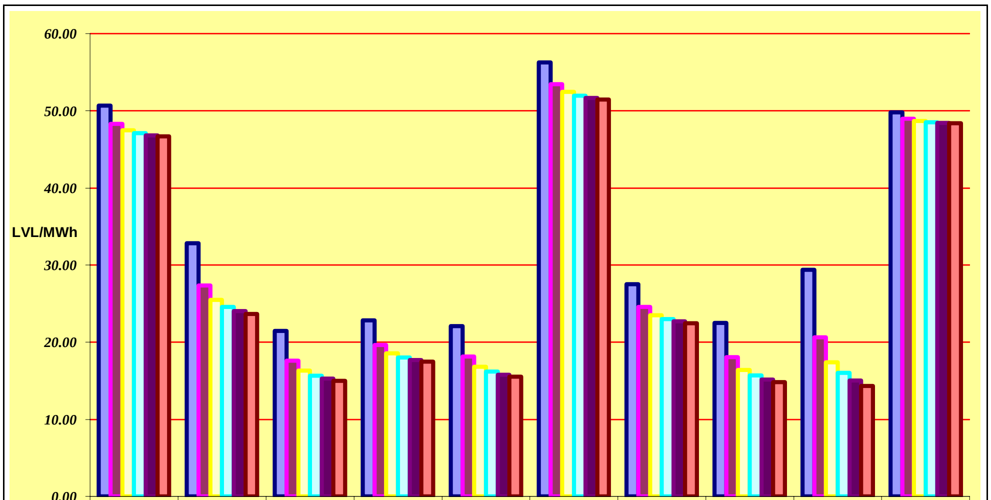
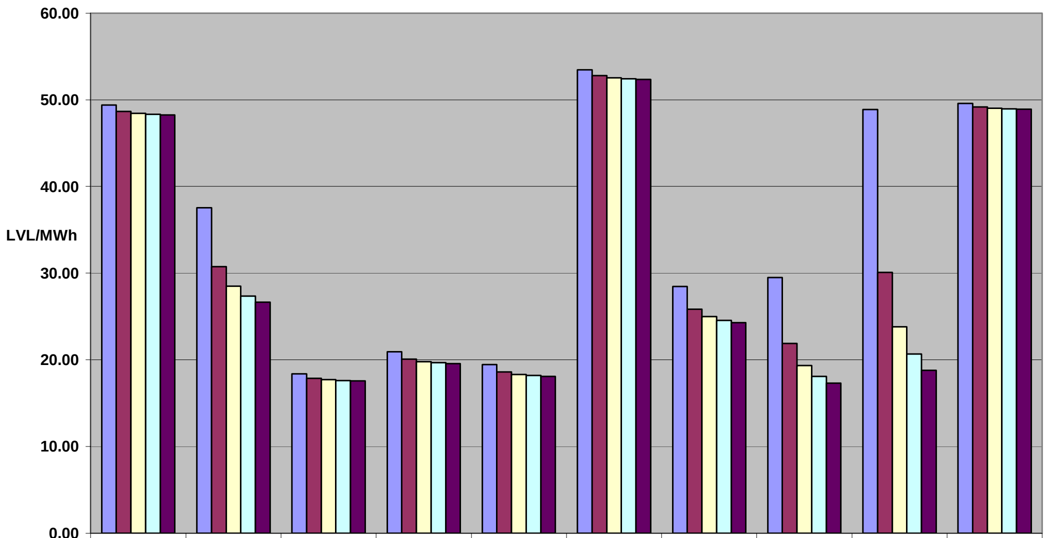


Figure 9: Division of provision of heat energy.



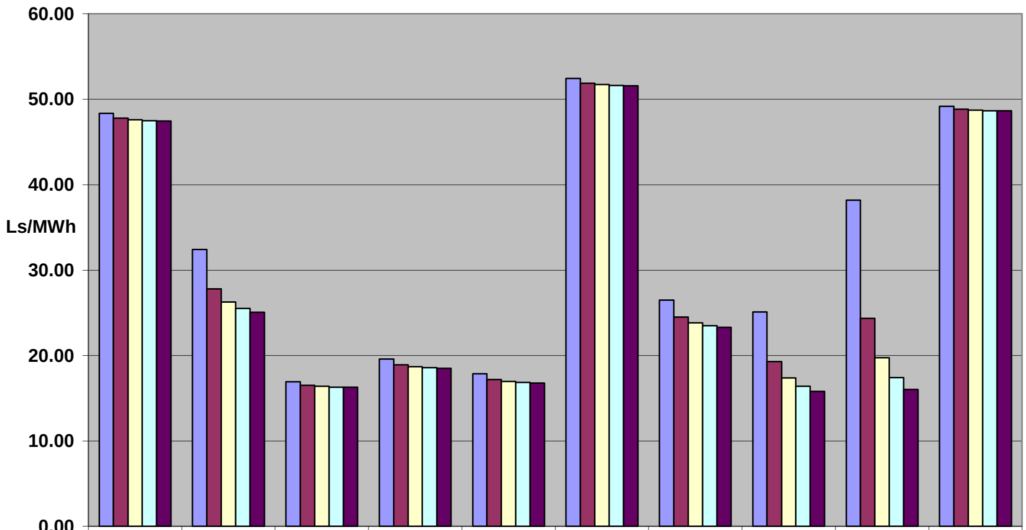
	LPG	Natural Gas	Wood	Pellets	Woodchip	Diesel	Geo 1	Geo2	Geo3	Electricity
500 kW	50.70	32.85	21.47	22.82	22.09	56.28	27.53	22.52	29.40	49.79
1000 kW	48.31	27.35	17.62	19.64	18.17	53.46	24.55	18.06	20.66	48.96
1500 kW	47.49	25.50	16.32	18.56	16.83	52.44	23.49	16.40	17.42	48.66
2000 kW	47.09	24.59	15.68	18.04	16.19	51.99	23.01	15.70	16.04	48.53
2500 kW	46.84	24.03	15.28	17.71	15.78	51.67	22.69	15.17	15.02	48.44
3000 kW	46.67	23.66	15.02	17.49	15.51	51.45	22.47	14.82	14.34	48.38

Figure 10: Comparison of singular heat energy expenses depending on kind of utilized power resource and capacity changes.



	LPG	Natural Gas	Wood	Pellets	Woodchip	Diesel	Geo 1	Geo2	Geo3	Electricity
5 years	49.39	37.55	18.38	20.93	19.45	53.46	28.45	29.50	48.88	49.58
10 years	48.67	30.75	17.87	20.07	18.60	52.77	25.85	21.88	30.06	49.16
15 years	48.43	28.48	17.70	19.79	18.31	52.54	24.98	19.33	23.79	49.03
20 years	48.31	27.35	17.62	19.64	18.17	52.42	24.55	18.06	20.66	48.96
25 years	48.24	26.67	17.57	19.56	18.08	52.35	24.29	17.30	18.78	48.92

Figure 11: Comparison of singular heat energy expenses depending on kind of utilized power resource and project time period changes (1.0 MW).



	LPG	Natural Gas	Wood	Pellets	Woodchip	Diesel	Geo 1	Geo2	Geo3	Electricity
5 years	48.35	32.40	16.92	19.58	17.86	52.44	26.48	25.10	38.18	49.16
10 years	47.77	27.80	16.52	18.90	17.18	51.88	24.49	19.30	24.34	48.83
15 years	47.58	26.27	16.38	18.67	16.95	51.70	23.83	17.37	19.73	48.72
20 years	47.49	25.50	16.32	18.56	16.83	51.60	23.49	16.40	17.42	48.66
25 years	47.43	25.04	16.28	18.49	16.76	51.55	23.30	15.82	16.04	48.63

Figure 12: Comparison of singular heat energy expenses depending on kind of utilized power resource and project time period changes (1.5 MW).

4. CONCLUSION

1. Potential for geothermal energy utilization exist in many regions of Latvia, but its real utilization is possible only after economic and technical investigation of energy availability recourses is completed.

2. Geothermal underground water in Latvia is characterized by low enthalpy. However, this type of underground water has been utilized in Germany, Denmark, Sweden, Lithuania other European countries. This provides a model for underground water utilization in Latvia.

3. A pilot project in a small rural district Eleja that is described in the paper illustrates, which

geothermal energy utilization is economically efficient only if this source of energy is of long-term period and minimum of 10 years long. Additional requirement concerns energy consumption power that should be higher, than 1 MW.

4. The above mentioned experience and pilot project of Eleja provides an example and method that could be used in the other similar regions of Latvia. At the same time, it should be taken into account that this method has to be adapted to the other regions' geothermal water conditions.

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