# Geothermal Energy Competiveness in Latvian Heat Market

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## ABSTRACT

Analysis of the energy development tendencies and demand for energy, which is especially characterised for the 21 century, shows a number of problems. One of the most important is the proportion of the use of different types of energy resources. The answer to this problem depends not only on the existence of energy resources, but rather on competitiveness of technologies employed, traditional energy resources, and renewable resources, especially geothermal resources. Equally important factors are the market situation and market regulation. The competitive situation in the Latvian heating market has been a debated topic during the last years, not the least considering the large price differences regarding district heating in different Latvian regions.

## 1. INTRODUCTION

The regulation in the Latvian district heating market was due to that the market can be considered as a natural monopoly. These services have earlier been owned by the state or the municipality. After the deregulation of the district heating market, some of the earlier state owned companies were now sold to private companies. The competitive situation in the Latvian district heating market has been a debated topic during the last years. This is due to the still existing state price regulation and the need for diversification of energy sources used.

### 1.1 Characterise of heat market

The heat market is characterized by the fact that it cannot be analyzed as a single unified national market. The total national heat market should be seen as a set of the local heat market. Therefore, the analyses of the local heat market influencing forces are very critical not only for state and municipality leaders, but also for private investors to make reasonable investment decisions. From the point of economic theory view, the local heat market can be described as natural monopoly. The natural monopolies are specific to sectors with a very high proportion of fixed costs; heat production is one of them. From one side the monopoly of the heat supply to the market, on the other hand it is a monophony in the energy supply.

Theoretically the heat market can be divided into several business models that determine the competitive situation:

- The heat supply through wholesalers. In this model the heat is supplied by the producer to the wholesaler heat collector. The cost of delivered heat in accordance with the rates is set by the public regulator.

- The heat producer supplies the heat to final consumers. In this model the generating company owns both the trunk and the heat distribution networks or whether they are rented. In this model intermediaries are eliminated.

- The heat producer supplies the heat to final consumers through infrastructure owned by other companies. This model is essentially slipped into the potential conflicts that are very difficult to enforce.

Coming into existence of different models are related to several factors. As the essential can be stressed:

- Privatization. In Latvian as well as in all post-communist countries the producers of heat and owners of infrastructure belonged to the local government or municipalities, which ruled out any competition. Privatization led to the creation of the necessary conditions for competition.

- The development of technology gave the possibility to create a new type of competition, that is, competition between centralized heat production and private heat production.

- Whatever the business model is used in the heat market, the main problem for producer of the heat and distribution companies is gain of profit. Although the privatization had been done, the heat tariff determination is still in the responsibility of the state and municipality authorities. In the heat tariff determination a major role is played not only by economic situation but also by social and political factors. Therefore very Costs of the heat production can be reduced using new more effective technologies for generating heat or incorporate in economic mainstream of new forms of energy use. Therefore the heat market development is largely related to competition in the market of energy resources. In Latvian as well as in the European Union the main focus is on the use of local renewable energy resources.

## 2. CHARACTERISE OF LATVIAN GEOTHERMAL RESOURCES

Increased temperature in cambrian system sediments are found in areas of Elejas and Liepaja. Latvian territory sedimentary and crystalline basement prospecting data obtained on a rock thermo physical properties and temperature at different depths and geological cut parts as well as certain underground heat flow and structural characteristics of the earth crust.

Sedimentary rock temperature is mainly determined by the earth's internal heat flow intensity which differs in different Latvian regions. In Latvia the heat flow value is from 20 – 30 till 70 – 80 W/m2. In Latvia the largest heat flow in the central part but the maximum size of that is in the area of Eleja. A large heat flow can be attributed to a specific type, so-called proto oceanic Earth crust sections, which due to small changes in those original conditions have a high thermal conductivity. Another important factor is that in these stations the Earth's crust is significantly thinner and that upper part gets more under the mantle heat flow.

The heat flow values are measured by the geothermal gradient and the sedimentary rock cover permeable to water (ordovic and evonian) rock thermal conductivity coefficients. According to estimates it is believed that in Latvian sedimentary rock blanket flows in 6.9x10 / 7 GJ of heat energy per year, which corresponds to 2.3 mio t of the relative amount of fuel.

In Latvia the highest temperature is found in sedimentary rocks of Cambrian bottom Kurzeme's Elejas – Jelgava destinations (+40 – 57 ° C) but the highest temperature (> 25 ° C) is characterized by the following general areas adjusted to those regions of about 18'000 km2 in area. Also sub devonian rocks have higher temperature (+25 – 30 ℃ or even more) in areas of Jelgava and Eleja.

Based on the permeable to water rock temperature, the thermo physical properties and heat flow intensively is set the amount of heat energy in sedimentary rocks as well as from that extractable part – geothermal resources. Geothermal resources have been estimated in accordance with the recommendations of the European Commission, by following these conditions:

- The temperature of underground water horizon sedimentary is more than +30 ° C

- Rock-water flow ratio is more than 5m2/d.n.

Based on these criteria's have been identified the most promising areas of getting geothermal resources, that are located in Liepaja and Jelgava – Elejas' area. For production of geothermal energies the most perspective is upper part of middle Cambrian -Deimena, Tebra and Ovishi suites with water saturated sandstones. General information – the spread of the area, heat flow, and amount of thermal and geothermal energy resources- is shown in the table below.

| Name of district | Area, km$^2$ | Heat stream per year, Jx10$^{-15}$ | Layer heat energy resources, Jx10$^{-15}$ | Geothermal resources, Jx10$^{-15}$ |
|---|---|---|---|---|
| Liepāja | 1'764 | 3,00 | 11'010 | 1'990 |
| Eleja | 4'808 | 9,10 | 34'990 | 3'770 |
| **Total** | **6'572** | **12,10** | **46'000** | **5'760** |

**Figure 1: Geothermal resources in Latvia**
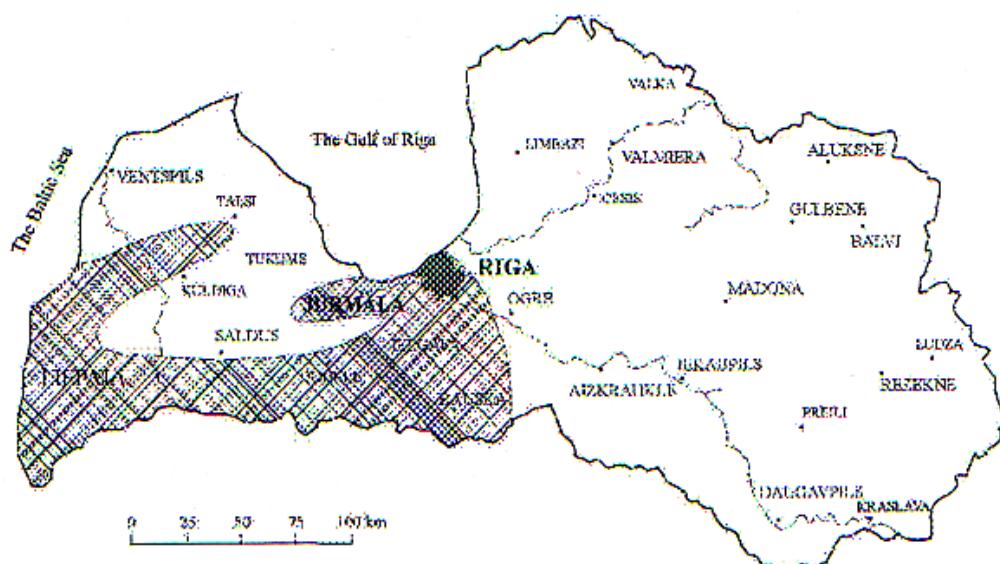


**Figure 2: Latvia's geothermal resource geographical placement**

## 3. GEOTHERMAL RESOURCES USAGE TECHNICAL CAPABILITIES

Technically, there can be several schemes to realize economically capacious projects and acquire geothermal waters with higher enthalpy.

Realizing the geothermal project it is required that geothermal waters must be used optimized all year around including the summer season, so it is needed to attract and to interest other area's energy consumers.

By the fact that geothermal resources are located in that part of Latvia that is not widely populated, it cannot be centralized heat supply over all country due to the lack of large consumers. That's why the geothermal energy is used by cascade type. However, it should be noted that this area has a great potential which development can be succeed by use of the geothermal energy.

The use of geothermal energy can be developed in several directions. Can be emphasized three geothermal power usage technical options in Latvia:

- The first option (GEO -1) - using geothermal waters from about 1,350 meters deep drill creating a cascade type heat supply and providing centralized heat supply for social sector and other objects in a small compact area (pools, agriculture) (using geothermal water at 54oC)

- The second option (GEO -2) - using geothermal waters of about 1,350 meters deep drill creating a cascade type heat supply and providing centralized heat supply for urban area and for other purposes (geothermal water temperature is raised to 75oC using heat pumps)

- The third option (GEO -3) - using geothermal waters from 2000-4000 meters deep drill if it is possible to get water at a temperature of 100 - 120oC, it is possible to make cogeneration station that would use steam for electricity generation, followed by a cascade type heat supply to provide centralized heat supply to the city and other consumers.

In all three versions of the heat load assessment was divided into following types:

- Minimum load option - a geothermal station with a capacity of 5 MW

- The average heat load option - a geothermal station with a capacity of 10 MW

- The maximum heat load option - a geothermal station with a capacity of 20 MW.

This approach provides not only technical analysis but also gives a base for competitive analysis.

## 4. ECONOMIC EFFICIENCY

Economic efficiency determines competitiveness. By implementation of geothermal projects must consider that initial investments are very high and this should be done in a relatively short period of time. Besides it is not possible to launch a full functioned geothermal station without fully equipped. The most important part of investments is drilling arrangement which includes the drilling placement and installation of pumping systems. However, it should be noted that the large initial investments are compensated by relatively low operating costs. . Investments and costs were calculated in current prices, taking into account the proposals from interested firms.

| Technical variant | 5MW | 10MW | 20MW |
|---|---|---|---|
| GEO-1, EUR | 5'600'000,00 | 6'900'000,00 | 8'400'000,00 |
| GEO-2, EUR | 8'600'000,00 | 9'800'000,00 | 10'600'000,00 |

**Figure 3: Amount of investments**

Technical variant GEO-3 was not discussed due to lack of the geological information. The geothermal project has the advantage that the amount and time of investments are compensated with low running costs. The operating costs are primarily associated with the pump system and heat pump operation. If is used the peak load equipment then appears expenses related to the supply of fuel for the equipment. Maintenance costs, salaries and other costs make a small part of all costs. The version of GEO-1 is not intended for the use of heat pump thus significantly decreases costs. Since both the pump system and the heat pump uses electricity, costs are very influenced by the price of electricity. As the fuel's that is used for peak load operating equipment, the volume is small, and then the impact on the price changes is negligible.

| Technical variant | 5MW | 10MW | 20MW |
|---|---|---|---|
| GEO-1 (EUR/year) | 989'800,00 | 1'307'600,00 | 2'018'800,00 |
| GEO-2 (EUR/year) | 4'069'800,00 | 4'667'600,00 | 8'738'800,00 |

**Figure 4: Present costs**

The methodology of economical evaluation of the geothermal energy bases on the discounted cash flow. Assuming that:

- The duration of the project is 20 years. This assumption is based on the used equipment usage life.
- The discount rate base - 10% that relates to the fact that the project in Latvian conditions can be considered as innovative.

Were calculated leverage energy costs for each option, it is a minimum price for which the energy can be realized.

|                | 5MW   | 10MW  | 20MW  |
|----------------|-------|-------|-------|
| LEC (EUO/MWh)  | 58,53 | 35,83 | 23,34 |

**Figure 5: Leverage energy costs GEO-1**

|                | 5MW    | 10MW  | 20MW  |
|----------------|--------|-------|-------|
| LEC (EUR/MWh)  | 130,11 | 89,84 | 69,63 |

**Figure 6: Leverage energy costs GEO-2**

Stated variants show the sensitivity of the project in connection to geological factors.

As can be seen from tables the more cost effective is direct use. In both versions 5MW station is not effective economically. But 10MW and 20MW station in GEO-1 variant is more attractive, but taking into account the geological situation it is highly possible that with two drillings will not be enough. That is why for further analysis was carried out calculations of 10MW and 20MW geothermal station in GEO-1 version but with four drillings.

|                | GEO-1A (10MW) | GEO-1B (20MW) |
|----------------|---------------|---------------|
| LEC (EUR/MWh)  | 43,11         | 26,98         |

**Figure 7:**

Competitors' who use other energy sources, heat costs which are determined in accordance with the present legislation varies from about 62,00 EUR / MWh to 86,00 EUR/ MWh. Then it can be assumed that the energy of geothermal is competitive. At these prices IRR =11% and the repayment period is from 10 to 16 years which can be considered as acceptable performance. The analysis of the discounted cash flows shows that the repayment period ranges from 10 to 12 years. It can be considered as a very good indicator.

## 5. ENPEP MODEL SCENARIOS AND RESULTS

To test the competitiveness of geothermal energy analysis was performed using ENPEP BALANCE model.

ENPEP (Energy and Power Evaluation Program) MS Windows model is recycled ENPEP DOS version of the model, which was created by Argonne National Laboratory with the United States Department of Energy and the International Atomic Energy Agency support .The model scheme given in Fig 2.  ENPEP model used to perform the following tasks:

- trace the flow of energy through the entire energy system from energy extraction, through processing and conversion to useful energy demand (e.g. for heating, transport, electricity);
- To identify future energy supply and demand balance is based on the assumption of market simulation of non-linear algorithm and the operator of decentralized decision-making;
- Plan alternative energy production technology balance of the market, such as a variety of new generating capacity of the electricity and heat market;
- Assess the rates and impact on the environment combined with the planned development of the energy system.

BALANCE model works with the energy sector network consisting of nodes and links. Nodes denote processes (such as geothermal energy extraction), as long as the link shows the energy flow between the nodes. Energy Network is designed to determine the flow of energy between the 10 different types of systems. Each node represents a different type of program sub-module, which is used in certain equations invoice price and the flow of energy and node introductory output. The model used for the node types are described in Fig 9.
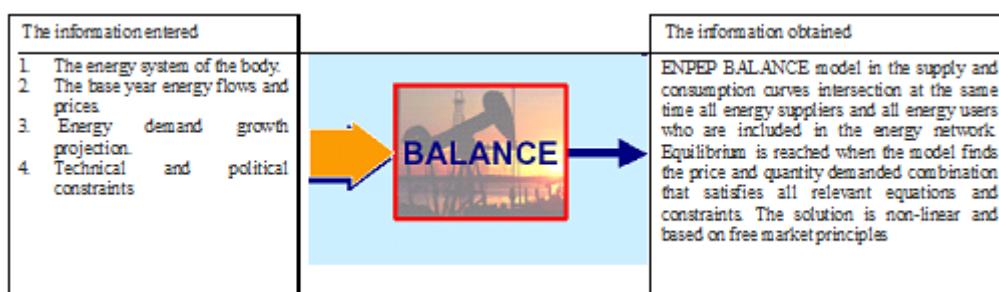


**Figure 8: ENPEP BALANCE Scheme**

BALANCE model, processed at the same time non-linear systems of equations and constraints. This relationship is determined by the input parameter combinations, with the energy network each node, specifying the quantities and prices of energy through the conversion of energy production, processing and use of the various stages. Equilibrium model, which captures the energy network, is obtained by finding the energy price and the quantity of kits to meet all the essential equations and constraints.
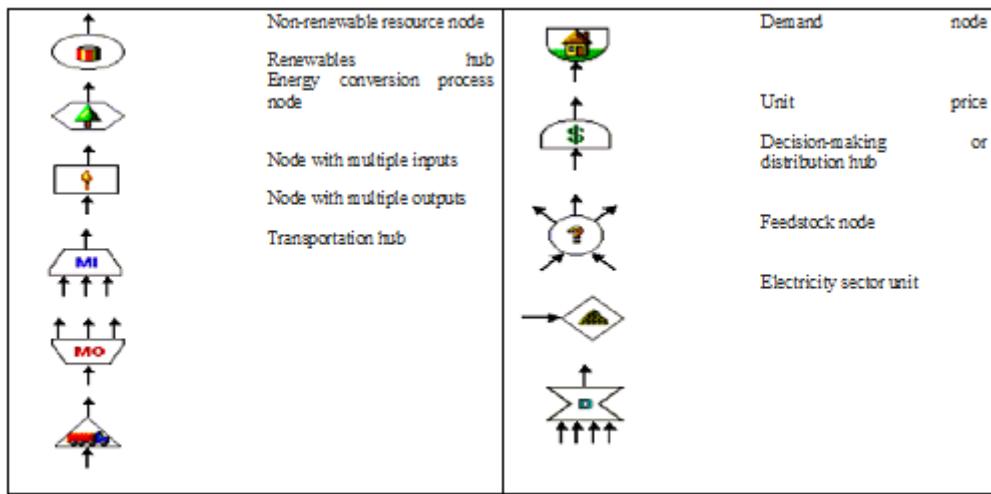
**Figure 9: ENPEP BALANCE model used in nodes**

Finding a solution to the model, the network is based, requires a fuel value of the initial assessment of imported and produced in quantity. Then fuel prices for each subsequent link to go up over the network, they are calculated with the price of certain equations at different nodes. Are then calculated for all quantities of the equations combined with the nodes, the following link went up over the network. If all the equations are satisfied with the network at the beginning of the estimated quantities of the model solution will be found. Otherwise, amounts are based on the network is automatically adjusted and all the equations are solved again. This iterative process continues until the amount of the value obtained in the corresponding underlying network nodes.
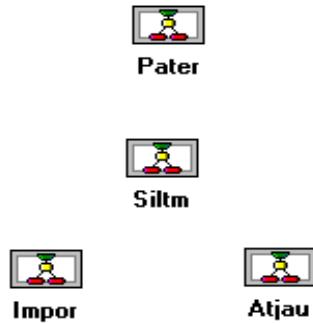


**Figure 10: ENPEP model sector**

Geothermal Energy assessment Latvian, ENPEP model is modeled using four key sectors - imported energy sector (Impor), the renewable energy sector (Atjau), heat production and heat supply security sector (siltm) and the consumer sector, which includes the heat supply and heat consumers demand.
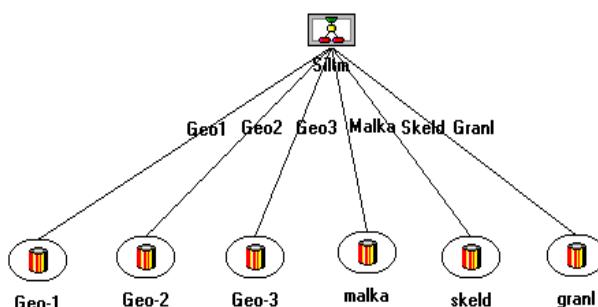


**Figure 11: Renewable energy sector**

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ENPEP Model renewable energy sector were included in the three geothermal technical options - GEO-1, GEO-2, GEO-3 and fuel uses of wood (firewood (malka), wood chips (skeld) and pellets (grant)).
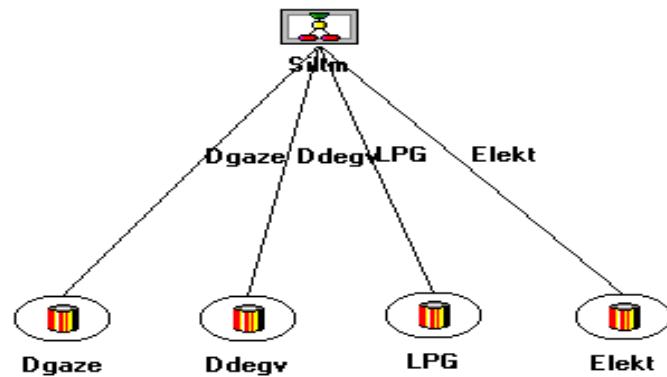


**Figure 12: Imported energy sector**

Of imported energy sector includes natural gas (Dgaze), fuel oil (Ddeg), liquefied gas (LPG) and electricity (Elekt) can be used.
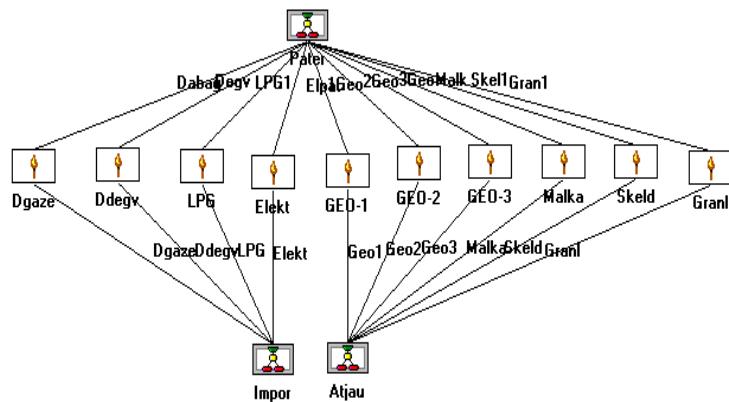


**Figure 13: Heat supply sector**

The heat supply sector (silt) is modeled to include the entire energy conversion heat production, including technology costs, and operating and maintenance costs, operation and technology efficiency ratio indicators.
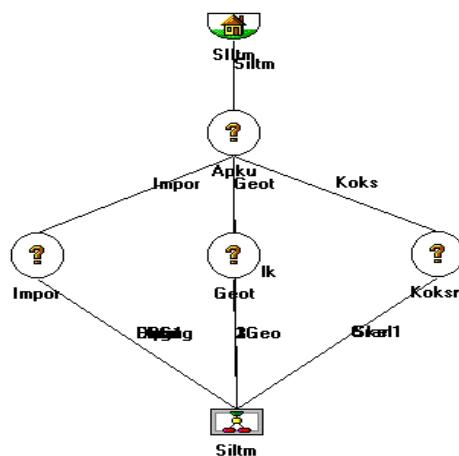


**Figure 14: Consumer sector**

The consumer sector was included in the heat consumer unit, which was defined as consumption of heating energy demand and the choice of the units - imported energy (impor), geothermal energy, technical options and fuel wood (koksn) use.
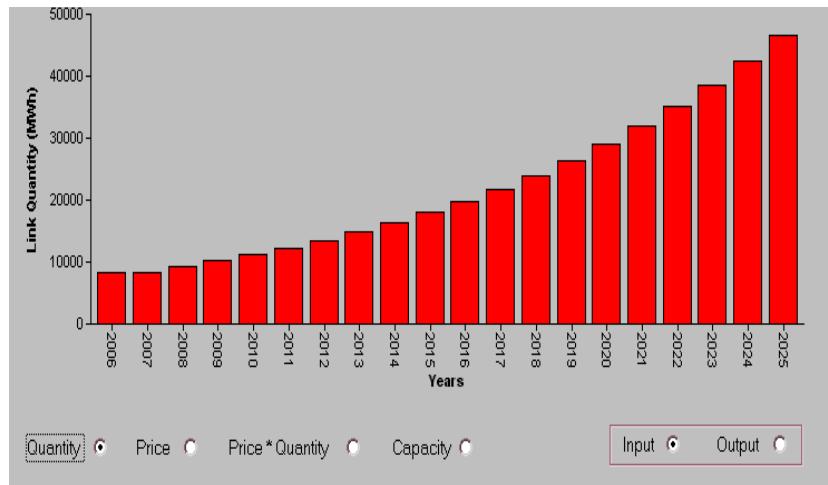


**Figure 15: Heat demand changes**

Heat demand is modeled by increasing demand by 10% annually, taking into account that all objects will be constructed at once in one year, as well as be able to analyze energy costs, depending on the heat demand changes
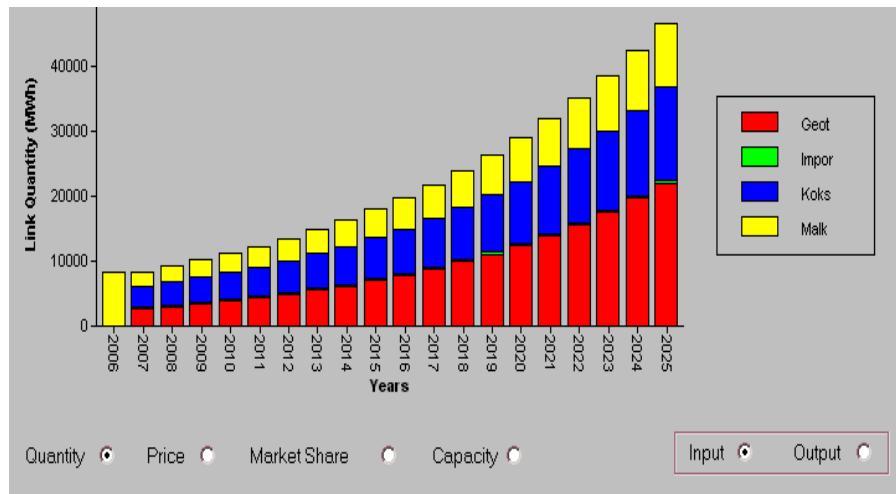


**Figure 16: Heat supply security selection node**

Analyzing ENPEP model solution ENPEP first few years prefer fuel wood, however, an increase in heat demand and time period model are increasingly choosing geothermal energy. Imported energy consumption of heat energy is used for covering the very minimum.
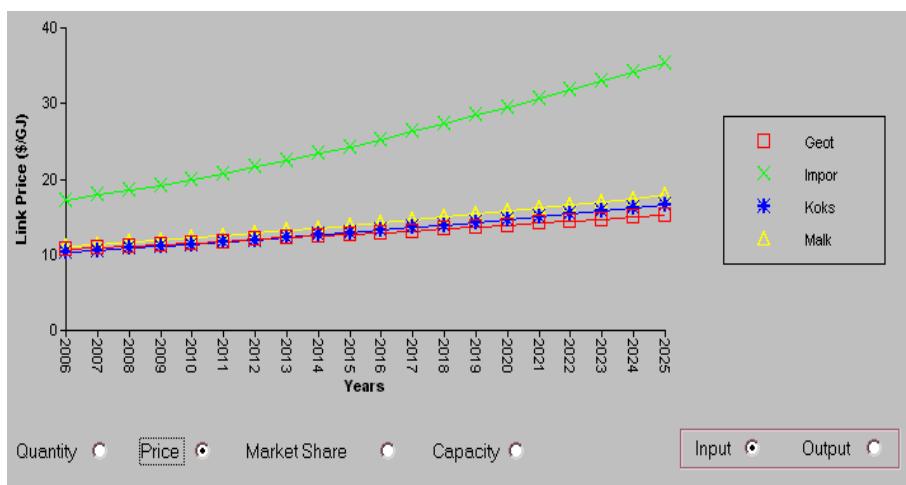


**Figure 17: Specific heat cost comparison**

The most beneficial heat production variations depend on the type of energy down the specific costs per unit of thermal energy. Higher heating costs of imported fuels, which includes - natural gas, diesel, liquefied petroleum gas and electricity resources. In turn, geothermal energy (geot) costs only in the early years is slightly higher than using wood fuel costs, however, with the heat demand increases over time and the cost of geothermal energy is the most advantageous option.
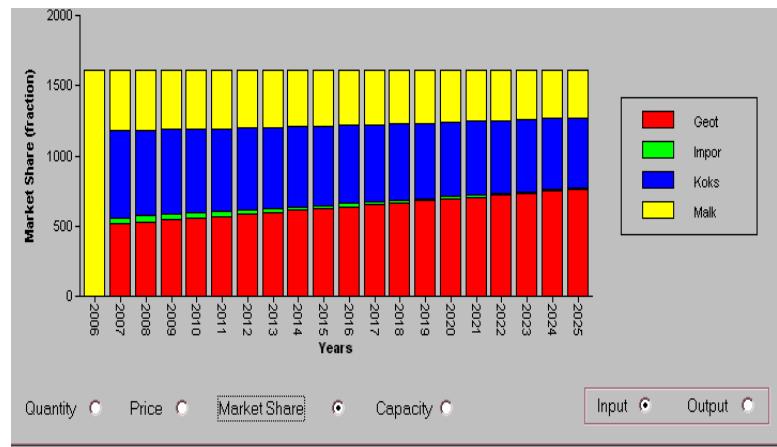


**Figure 18: Heat supply security breakdown**

After the market share distribution is obvious geothermal energy growth, which gradually covers the portion of fuel wood
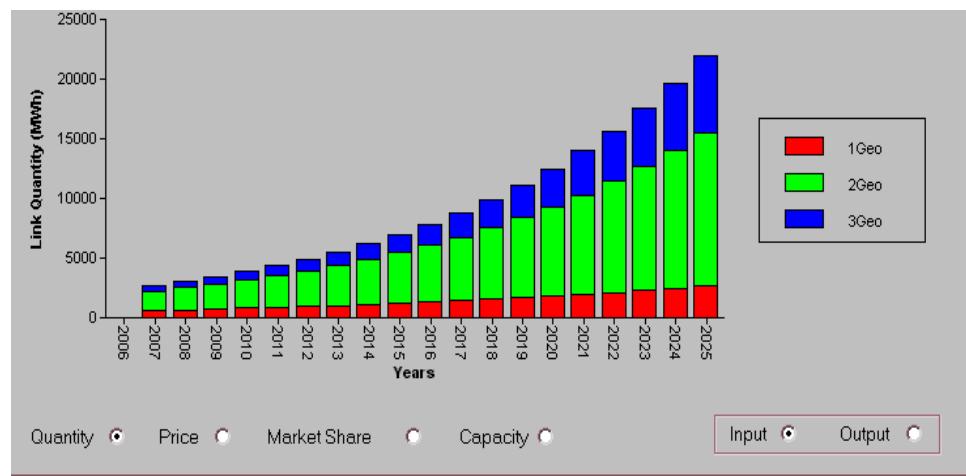


**Figure 19: Geothermal energy distribution of technical solutions**

Comparing geothermal technical options ENPEP model selects Geo-2 variant, which over time covers most of the heat demand.
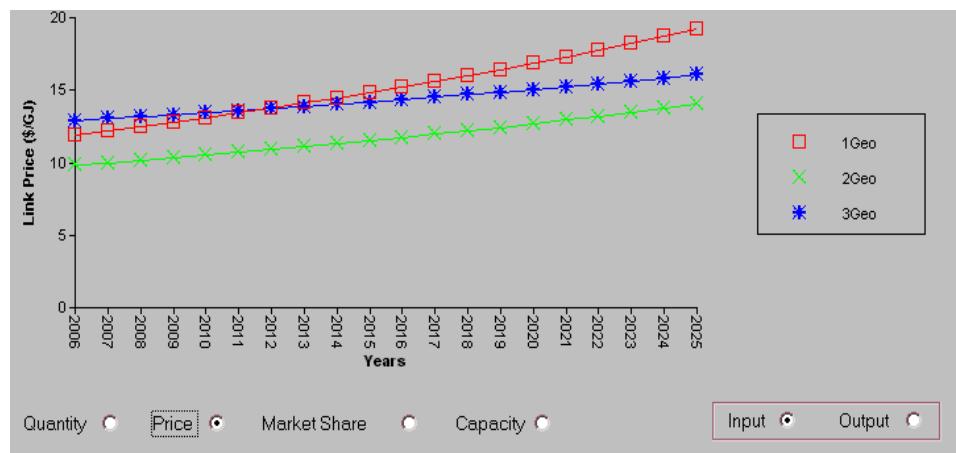


**Figure 20: Geothermal technical solution heat price comparison**

After analyzing the technical options for geothermal energy for heating costs are the lowest prices for Geo-technical version 2, which is 10 USD / GJ and increases depending on the electricity price increase of up to 20 USD / GJ. Geo-technical Option 3 costs in the initial period only slightly higher than the 1 Geo-technical options, however over time Geo-3 variant is becoming less expensive and more advantageous for Geo-technical version 3 heat costs
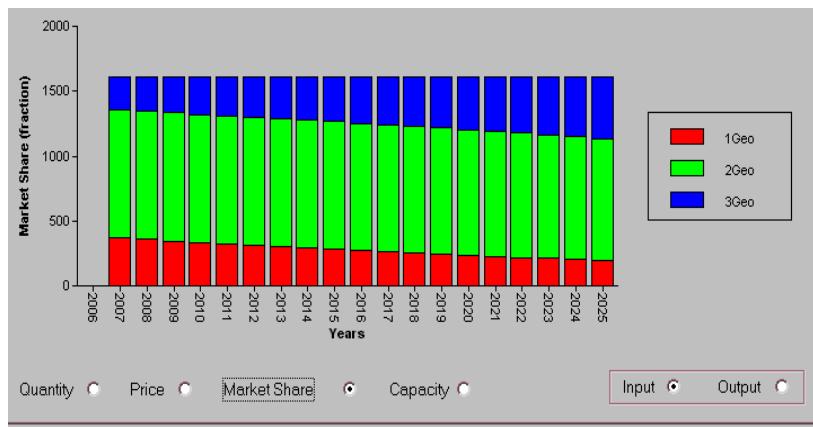
**Figure 21: Geothermal energy technical solutions for market share**

The share of total preponderance of Geo-technical version 2 increases every year.

### 6. CONCLUSION

From the made calculation can be concluded that geothermal stations project from an economical perspective may be viable if these conditions are realized:

- Geothermal water is sufficient to establish a geothermal station with not less than 10MW capacity

- Geological conditions do not require to use a very expensive drilling technology

- There should be maximum utilization of geothermal power plants due to incomplete use of the energy means obtained energy cost raise.

So as in Latvian is not realized any geothermal project, then realization of that kind of project will be considered as high-risk project. This can lead difficulties to attracting investments on a commercial basis, as the cost of capital may exceed IRR.

### REFERENCES

Energy to 2050 (2003) -- Scenarios for a Sustainable Future, International Energy agency 2003.

Limiting global climate to 2 Celsius - the way ahead for 2020 and beyond. Communication from the European Commission. - COM (2007). - Brussels, 2007.

Renewable energy targets for Europe: 20% by 2020/ European Renewable Energy Council. - Brussels, Nov., 2008.

A.Freimanis, E. Eihmanis, V. Driķis, J. Prols, L. Sokurenko, A. Zozimenko, M. Morozova. European Commisision. Atlas of Geothermal Resources in Europe Latvia.2002

Sharkey, W. W. (1982). The Theory of Natural Monopoly, Cambridge University Press, New York.

Westin, P., and F. Lagergren (2002). "Re-regulating District Heating in Sweden," Energy Policy, Vol. 30, s. 583-596. R.

Gordon Bloomquist „The economics of geothermal heat pump systems for commercial and institutional buildings", 2003.g.

Laura Vimmerstedt „Opportunities for small geothermal power projects", 1999.g.

Chuanshan Dai and Jun Liang „Direct and indirect low temperature geothermal district heating systems", 2000.g.