IGEIA

Integration of Geothermal Energy into Industrial Applications

D14: IDENTIFICATION OF MOST INTERESTING INDUSTRIAL MARKETS AND SITES FOR GEOTHERMAL APPLICATIONS SITUATION IN ESTONIA

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Identification of Most Interesting Industrial Markets and Sites for Geothermal Applications. Situation in Estonia

Project
Integration of Geothermal Energy into Industrial Applications
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<u>Disclaimer :</u>

1.Introduction

The main document presenting major issues of Estonia's energy policy is the second *National Long-term Development Plan for the Fuel and Energy Sector until 2015* , prepared in compliance with EU energy policy and which was approved by the Riigikogu (Estonia's Parliament) in December 2004.

Among other strategic objectives of the Estonian fuel and energy sector, presented in the Plan , are:

- ensure that the share of renewable energy sources in primary energy supply will be 13-15% by 2010 (being 10.2% in 2000);
- ensure compliance with the environmental requirements established by the state;
- increase the efficiency in the heat, energy and fuel sector;
- until 2010, maintain the volume of primary energy consumption at the level of the year 2003.

In this background, the geothermal energy presents an interesting option to meet set targets and to widen the use of renewables.

In Estonia sufficiently high temperature geothermal energy, usable directly, is not (so far) available and geothermal energy presents interest only using heat pumps for low temperature applications.

The objective of this document is to bring to industrial developers in Estonia information and experience enabling them to apprehend the interest of geothermal energy in their applications. This work is based on the results of Market study, Guidelines for industrial developers and feasibility studies undertaken for three industrial sites in the framework of this project and also other relevant information:

- A standard supermarket in Germany
- A foundry in Sweden
- A shopping mall in France

It should be noted, that energy statistics in Estonia gives general outlay of energy consumption between branches of economy, but do not specify separate data of energy consumption, depending on temperature levels of applications etc., needed. to evaluate possible geothermal energy use.

It is estimated that in Estonia approximately 40% of total energy is used for heating and other low temperature needs. All these needs can be potentially met by geothermal energy.

Geothermal energy is not considered as potential for electricity production in Estonia.

Detailed energy consumption data for enterprises require case by case studies and are usually not public.

Thus this study will apply preferentially to similar industrial activities, having in view the local geological, climatic, economic and regulatory aspects.

The study must support the industrial developers and attract their attention to the usefulness of geothermal energy.

2. Energy needs that can be covered by geothermal energy in Estonia

As low temperature geothermal energy in Estonia is usable only using heat pumps, the temperature levels of the applications must also be low and remain below 60-70°C. The less the temperature difference, the higher the efficiency of heat pumps. This constraint influences directly all types of geothermal applications: for a building heating, and for an industrial applications.

2.1 Heating/air-conditioning needs in buildings

It is estimated that for HVAC needs in all kind of buildings about 40% of all primary energy is used. This is the main potential for geothermal energy application.
Geothermal systems should generally be sized, in terms of capacity, to cover base load. It is economically reasonable that the installed geothermal equipments have a maximum annual operating span. It is usual that geothermal energy covers only 50-60% of the capacity demand for an application. In energy terms it still makes up to 90% of total energy needs. But depending on the situation, geothermal energy can cover only part of the low temperature energy needs, be used for some specific purpose or used in some section of the technological process. Soil can be used also as seasonal storage of heat for excess heat from technology.
General aim for geothermal energy use is to reduce conventional energy costs and emissions.

For buildings, the energy demand is evaluated based on the data on energy consumption or on design data for new buildings.

Building energy demands depend on climatic conditions of the region where the building is located, and on the thermal quality of its envelope.
Monthly climatic conditions for Tallinn city are presented on the Fig.1

Country		Estonia	
Province / State		n/a	
Climate data location		Tallin	
Latitude	°N	59,4	
Longitude	°E	24,8	Source
Elevation	m	44	Ground
Heating design temperature	°C	-15,2	Ground
Cooling design temperature	°C	23,8	Ground
Earth temperature amplitude	°C	20,1	NASA

	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
Jan	-3,2	86,4%	0,39	100,6	4,2	-6,9	657	0
Feb	-4,2	83,6%	1,11	100,8	4,1	-7,0	622	0
Mar	-0,9	79,2%	2,47	100,9	3,7	-2,5	586	0
Apr	4,5	73,6%	4,06	101,0	3,7	4,8	405	0
May	9,8	68,8%	5,62	101,1	3,6	12,1	254	0
Jun	14,1	73,8%	5,94	100,8	3,3	16,6	117	123
Jul	16,8	75,4%	5,65	100,8	3,1	18,7	37	211
Aug	15,6	79,4%	4,39	100,9	3,1	16,8	74	174
Sep	10,7	82,7%	2,72	100,8	3,3	11,2	219	21
Oct	6,6	84,3%	1,30	100,8	3,8	5,1	353	0
Nov	1,0	86,5%	0,53	100,9	4,0	-1,1	510	0
Dec	-2,1	87,5%	0,26	100,7	4,0	-5,7	623	0
Annual	5,8	80,1%	2,88	100,8	3,7	5,3	4 458	528
Source	Ground	Ground	NASA	NASA	Ground	NASA	Ground	Ground
			Measured at	m	10	0		

Fig. 1 Monthly climatic conditions for Tallinn

In Estonia the minimum requirements to the building energy efficiency (BEE) (kWh/y*m²) are established and these requirements can be used as a first approach. BEE values are reduced to the primary energy consumption and take into account also CO2 emission.

For example, for new office buildings the BEE value must not exceed 220 kWh/y*m², for public, business buildings 300 kWh/y*m².

To avoid overheating of the rooms in summertime generally architectural, structural measures are recommended, but also cooling equipment can be used.

Maximum load can be calculated – yearly consumption divided length of heating period in hours and average difference of temperatures inside and outside and multiplied with maximum temperature difference.

The Dimensioning Outdoor Temperature is usually taken –22ºC, though the actual winter temperatures may vary down to -33°C. and maximum summer temperatures rarely reach over 30 ºC..

Energy demands of a building depend on the climatic conditions and on various thermal contributions, like solar radiation and the building internal contributions (lighting, machinery etc.). These energy sources should be taken into account on case by case basis.

Energy balances of the building for winter and summer conditions could be built as a function of these contributions:

2.2 Geothermal energy in industry

Industrial processes represent a target for geothermal energy application because usually there are low temperature energy needs and sometimes waste energy, which can be seasonally stored..

The majority of industrial processes release heat generally into the surrounding air or water, using heat exchangers. Heat is lost, because:

- demand is lacking
- heat recovery systems are lacking.
- heat production and heat needs are not simultaneous

Geothermal applications offer here the possibility of storing the excess heat in order to re-use it later.
Though this kind of experience of storing energy underground is at the moment missing in Estonia, it is worth to investigate the possibility, relaying on data from other countries.
For this kind of application the feasibility study for industrial complex was selected (Site e below).

This stored heat can be restored using a heat pump that allows to reach usable temperature levels.
By various data, the 50-70% of stored heat can be restored.
An option is to consider the sale of excess heat to nearby DH system, if that exists.

<u>Geothermal energy in an industrial process</u>

Geothermal energy can be used to supply heat for an industrial process, either by drawing heat from the ground, or by recovering heat previously stored.
The temperature level needed for the process is a crucial design parameter and in most cases is a limiting factor: because of limited temperature levels, geothermal energy may not entirely cover the process. However, it may allow the pre-heating in the process chain.

Geothermal energy offers other opportunities such as supplying cold for an industrial process chain. The interest of this solution consists primarily in:

- making use of comparatively low temperature soil or “stored” cold to cool down the cooling agent.
- Avoiding the use of cooling towers.

The use of geothermal energy in cold supply application is limited, because of climate and since it is in competition with other cold technologies exchanging their excess calories with the surrounding air (the energy profit lies only in the difference in COP between the two solutions).

2.3 Energy balance

It is necessary at first to estimate of the capacity that is expected to be supplied by a geothermal heat source (for building heating or air-conditioning, for industrial processes and heat recovery systems).

The corresponding energy demand can be evaluated taking into account the power of the equipment installed and its operating time – heating and cooling power demand (kW); yearly heating and cooling needs (kWh/y). And also needed capacity of geothermal system – usually recommended to cover baseload.

3. Potential branches of industry and sites for geothermal energy

Data on energy consumption in different brances of Estonian economy (Fig.2), gives some hint, where the potential for geothermal applications is highest by the total use of energy, but the real outlook of implementation depends on on-site studies, economic situation and outlook.

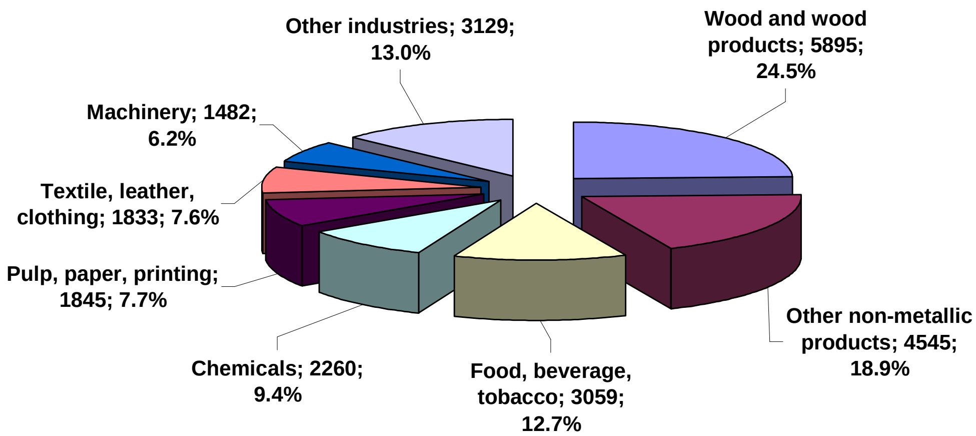

Figure 2. Energy use in branches of manufacturing industry in 2005 (TJ)

All enterprises, consuming low temperature heat, are potential users of geothermal energy. Including:

- Office buildings
- Shopping centers
- Supermarkets
- Hotels
- Spa`s
- DH systems
- Food industry

- Wood and wood processing
- Chemical industry and other industry with waste energy.

Most of the Estonian population and industry is contcentrated into the Tallinn, and surrounding area, Tartu, Narva, Pärnu cities and in the North-East region. It should be noted also, that in cities and in many smaller settlements there are DH networks, which compete for heating market and sometimes are safeguarded by so called DH regions, established by Local Municipalities, which prohibit to instal other heating systems. Though, DH systems may be themselves possible targets for geothermal and heat pump applications.
Geographically vertical temperature differences of the soil are much similar all over Estonia and geologically uper crust is everywhere sedimental rock.

The following 5 sites were selected with potentially high feasibility of geothermal application and possibilities for future extension of application to similar situations.

a) Supermarket in Valga city
It is located within the DH reach, has parking area, which can be used for boreholes
Total heated space – 4062 m²
Cooling and freezing load (electrical) - 42 kW
Heat supply – from city DH system, 180 MWh/y.
Heat recovery from cooling and freezing systems through ventilation system.

Geothermal system allows to store the excess heat from cooling during summer and cover all heating needs.
Necessary lenght of boreholes – 2100 m (0,07 kW/m)

b) Sport hall in Narva, with icefield
Total heated space – 6798,5 m²
Electricity consumption – 1200 MWh/y; heat consumption 500MWh/y
Required heating capacity 200kW, cooling 400kW.
Geothermal system allows to store excess heat in summertime, cover all heating needs and reduce purchased heat cost.
Necessary lenght on boreholes 2900 m

c) Swimming pool in Narva
Total space 2688,7 m².
Electricity consumption 240 MWh/y, heat consumption 1200 MWh/y, incl. hot water 281 MWh/y.
Required heating capacity 400 kW, which is possible to reduce 30% by heat recovery and energy saving measures.
Geothermal system can reduce the purchased amount of DH heat and store the excess heat in summertime.
Necessary capacity of geothermal system 280 kW and estimated lenght of boreholes 4000 m..

d) Culture House in Narva
Total space 5982 m².
Electricity consumption 50 MWh/y, heat consumption 650 MWh/y
Heating capacity 250kW.
Building needs renovation. Heat demand can be reduced 40%, implementing energy saving measures.
Geothermal system reduces the purchased heat cost and allows to store cooling excess heat.

e) Industrial complex in Pärnu (selected for Feasibility Study)
Total space 32 000 m²
Heat consumption 9990 MWh/y, cooling need 200 MWh/y
Heating capacity 4 MW, from own oil firing boilerhouse.
Geothermal system allows to save oil, reduce CO2 emission, store heat from cooling system and store river water heat summertime.

The last site was selected for more detailed feasibility study because of large oil fuel saving potential and plant management interest in such study.

4. Possible technical solution

4.1 Geothermal application type

Three types of geothermal application should be considered: Borehole Heat Exchanger (BHE); Aquifer Thermal Energy Storage (ATES) and Borehole Thermal Energy Storage (BTES).

<u>Borehole Heat Exchanger (BHE)</u>

This is horizontally of vertically built piping system below the ground level, which allows extract heat (or cool) from the soil using heat pump (HP).

<u>Aquifer Thermal Energy Storage (ATES)</u>

Aquifers with a depth less than 100 m contain water at approximately 7-8°C. Deeper aquifers can be used to extract more power, but the aquifer temperature remains nearly the same.
The possibility of using this technique depends on the presence of an exploitable water resource next to the site This resource is found in sedimentary basin all over Estonia, consisting porous sedimentary rock and glaciofluvial deposits and alluvial aquifers coming along with water flows.
Environmental legislation requires the recharge of water into the aquifer after the temperature has been changed. Exception is the water pumped out from mines in the N-W region in Estonia, but there are no potential consumers nearby.
Main factors influencing the usability of aquifer systems are:

- Aquifer transmissivity

- Groundwater temperature
- Groundwater chemistry
- Aquifer stability (determines well construction)
- Drilling conditions
- Environmental requirements

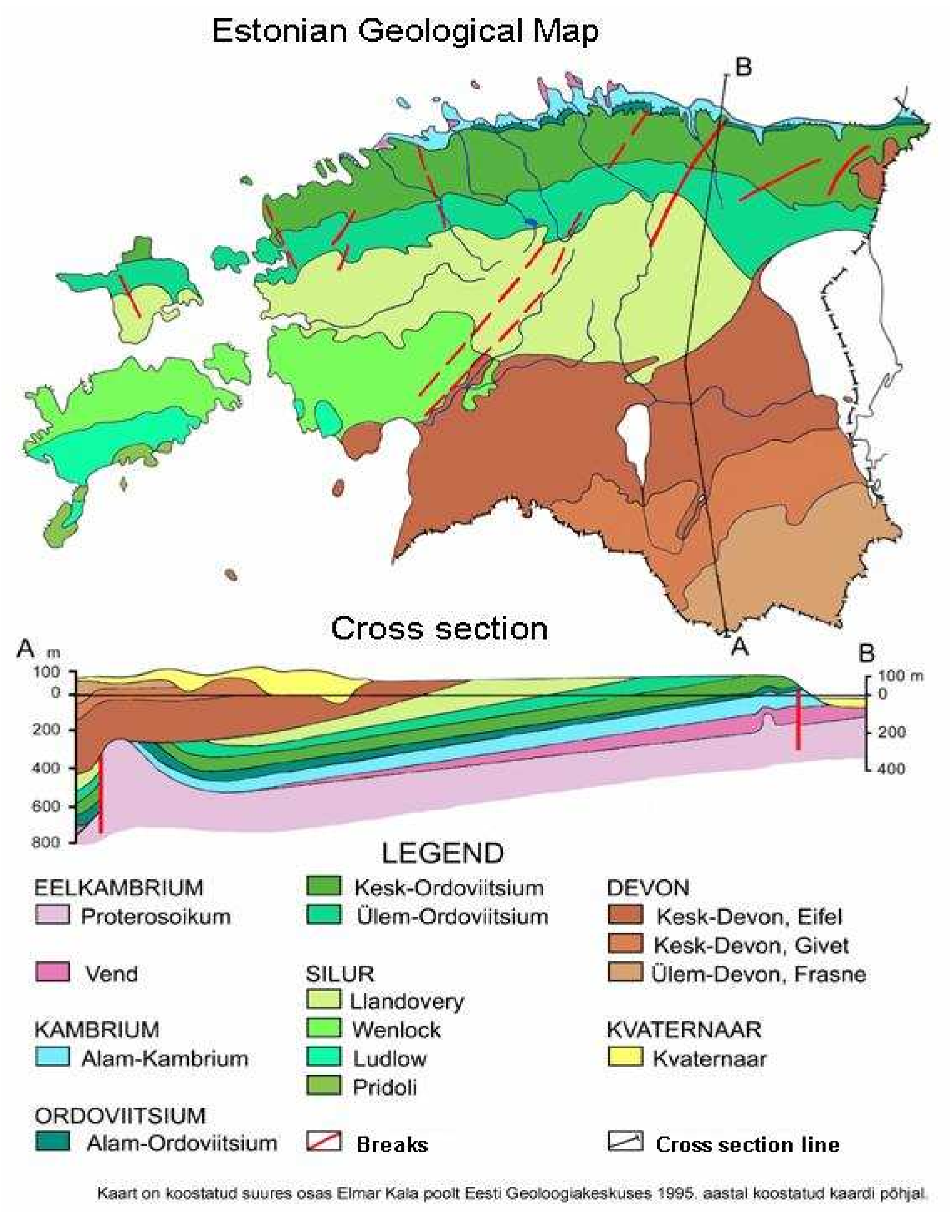

Figure 3 Estonian Geological map

Minimum and maximum temperatures of re-injection are constrained by physical and regulatory considerations. The main limiting factor is water flow, which in most known cases do not exceed 10-30 m³/h.

To provide the required power, it is possible to use several doublet -well systems, or to search for deeper aquifers.

<u>Borehole Thermal Energy Storage (BTES)</u>

If it is impossible to exploit an appropriate aquifer, a borehole thermal energy storage system can be considered. The number of borehole heat exchanger to be installed depends mainly on the application power demand.

The power exchanged with the ground depends on the soil type and corresponds approximately to 4-5 kW per 100 m BHE.

Main factors influencing borehole heat exchanger systems are:

- Rock thermal conductivity
- Undisturbed ground temperature
- Drilling conditions

In Estonia the experience of using ATES and BTES is limited

4.2 System sizing

Curves of consumption and waste heat emissions should be built and the possible role of geothermal heat estimated in the energy balance. Usually several options should be analysed.
With heat pumps the heating capacity is approximately calculated:
Thermal power produced at the heat pump outlet = power exchanged with the ground X 1,25
And for cold production:
Thermal power evacuated in the ground= Cooling power produced at the heat pump outlet x 1,25

In the case of reversible system, where both heat and cold production are achieved using geothermal energy, it is usually optimal to size the geothermal system based on heating needs.

4.3 Energy balance

Rough calculation of the wells theoretical depth (it should be made sure first that an aquifer exists in the considered range of depth by test hole for example), and the number of doublet –wells can be made, based on energy balances.

In the similar way, based on the energy balance, the number of BHESs required to meet the power needed in the case of a BTES application.

5. Payback

5.1 Investment costs estimate

As data from Estonia for borehole type of systems do not exist, the approximate estimation of investment costs can be done, relying on data from other countries.
Fig. 4 presents investment cost of building the doublet well in France. Price for Estonia can be reduced around 20% due to the cheaper workforce.

Aquifer construction cost

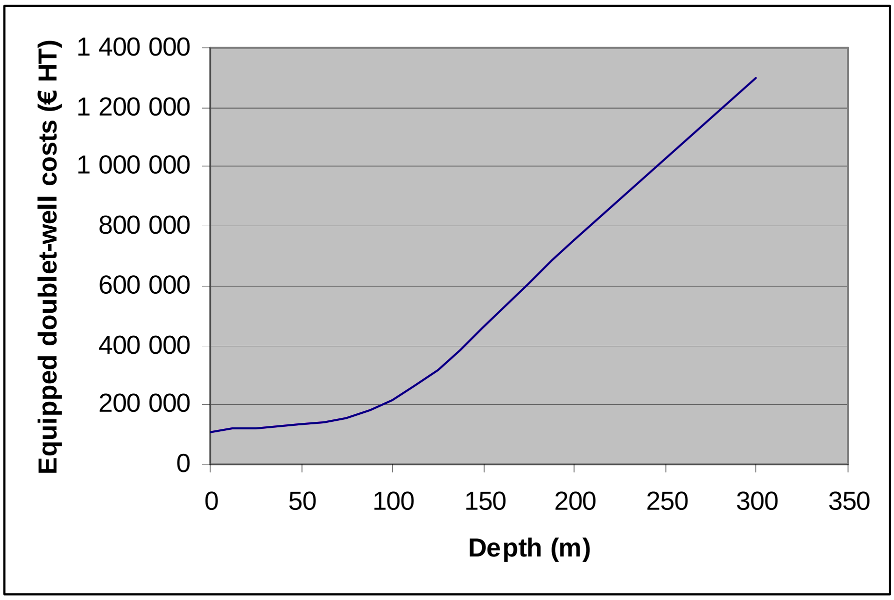

Figure 4 – Investment costs of an equipped Doublet-well

Heat pump cost

The installation of a heat pump is usually estimated at 400-500 € /kW_{heat}.

Financial aids

At the moment no state support is available, but the situation may change, as the financial support packages for renewables are on Government agenda.
Knowing both expenses and subsidies amounts, it is possible to evaluate the geothermal application investment costs.

It is recommended to investigate the possibility of implementing different types of geothermal applications (ATES and BTES) to take into consideration the economical criterion.

5.2 Running costs evaluation

Average fuel energy prices for 2008 are presented in Table 1:

Energy type	Average price (€/ MWh)
Gas	25
Electricity	65
LFO	50

Table 1 – Average energy prices in Estonia

As recent shifts in world economic situation have indicated, the fuel price volatility is high, but it is generally beleived, that long term fuel price trend is upward and this is favouring geothermal energy.

The use of geothermal energy is compared with other possible solutions: the existing one or the one that would have been implemented instead of geothermal application.
If there is no DH/DC networks available, the alternative to geothermal applications are usually oil, gas or electrical heating coupled with utilization of waste heat.

In first approach, the difference in maintenance and repair costs between alternative solutions may be neglected.
Under these conditions, energy expenses incurred by integrating geothermal application correspond to expenses generated by heat pump.

Following rough estimation can be used to evaluate heat pump (COP=4) electrical consumption:

Electricity consumption for heat production = Heating energy needed (kWh/y) / 4

Electricity consumption for cold production (kWh/an) = Cooling energy needed (kWh/an) / 3

The difference between running costs of both solutions gives annual energy savings (€ /an).

5.3 Payback time estimate

The simple payback period can be evaluated using the following expression

Payback period (yr) = Investment costs for geothermal application (€) / annual energy savings (€ /yr)

It is assumed that energy prices remain constant throughout the period considered. The integration of an inflation rate to theses would decrease considerably payback periods.

	BTES – HP	**ATES – HP**

Investment costs (€/kW)	1 000 –1 200	600 – 800
Operating costs (€/kW, yr)	0	0
Maintenance costs (€/kW, yr)	0	0 - 30
COP (-)	4	4-5
Energy cost (€/MWh)	150 - 250	120 - 180
Lifetime, below ground part (yr)	40 - 100	20 - 100
Lifetime, heat pump (yr)	25	25
Pay-back time (yr)	5 - 10	5-10

Table 2 – Economical data of geothermal systems in Estonia

The figures in table 2 relate to geothermal applications that are correctly designed and operated. If constructed or run in an incorrect way, geothermal energy systems can be costlier and less efficient.

Also note that the common geothermal applications behind the figures in table 2 are mainly derived from the heating and cooling of buildings and offices. Regarding waste heat recovery, there is not yet sufficient experience for general conclusions.

Actual payback periods, calculated for ground coupled heat pump systems in Estonia vary from 3- 15 years. So each case needs separate investigation, depending on local situation and alternative possibilities.

5.4 Environmental considerations

The environmental performances relative to both geothermal and reference solution are estimated based on greenhouse gas emission ratios, accordingly with the type of energy used.

As in Estonia nearly 90% of electricity is generated in low efficiency oil-shale firing power plants, the CO2 specific value is relatively high. But still can be in favour of geothermal solution, if compared with conventional solutions. Having in view the future development of power system, the environmental advantages of geothermal energy are growing.

Energy type	Average emission (g CO_2 / kWh)
Gas	240
Electricity	~1200
Fuel oil	270

Table 4 – Greenhouse gase emission ratios for Estonia

6. Conclusions

Estimation of possible area of applications for geothermal energy in Estonia indicates that potential projects can be found in all branches of industry and services, were low temperature heat or cooling is needed. Actual feasibility depends on individual situation. Stages, described in this document, allows to have a first opinion on the interest of such an application in Estonia, based on a simplified way of evaluating a payback period of investments incurred.

The thermal energy demand is of importance when designing geothermal energy systems. The best preconditions for these systems are:

- Both heating and cooling is required
- Heating and cooling is seasonally shifted
- Distribution temperature for heating is low and this for cooling is high
- The power needed (kW) is low in comparison to the energy needed (kWh)

Obviously individual cases need more investigation of specific site conditions for building BTE; ATES or BTES.

The specific studies remains essential to specify energy needs, define possibilities of implementation of geothermal solutions in industrial processes, the land geological and hydrogeological conditions, the system design, accordance with legal regulations etc.