Feasibility Study Geothermal Heat Pump for Flax Processing Factory (FPP) Estonia

Supported

Intelligent Energy Europe

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Feasibility Study for Geothermal Heat Pump for Flax Processing Factory in Estonia

Project

Integration of Geothermal Energy into Industrial Applications

in frames of *Intelligent Energy – Europe* (EIE-06-001/SI12.4475709)

Contents

1. Introduction

The main document, establishing the framework of Estonian Energy Policy, is “Long Term State Development Plan for Fuel and Energy Sector until 2015”.
It states the strategic target for renewables to achieve 13-15% of total primary energy by 2010. It includes also further development of low temperature geothermal energy use, which has already found application in heating of buildings.

Schemes for financial support of renewables are discussed , but except electricity, no schemes today exist.

Since 1996 FPP owners have invested much into the renovation of infrastructure, buildings, and technology

Plant has production halls and office with the total area of 32 500 sq. meters.

For HVAC needs the boilerhouse with 2 oil-firing boilers (8 and 6 MW) is used, the maximum actual load is up to 4 MW.

Ventilation system has no recovery of heat and exhaust heat is lost to the ambient air.

For the plant, the question stands, how to utilize waste heat and reduce expensive fuel oil consumption.

As an option, geothermal energy is considered.

2. Geological Situation

The site is located ca 200 m from the river.

The geological conditions are similar all over the factory site, and free area between buildings can be used for boreholes with the condition, that it will not be an obstacle for transport and some greenery is maintained.

Therefore, it is appropriate to place the boreholes in the area with grass and asphalt between the buildings.

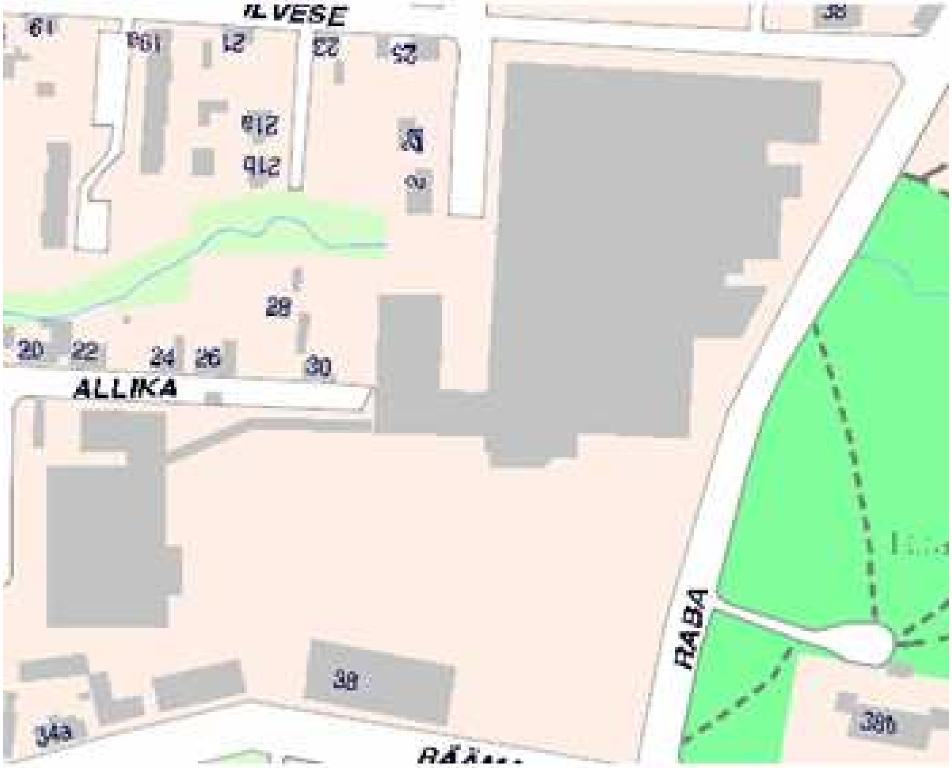


Figure 1 Layout of the FPP site

Hydro geological conditions

Hydro geological conditions can be approximately estimated relying on the data from nearby 140 m deep water supply borehole. The main results are summarized as follows:

- Water supply 30 m^3/h.
- Soil is mainly sandstone, sandy clay, clay and limestone
- The ground water level is approx. 4-5 m below the ground surface

Drilling ability

No drilling problems are foreseen.

Thermal properties

Thermal properties can be estimated on the basis of water measured temperature and other similar data:

- The temperature of the water varies between +8 and +10°C and the geothermal gradient is around 1°C/100 m.
- The thermal conductivity of the rock mass is between 2-3 W/m,K.
- The heat capacity is 0, 6 kWh/m^3 x °C.
- The thermal resistance with water filled boreholes and single U-pipes is 0,06 K(W/m)

3. Principle of Geothermal System

The objective is to estimate the possibility to convert part of the heat load to geothermal energy, using heat pump.

Consequently, the Borehole Thermal Energy Storage (BTES) is proposed.
The goal is to substitute part of the fuel by geothermal energy in the" base load mode".

Waste heat

There is unutilised waste heat from ventilation system, which can be used for preheating the incoming air

Current system

The current heating system consists of a boilerhouse with two boilers using oil from oil-shale processing, internal DH system and ventilation air preheating.

Heat is not metered and heat consumption is calculated on the basis of fuel consumption

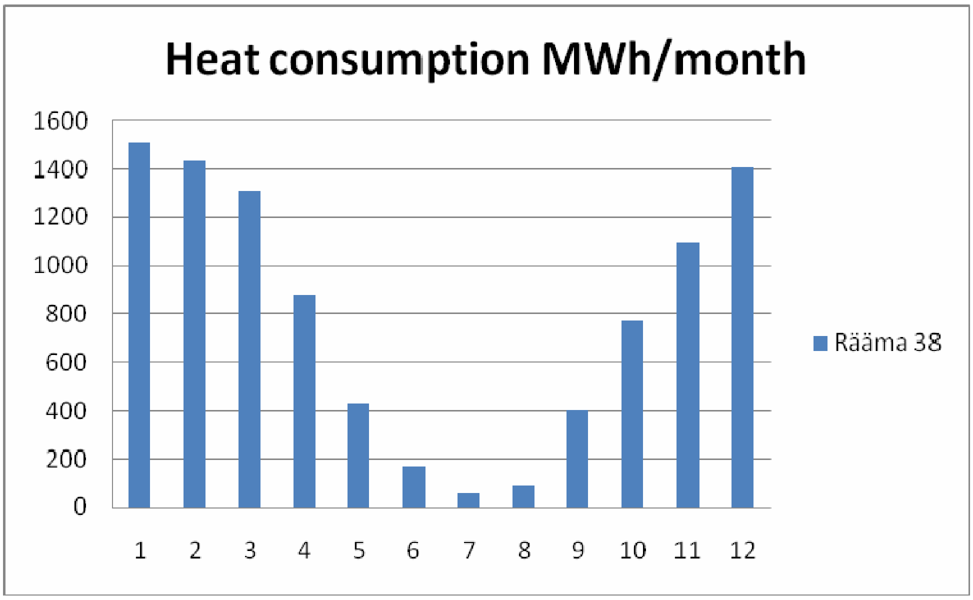


Figure 2 Current heat consumption per month

Planned change of current system

Additional components

The proposed system is coupled to the existing one and has the main following components (Fig. 3): A heat pump (HP) for utilization of heat from the soil and river water (from April to October, when the water temperature remains >+5°C.

The direct extraction of heat for heating needs from river delivered by the heat punp is approximately 1200 MWh (857 MWh/y from river) and during this period no more is needed (refer to Fig.4).

An excess of 200 MWh of cooling can be stored in BTES during the summer season (stored directly, no HP involved). In addition, 2160 MWh from river water is stored during the summer to restore the temperature level in the soil (stored directly, no HP).

Consequently annual BTES heat balance is 2570-2160-200= 210 MWh/y, the last number indicating the heat extracted purely from the soil.

Heat delivered by HP from soil is of 3600 MWh/y approximately with a coefficient of performance (COP) of = 3, 5.

Additionally 1200 MWh is delivered by HP from river – total 3600+1200=4800 MWh.

- Heat exchangers for preheating of plant DH water and air.
- Borehole thermal energy storage (BTES) for extraction of heat and store of waste heat
- Heat exchanger for using the heat from river water to charge the BTES during summer and partly as HP heat source during spring and autumn
- Other auxiliary equipment (river water pumping station etc.)

Functional description

The factory has already a control system with monitoring equipments. With the additional new components for geothermal energy recovery, the control and monitoring system needs to be modified.

As can be seen in Fig. 3, the connection to the local DH is such that the heat can be delivered to both the supply line of fresh air and the return pipe of the DH net.
The primary source will always be the heat from heat pump for temperature increase.

With such a connection only peak loads, are covered by the boilers.
The system will have the following main operating modes

- For cold weather, the outlet air heat recovery system is primarily used, followed by BTES supply and boilerhouse. .
- At moderate cold weather all heat is expected to be delivered by the HP system.
- At mild weather all heat is supplied by the ventilation heat recovery system.
- At hot weather the HP can be reversed and used to cool incoming air. In this mode the heat is stored underground

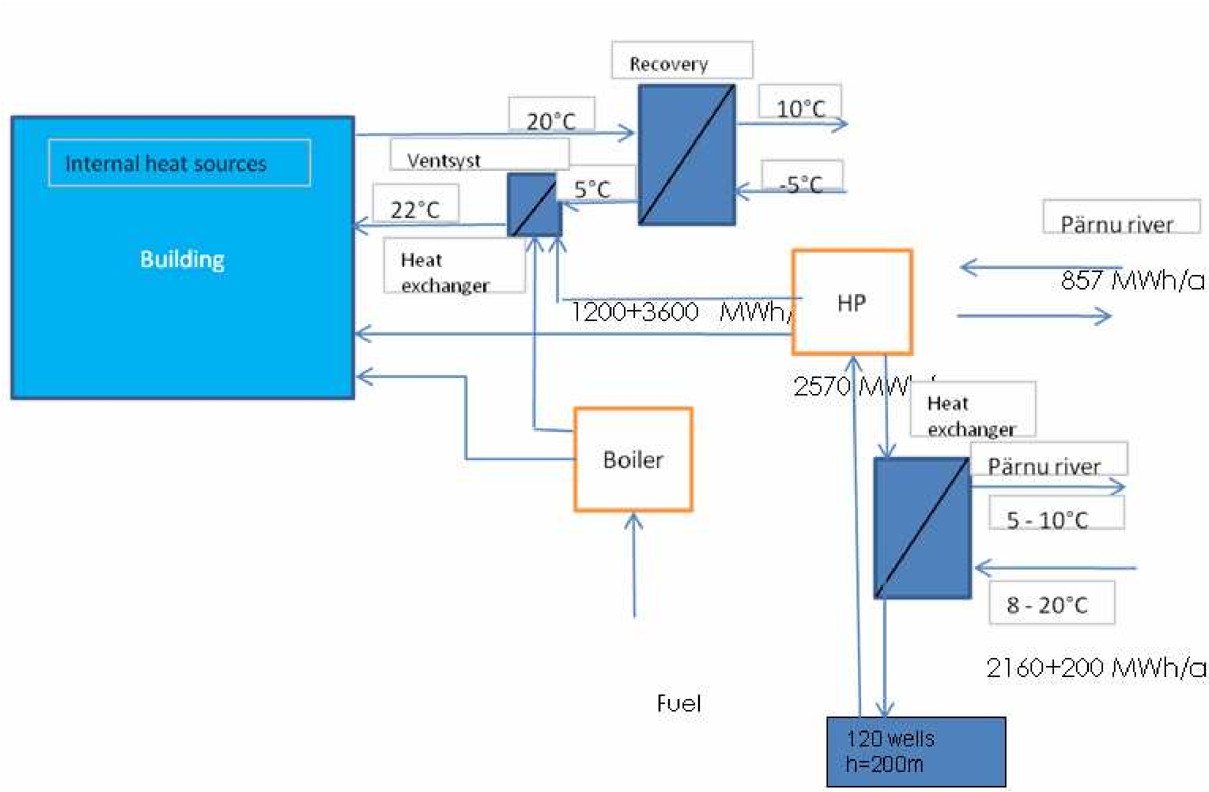


Figure 3 Main components of the proposed system

4. Performance of the System

Energy demand

Heat and heat load demands

The annual heat consumption has been around 10 000 MWh. Of this 1/3 was spent on preheating of ventilation air. The maximum heat load demand is around 4 MW.

System design

The proposed new system is substituting part of the fuel energy with geothermal energy and recovering also part of the exhaust heat from ventilation. The need for the peak load is covered by existing boilerhouse.

Additional components

The main additional components are:

- HP for utilization of geothermal energy, which is lifting temperature from 5-10 ˚C to 30-40 ˚C .
- The BTES system

.

Supply and return temperatures

The supply temperature in the local DH system is around +60°C during winter extreme days. However, for normal winter conditions, this temperature is kept lower.

These temperatures can be supplied by the HP and ventilation heat recovery system.

The return temperature of local DH is around 10°C or lower and kept within the bracket of +30-40°C. This indicates that the BTES can produce heat down to + 40°C for the return line,

Potential for an increased recovery

Recovery of exhaust air heat reduces 10% of total annual heat needs. Approximately 200 MWh excess heat from cooling can be stored in BTES during the summer season. Additionally 2160 MWh will be stored during the summer from river water.

BTES system

The approximate calculation shows that it takes around 120 boreholes á 200 m to create the 720 kW of geothermal heating capacity.

Performance of the system

HP is estimated to produce some 4800 MWh of heat annually at a COP of 3,5. This translates to about 1340 MWh of electricity being used for this heat production.

The heat pumps and the BTES system will deliver an extra 4800 MWh of heat to the internal DH and ventilation system. At the same time, the use of electricity will increase with about 1340 MWh, used by the HP.

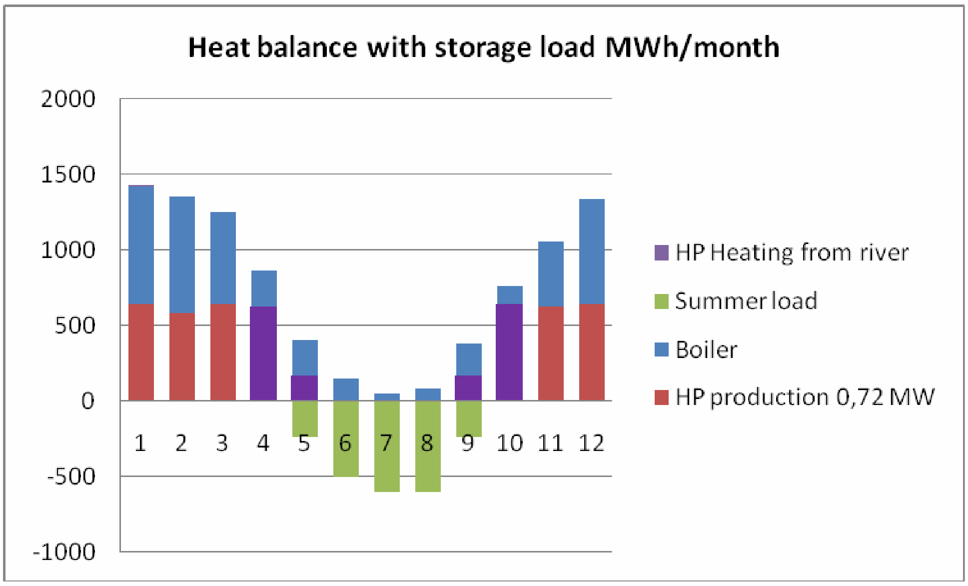


Figure 4 Heat balance with storage load

Month	HP, delivered heating (MWh)	BTES,delivered heating (MWh)	River, delivered heating (MWh)	BTES, delivered cooling (MWh)	River, delivered heating (MWh)
Jan	643	460	0		
Feb	581	415	0		
Mar	643	460	0		
Apr	622	0	444		
May	170	0	121		300
Jun	0	0	0	66	500
Jul	0	0	0	67	530
Aug	0	0	0	66	530
Sept	170	0	121		300
Okt	643	0	459		
Nov	622	444	0		
Dec	643	460	0		
Total	4736	2239	1145	200	2160

Tabel 1 Heat balance

Environmental balance

The type of borehole heat exchanger used will not allow heat carrier to have direct contact with the ground water in boreholes. Heat carrier pipes are submerged into the ground water. The ground temperature remains between 5 and 12 ˚C.
It is suggested, that the ground water horizontal transport occurs at a speed lower than 1 m/y in the direction of river. Vertical temperature gradient remains low.

CO_2 reduction

As stated above, there are no expected local environmental concerns or impacts installing and operate a BTES system.

4800 MWh of HFO is saved, the release of CO_2 to the atmosphere will be reduced by about 1589 tonnes each year. Power production emissions are accounted for.
For producing 4800 MWh of heating, an additional 1340 MWh of electricity is used.

5. Financial balance

Investment costs

The investment has been calculated following items:

- Heat pump HP, installation and auxiliary equipments included 290 thousand €.
- BTES, borehole heat exchanger piping system and heat exchangers included 640 000 €.
- Controlling system and electrical, 70 thousand €.

Operating costs

The investment is estimated to reduce the dependence on boiler house with 4800 MWh annually. This amount will be supplied by HP from BTES and from river water.
For running the system, mainly the heat pumps, 1340 MWh of additional electricity is used. The present annual cost for this is 101 000 €.
Based on these figures, the annual savings will be 82 000 €.

Pay-back time

The net investment is 1 M€.
Annual savings are approximately of 82 000 €.
Using the net investment, the straight payback will be in the order of 12 years.

Future fuel prices will probably increase the profitability assuming electricity cost remains constant.

It should be mentioned, that the operation and maintenance cost for running the BTES is practically low and that the investment in BTES can be written off on a very long period of time. The technical lifetime of the BTES part of the investment is commonly set to 40 years or more.

RETScreen

Building envelope: 1 2 3 4 5 — Description

		Base case				Proposed case				Incremental initial costs
Building north	°					0 ☑				
Schedule		Schedule 1				Schedule 1				
Description		24/7				24/7				
Building envelope		North	East	South	West	North	East	South	West	
Walls						☑				
Area	m²	8 000	8 000	8 000	8 000	8000	8000	8000	8000	
R-value	m² - °C/W	1	1	1	1	1	1	1	1	$
☑ **Window**						☑				
Area	%	20	20	20	20	20	20	20	20	
R-value	m² - °C/W	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	$
Solar heat gain coefficient						0	0	0	0	
☑ **Solar shading - season of use**						☐				
Solar shading - winter	%									
Solar shading - summer	%									
☑ **Doors**						☐				
Area	%	5	5	5	5	5	5	5	5	
R-value	m² - °C/W	0,5	0,5	0,5	0,5	0,5	0,5	0,5	0,5	$
☑ **Roof**						☑				
Area	m²	25 000				25000				
R-value	m² - °C/W	1				1				$
☑ **Floor**						☑				
Area	m²	25 000				25000				
R-value	m² - °C/W	1				1				$
☐ **Wall - below-grade**										
☐ **Floor - below-grade**										
Next										Next

Table 2 Building envelope

		Base case	Proposed case	
Heated floor area for building	m²	32 500		
Energy efficiency measures			10%	
Heating load for building	W/m²	129	116	
Domestic hot water heating base demand	%	5%	5%	
Total heating	MWh	9 990	8 991	
Base load heating system				
Technology			Heat pump	
Capacity	kW	4 192,5	720,0	19,1%
Heating delivered	MWh	9 990,1	4 685,1	52,1%
Fuel type		Oil (#6) - L	Electricity	
Seasonal efficiency	%	80%	350%	
Fuel consumption - annual	L	1 161 963	1 339	MWh
Fuel rate	€/L	0,260	0,075	€/kWh
Fuel cost	€	302 110	100 395	
Peak load heating system				
Technology			katel	
Suggested capacity	kW		3 053,3	
Capacity	kW		2 800,0	**74,2%**
Fuel type			Oil (#6) - L	
Seasonal efficiency	%		80%	
Fuel consumption - annual	L		459 295	
Heating delivered	MWh		3 948,9	**47,9%**
Fuel rate	€/L		0,260	
Fuel cost	€		119 417	

Table 3 Heating project

Base case electricity system (Baseline)		**GHG emission factor (excl.T&D)**	**T&D losses**	**GHG emission factor**	
Country - region	**Fuel type**	**tCO2/MWh**	**%**	**tCO2/MWh**	
Estonia	Oil (#6)	0,408		0,408	
GHG emission					
Base case	tCO2	3 530			
Proposed case	tCO2	1 941			
Gross annual GHG emission reduction	tCO2	1 589			
GHG credits transaction fee	%				
Net annual GHG emission reduction	tCO2	1 589	is equivalent to	323	Cars & light trucks not used
GHG reduction income					
GHG reduction credit rate	€/tCO2				

Table 4 Emission analysis

Financial analysis

Financial parameters			
Inflation rate	%	5,0%	
Project life	yr	15	
Debt ratio	%	0%	
Initial costs			
Heating system	€	0	0,0%
Other	€	1 000 000	100,0%
Total initial costs	€	1 000 000	100,0%
Incentives and grants	€		0,0%
Annual costs and debt payments			
O&M (savings) costs	€		
Fuel cost - proposed case	€	219 812	
Other	€		
Total annual costs	€	219 812	
Annual savings and income			
Fuel cost - base case	€	302 110	
Other	€		
Total annual savings and income	€	302 110	
Financial viability			
Pre-tax IRR - assets	%	7,9%	
Simple payback	yr	12,2	
Equity payback	yr	9,4	

Table 5 Financial analysis

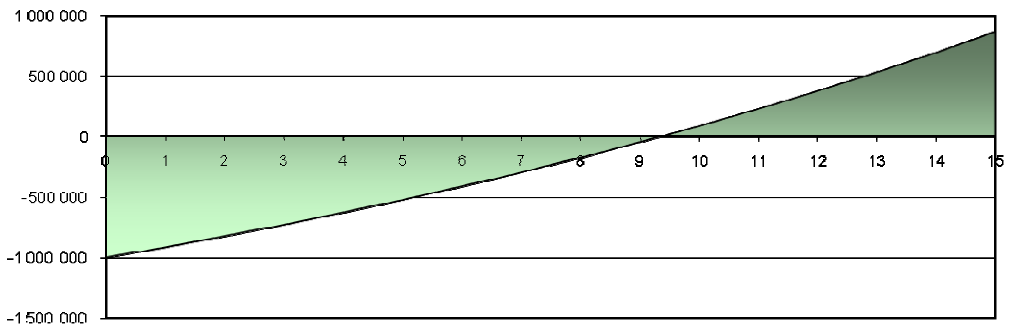
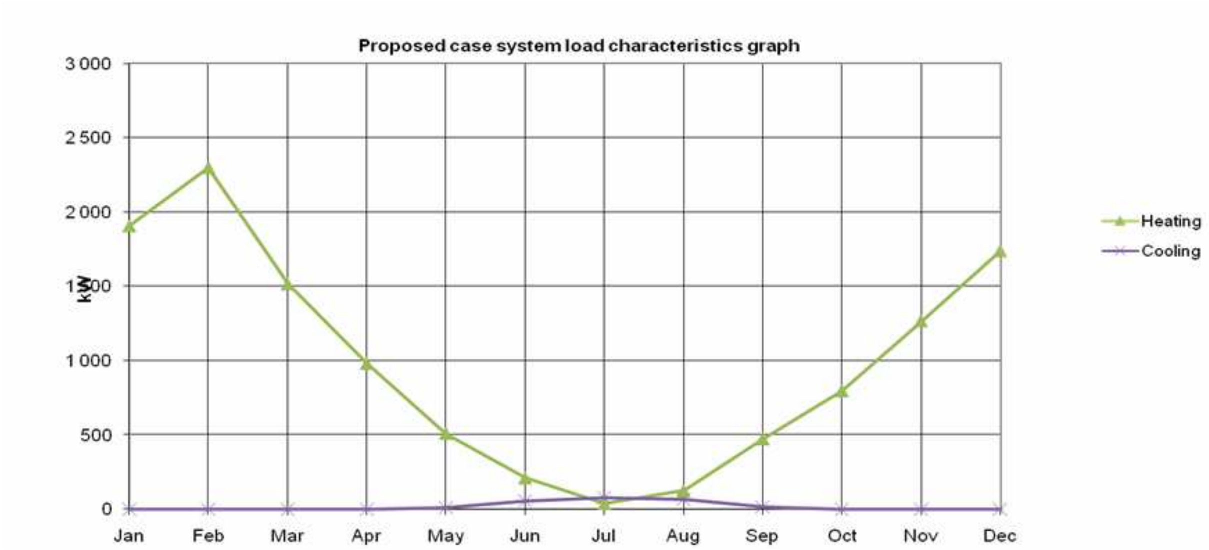


Figure 5 Cumulative cash flow graph (€)



Proposed case load and energy		Heating	Cooling
System peak load	kW	3 773	144
System energy	MWh	8 991	184

Figure 6 Proposed case system load characteristics graph

6. Conclusions

The objective of the study was to evaluate the technical and financial feasibility of converting a part of heating load in the plant into geothermal energy, using a heat pump system.

The designed BTES system consists of 120 boreholes of 200 m depth. Boreholes act as heat exchangers to 1 200 000 m^3 rock mass.

The boreholes are also used to store 200 MWh of recovered heat from summer cooling and 2180 MWh from river to be used in wintertime.

The use of a heat pump (HP) makes it possible to recover heat from the soil and river water and to provide basic heating load instead of using the existing boiler house.

The system will replace approx. 4 800 MWh of bought fuel oil annually at an SPF of 3,5. With the current energy prices the investment will be paid back within 12 years.

The project will reduce emission of CO_2 with 1589 tons per year.

An environmental preliminary assessment indicates that the BTES system will not cause environmental impact on the nearby surrounding.

It should be mentioned, that having in view the current low fuel prices, outlook for substantial increase and relative stability of electricity prices, the profitability of geothermal energy can be much higher in the future.