Heat Utilization and Consumption in Research Laboratory Building

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Master's Thesis

Accepted ___. ___. ______ ______________________________

SAVONIA UNIVERSITY OF APPLIED SCIENCES **THESIS**
Abstract

Field of Study Technology, Communication and Transport			
Degree Programme Master’s Degree Programme in Industrial Management			
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Title of Thesis Heat Utilization and Consumption in Research Laboratory Building			
Date	1.11.2012	Pages/Appendices	36
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Client Organisation/Partners Savonia University of Applied Sciences			

Abstract

Savonia University of Applied Sciences is going to build new research laboratory in Varkaus campus area. In the new research laboratory building is generated a lot of heat by different kind power boilers. But, when there is no research activity, the building must be heated with another heating system.

In the thesis three different heating systems are compared: geothermal heating, district heating and wood fired boiler. In the first part there are the actual research and all dependencies when selecting suitable heating system to research laboratory building presented. This part was done together with the project team during the building’s design phase.

In the second part, investment calculations of all three heating systems were made, and after calculations these calculations are compared against each other. In the calculations investment costs, operating costs and maintenance costs are taken account. There is also limit value testing of some critical values, which are causing costs to heating systems.

Keywords
geothermal heating, district heating, wood fired boiler, investment calculation

CONTENTS

1 INTRODUCTION

1.1 The subject of final thesis

Savonia University of Applied Sciences started a new EU-funded project. This research laboratory is going to be a small power plant, where R&D- department and students could do e.g. firing test with different fuels, material testing and research of heat and electrical power production.

Varkaus Campus is already connected to district heating system provided by Varkauden Aluelämpö Oy.

The goals this thesis were to think and compare different heat sources to heat up the research building. Together with the project team was made a selection on, which heating system is going to be used in the new building. Also investment calculations were made on, what is the most economical way for the heating of this kind of building.

After investment calculations a sensitivity analysis was done, where some limit values of parameters were founded which are basis of investment calculations. This will help to think in future the price changes, because heating system investments are in normal use for about 30 years of use.

1.2 Company introduction

Savonia operates in three cities in Finland and they have in total over 600 employees. There are six main education areas, with about 6500 students from different countries. (Savonia year 2011 report, 2012)

The Research and Development (R&D) unit of Savonia University of Applied Sciences is connecting teaching and work life connection of studies. R&D brings new information to students and they also support local industry and companies by doing research projects in co-operation with them. R&D is divided to three main parts:

- Energy, environment and safety
- Welfare products and services
- Integrated product development

(Savonia web-pages, 2012)

In Varkaus R&D is concentrating on renewable energies very strongly. In Varkaus Energy technology R&D- department has five employees and some teachers are also involved in R&D working.

There has been a lot of talk about combining R&D and normal teaching together, and this project and the new building also provide a teaching environment to energy technology engineering students.

2 BACKGROUND OF HEATING SYSTEM SELECTION TO RESEARCH LABORATORY

2.1 First thoughts of designing

When starting the project, there an assumption were made that in average the small power plant is running appr. one week in a month during the winter season. When the power plant is running, the heat to research laboratory is made from the power plant by using the hot water coming from the boiler. The rest of the time, when the power plant is not running, the heat has to come from some other source.

At first the thought was that because a new power plant is coming, the energy coming from the power plant should be used economically for heating the Varkaus Campus buildings, by connecting the power plant to the district heating system. Varkaus Campus is divided to three buildings of, which each has its own district heating connections due to the fact that they are built at different years. It was decided that the only possibility is to connect the power plant to the newest part, C-part of Varkaus Campus.

FIGURE 1 Location map of Savonia- Campus with information (Maanmittauslaitos, 2012) 1. New research laboratory, 2. Existing district heating connection to building C, 3. Possible new connections to research laboratory

2.2 Connection to district heating network and to building C

District heating is distributed from power plants to consumers via pressurized pipes containing hot water. It is divided to two pipes, forward and return pipes of district heating water. (Energia ja ympäristö, 1997, 124-125)

A meeting with Varkauden Aluelämpö was held with conversation about connecting the power plant to building C's heating system or to the district heating network of Varkauden Aluelämpö Oy. The conclusion was that the hot water connection would be a pressure connection where pressure equipment directive (PED) will be applied. Varkauden Aluelämpö were not willing to take responsibility of this connection, and neither did Savonia, because then Savonia would take responsibility also of the Varkauden Aluelämpö district heating network. So it was very clear that the power plant would not be used to heat the building C via the district heating network. This decision was supported by a small research to building C's heat consumption over last years, the result of which are shown in next chapter.

Varkauden Aluelämpö Oy was not interested in paying for the heat produced by the research laboratory power plant, but price discounts to existing prices based on the research laboratory heat production to district heating network were discussed.

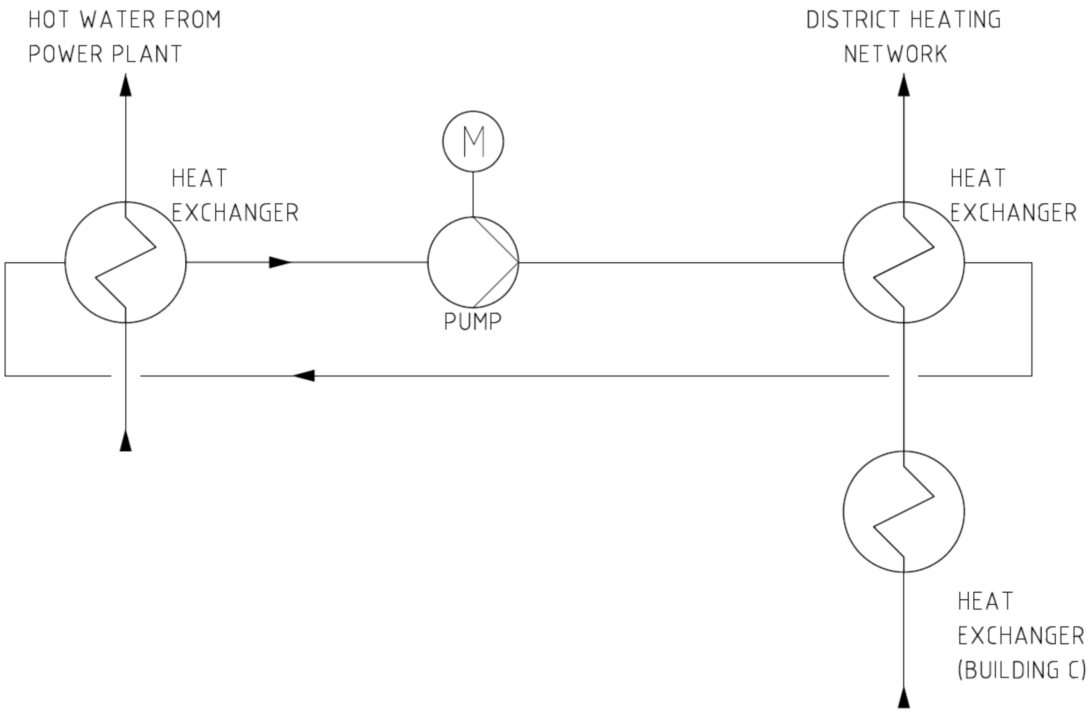

FIGURE 2 Process diagram showing connection of produced hot water to district heating system and heating system of building C

2.3 Connection only to building C's heating system

Basically in wood chip (or some other solid fuel) heating system the fuel is fed to furnace where it is burned. The heat is transferred from the hot flue gas by heat exchanger pipes to hot water. Hot water is usually lead to the hot water container which equalizes the need of fuel supply to boiler. (Pientalon lämmitysjärjestelmät, 2011, 15) Hot water container and it's locations and process connections were one big question, if the wood fired boiler is going to be connected to building C heating system.

The janitor has written up every month's total heat consumption over the years of the heat consumption of Savonia Campus. Based on this information a research of heat consumptions was done and calculated the possibility to use laboratory's power plant to heat building C or some parts of it.

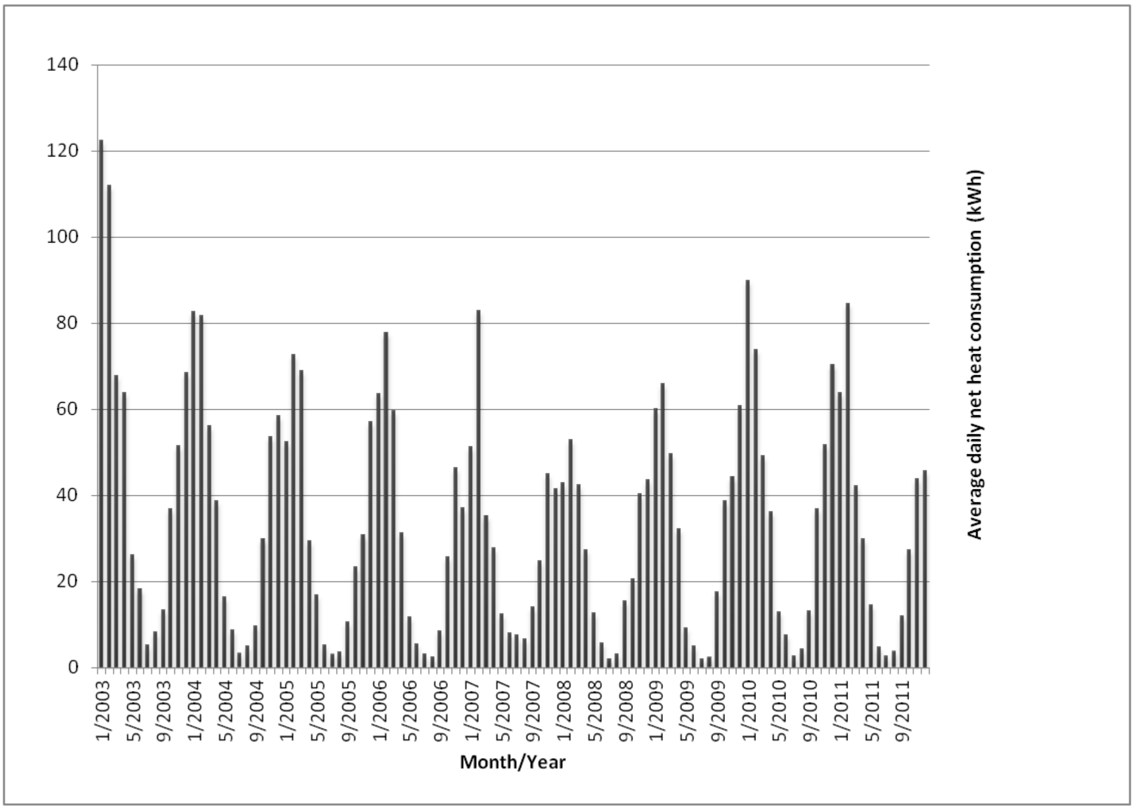

FIGURE 3 Average daily net heat consumption in building C (kW)

At this phase of the project it was estimated, that the new power plant boiler's net power will be appr. 390 kW and boiler efficiency appr. 88 %. It was easy to see that this sized boiler is oversized to give heat to building C, in only very cold days it is possible to run it with full power. Also change of process inside the building's heating network must be done, because the facts shown in chapter 2.2, that the power plant heat production shall not be connected to district heating network at all.

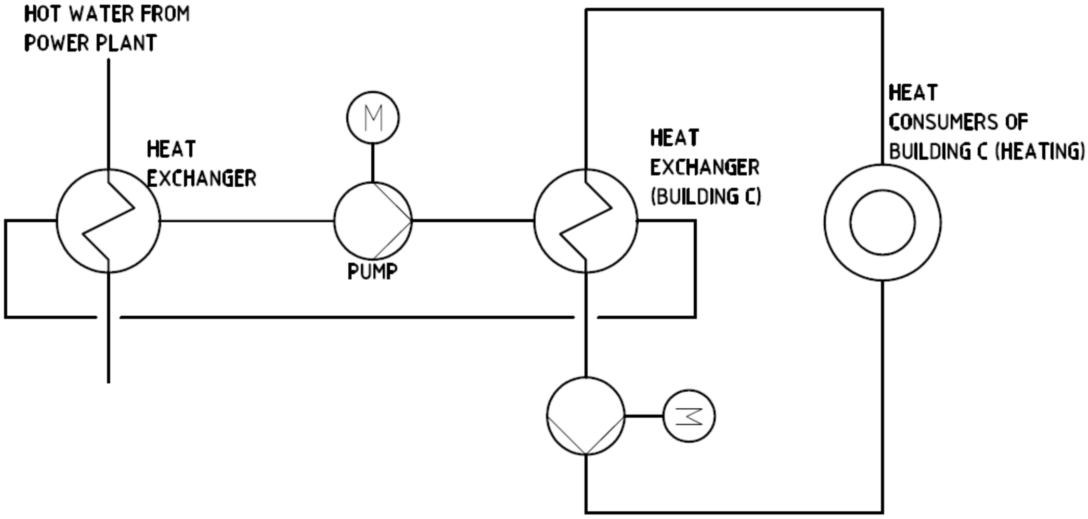

FIGURE 4 Process diagram showing connection of produced hot water to the heating system of building C. Diagram is not taking into account of the hot water container.

2.4 Air heating system via district heating

There was a choice, where a pipe branch from the C- building district heat connection is taken to new research laboratory building. Then the heat is done by air heating system. This system is very common in industrial buildings. Anyway in this case must be done some serious digging in the front of the main door, because the distance between district heating connection and the new building is appr. 60 meters.

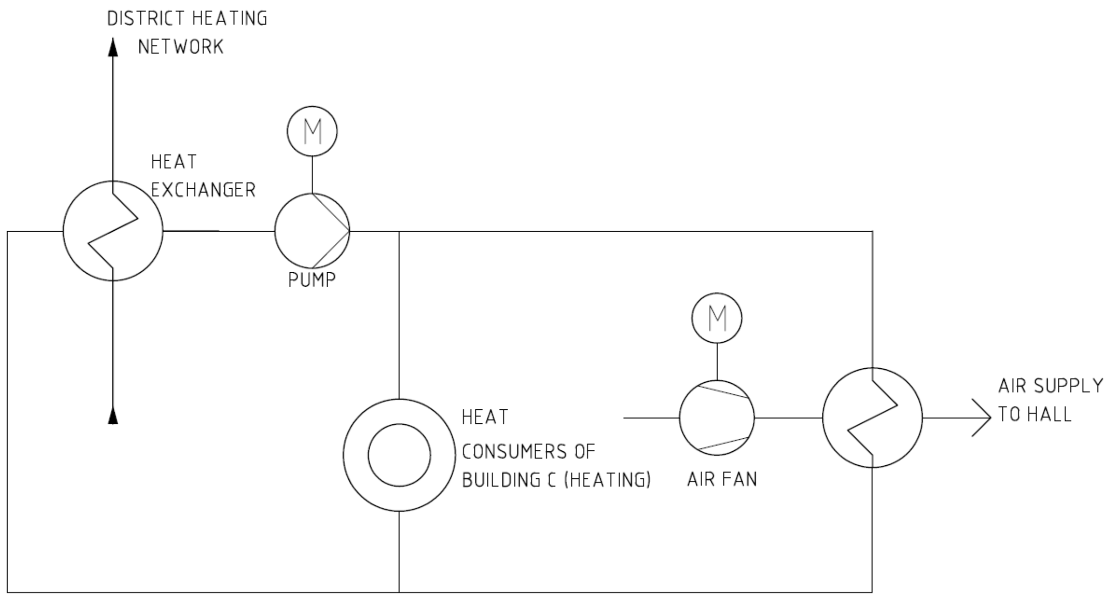

FIGURE 5 Process diagram showing connection of air heating system

2.5 Geothermal heating

So basically there were two problems. First is that research laborotary's power plant is going to produce too much energy during the test firing periods to be used in the laboratory heating and to the building C heating. So the heat must be lost somehow or to somewhere. Second problem is that there is still need to heat the research laboratory building when the power plant is not running.

After a few meetings was found an idea, that maybe the geothermal heating system should be in the research laboratory. The advantage is that there might be a economical way to loss some of the overproduced heat by pumping it back to the ground (geothermal well drilled inside the ground). This could be also a very interesting research project to R&D department of Savonia.

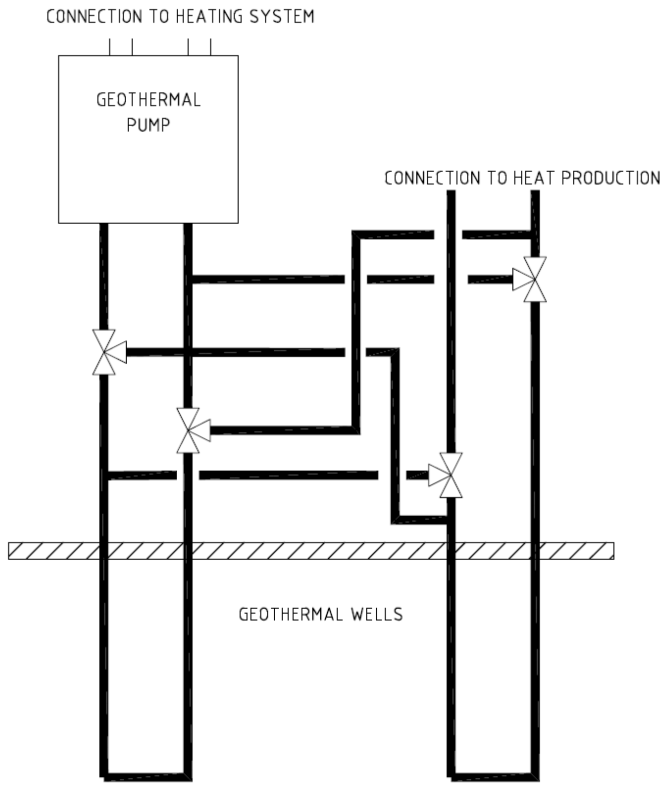

FIGURE 6 Principle process diagram showing connection of geothermal heating and cooling system.

So the final solution to the heating is that geothermal heating system is connected to hot water container. The overheat production from the power plant is also connected to hot water container. When the power plant is not in production, geothermal heating is producing the heating to the building in winter time. When the power plant is in operation, the geothermal heating system could be turned off automatically by the process automation system. The heating device was selected to be air convection heating which was introduced in the previous chapter. Air convection heating is good at industrial use, because it leaves the floor totally for the equipment. Heavy equipment installation could be tricky if there is a floor heating system.

In the air heating system the incoming air temperature is controlled in a similar way as water circulated radiator. In air convection heating the heating device could be controlled by keeping the water flow as constant. Other option is to control water flow, which could make changes to temperature differences after the convection blower. (Rakennusten lämmitys, 1995, 190)

2.6 Summary of heating system selection

If there is not so strict rules to connect power boilers to district heating network, it would be the most reasonable way to make the heat loss. In this case the heating of the building would be done also with district heating. In this case, the district heating connection would be very expensive due to the location of the new building.

Geothermal heating system is in this case very good because it is a modern heating system and it gives good research possibilities also. Savonia University of Applied Sciences is concentrating very much also on renewable energies, so geothermal heating system could be tested together with solar energy systems. (hybrid heating system.

3 COST COMPARISON OF DIFFERENT HEATING SYSTEMS

In the previous chapter the different heating systems of the new building and selection basis of the new building heating system were introduced, when thinking the technical side of the system. Because the research laboratory will be equipped with a wood fired boiler, I would like to do here cost comparison between geothermal heating system, wood fired boiler and district heating. The wood fired boiler in this comparison is selected to be about of the same size with geothermal heating. In this thesis calculations were made an assumption that heating energy needed in building in one year is 45 000 kWh.

The building is going to be a half warm building and the appr. area inside the building is 175 m^2. The building is higher than normal residence building, with also a little tower of 7 meters in height in one part of the building.

It should be mentioned that not all the costs in following calculations are from real-life offers, they are mostly estimations or assumptions. Also in the calculations only the most significant values are taken into account, i.e. electricity consumption of valves, control systems or small pumps are not taken account. After all the small electric devices in all three systems consume a similar amount of electrical power.

3.1 Costs and maintenance of geothermal heating system

In geothermal heating the biggest investment is the geothermal well and the equipment including compressor. Usually the geothermal heating system is purchased in whole package from one supplier, where the package includes the geothermal well drilling, piping and the compressor with necessary accessories.

INVESTMENT COSTS	
GEOTHERMAL HEATING	
Heat pump (€)	11 500
Drilling & well & piping (€)	17 000
Hot water tank (€)	3 200
Total investment cost (€)	**31 700**

TABLE 1 Investment costs of geothermal heating

In table 1 all costs are assumptions or estimations from real-life experience. In heat pump pricing one e-shop pricing was used and also some comparisons from technical magazines. The price of hot water tank is for a 3000 litre tank. Wells and drilling are calculated on the basis, that the first well cost of 7000 € and second and the third well cost 5000 € each.

Basically geothermal heating is maintenance free. When thinking possible malfunctions or breakdowns, the most expensive component is the compressor, which is estimated to be about 2000 €.

MAINTENANCE COSTS	
GEOTHERMAL HEATING	
New compressor (€)	2 000
Valve actuators (€)	200
Total maintenance cost for 30 years (€)	**2200**

TABLE 2 Maintenance costs of geothermal heating for 30 years.

Based on expected life-time of 30 years of use, it is made an assumption that compressor will break down outside of the warranty time and also replacement of valve actuator(s) is possible. Costs of spare parts in table 2 are assumptions. Motiva Oy, which is owned by the state of Finland, has been said that compressor will last about 15 to 20 years. (Lämpöä omasta maasta / Motiva web-pages, 2012)

Geothermal heating requires electricity to produce heat and a hot water tank is also needed to allow suitable working cycles for the heat pump, where the hot water tank is working as heat storage for water.

OPERATING COSTS	
Heating energy needed (kWh / year)	45000
GEOTHERMAL HEATING	
COP of the system	3,7
Electrical power needed to heating (kWh/year)	12 162
Cost of electricity (€/kWh)	0,12
Total operating cost in one year (€)	**1459**

TABLE 3 Operating costs of geothermal heating

In table 3, COP (Coefficient of performance) of the geothermal heating pump is from real-life system. (Stiebel-Eltron web-pages, 2012) COP means the ratio of the amount of heat that heat pump could convert from the consumed electric power.

Electrical power needed to heating could be calculated by formula :

$$Electrical\ power\ needed\ to\ heating\ (kWh)\ = \frac{Heating\ energy\ needed\ (kwH)}{COP}$$

There are small fluctuations in the price of electricity and in general it is slowly going to increase. In table 3 the cost of electricity is made by an assumption. In geothermal heating, the operating cost is the electricity needed to run the heat pump. It could be calculated by the formula:

$$Cost\ of\ electricity\ (€/year) = Cost\ of\ el.\left(\frac{€}{kWh}\right) \times El.power\ needed\ (kWh/year)$$

3.2 Costs and maintenance of a wood fired boiler

The biggest investment of this heating system is the boiler, and the investment is usually covered with bank loan. Boiler needs also a suitable room, where the boiler is placed. There is also need for fuel storage. Fuel storage size depends on the maintenance periods of the boiler.

INVESTMENT COSTS	
WOOD FIRED BOILER	
Boiler (€)	9 000
Hot water tank (€)	3 200
Fuel silo (€)	500
Total investment cost (€)	**12 700**

TABLE 4 Investment costs of wood-fired boiler

In table 4 the costs are based on a real-life offer, which was a few years old. The offer was for wood chips and pellets burning boiler, whose heat capacity was 40 kW. Hot water tank is sized to 3000 liters and its price is from real-life offer.

When thinking about maintenance costs, with wood fired boiler there is need for a person to take care and check the operations of the boiler. When firing any burnable fuel, there is always a result of ash and the ash needs to be removed with some time interval from the boiler, if it is not automatic. Even if the ash removal is automatic, the ash container needs to be taken care, where the ash is coming from the boiler. Other maintenance task is the fuel feeding system. If boiler is firing wood pellets, it is easier to maintenance due the smooth composition of the fuel. If the fuel is wood chips and wood boughs it could make the fuel feeding system to stuck sometimes. In this case the boiler usually goes to alarm/safe mode, where the heat is done by electric heating. In a modern boiler automation system there is always some kind of alarm to e-mail or SMS to a phone, to make sure that the maintenance people react fast to the problem.

The hot water tank equalizes heat producing problems that were described above, and it is good to have a hot water tank in the heating system to keep water temperature stable.

MAINTENANCE COSTS	
WOOD FIRED BOILER	
Valve actuators (€)	200
Maintenance of fuel conveyors (€)	700
Total maintenance cost for 30 years (€)	**900**

TABLE 5 Maintenance costs of a wood-fired boiler

In table 5 maintenance costs are assumptions made on the basis during that the expected life-time period of 30 years there some spare parts to conveyors and to valve actuators will be needed.

What comes to the fuel, it has to come from somewhere to the boiler's fuel storage, and somebody must do the work to order and receive the fuel to the storage. If forest waste is going to be burned and it is possible to do the work by own from own forests, it is cheaper than to order fuel from suppliers. In long life time period there could be some worn parts in the conveyors, which may require some spare parts to be purchased and replaced.

WOOD FIRED BOILER	
Lower heat value of fuel (MJ/kg)	13,00
Boiler efficiency	0,88
Fuel power needed (kWh)	51136
Cost of wood chips (€/MWh)	17,42
Cost of wood chips (€)	891
Wood chips needed (ton)	14,2
Fuel density (t/m^3)	0,3
Fuel storage needed (m^3)	47,2
Ash removal / weekly checking (€)	839
Total operating cost in one year (€)	**1729**

TABLE 6 Operating costs of wood-fired boiler

In table 6 the lower heat value of fuel is an example of wood chip lower heat value. This could be like birch wood with 30% moisture content. Fuel power needed is calculated by formula:

$$Fuel\ power\ (kWh)\ = \frac{Heating\ energy\ needed\ (kwH)}{Boiler\ efficiency}$$

Cost of wood chips (€/MWh) is a statistical value found from internet. (Bioenergiapörssi web-pages, 2012). Total cost for one year's wood chips could be calculated by formula:

$$Fuel\ cost\ (€/year) = Cost\ of\ fuel\ \left(\frac{€}{kWh}\right) \times Fuel\ power\ needed\ (\frac{kWh}{year})$$

Fuel density value is based on statistical values by Technical Research Center of Finland (VTT) and commerce- and industrial ministry, these values were found from the internet. (Bioenergy in Finland web-pages, 2012) First I did calculation of how much there is need to wood chips in one year by formula:

$$Wood\ chips\ needed\ (ton) = \left(\frac{Fuel\ power\ (kWh)}{\frac{Lower\ heat\ value\ (\frac{MJ}{kg}) \times 1000}{3600}}\right) \div 1000$$

When the density of fuel is known, the total fuel storage needed in one year could be calculated by formula:

$$Fuel\ storage\ needed\ (m^3)\ = \frac{Wood\ chips\ needed\ (ton)}{Fuel\ density\ (\frac{t}{m^3})}$$

These values above are interesting when thinking of wood fired boiler as primary heat source, because the owner must think how often he needs wood and how long he wants it to be dried up in the fuel storage before it is burned in the furnace of the boiler. Basically the size of the fuel storage determines how often the storage must be filled, and in Finland most of the energy is consumed in a few winter months.

In the last line of the table 6 the maintenance cost working hours of wood fired boiler are estimated. It was checked from financial department that janitor's working hour price inside Savonia is appr. 21,5 € per one hour, and the need to maintenance work is estimated to be in average of 0,75 hours in week. This includes weekly checking, ash removal, fuel storage filling and other small tasks with the boiler. When thinking outside of company, like in private housekeeping, normally people do not calculate their own work as part of the operating costs. And there is always possibility that someone has his own forests to be used in the boiler, which makes dramatic decrease to operating costs of the wood fired boiler.

3.3 Costs and maintenance of district heating system

District heating investment is divided usually to two parts. Building the heat distribution system is purchased from the supplier, which will provide the whole system including heat exchangers, control system and energy meter. Other part is enrollment pay to district heating supplier which includes ground work and piping to the building. Enrolment payment and heat distribution system investments are usually covered by bank loan.

INVESTMENT COSTS	
DISTRICT HEATING SYSTEM	
Heat distribution system (€)	7 500
Enrollment payment (€)	12 676
Total investment cost (€)	**20 176**

TABLE 7 Investment costs of district heating system

In table 7, heat distribution system cost is an assumption based on real-life investment of similar equipment to private house. Enrollment payment is directly from Finnish Energy Industries web-pages, where the association represents these costs two times in a year. (Energiateollisuus web-pages, 2012)

District heating system is very reliable and almost maintenance free. The system's expected lifetime is appr. 30 years (heat exchanges and piping) and heat supplier is responsible for providing necessary heat flow to building.

MAINTENANCE COSTS	
DISTRICT HEATING SYSTEM	
Valve actuators (€)	200
Leakage in heat-exchanger (€)	600
Total maintenance cost for 30 years (€)	**800**

TABLE 8 Maintenance costs of district heating system.

In table 8 it was estimated that there is some small maintenance to the valve actuators and to heat-exchanger.

Of the heating energy consumer will pay every month depending on the heat usage.

OPERATING COSTS	
Heating energy needed (kWh / year)	45000
DISTRICT HEATING SYSTEM	
Heating price (€/kWh)	0,0704
Total operating cost in one year (€)	**3168**

TABLE 9 Operating costs of district heating system

Heating price in the table 9 is also from Finnish Energy Industries web-pages, where the association represents these costs two times a year. (Energiateollisuus web-pages, 2012) Total costs for the heating is calculated by formula which is very similar to the one that was handled in the geothermal heating part of this thesis:

$$Cost\ of\ heating\ (€/year) = Cost\ of\ heat \left(\frac{€}{kWh}\right) \times Heat\ energy\ needed\ (kWh/year)$$

3.4 Summary of costs in different systems

To see the above mentioned in total, I made a table which summarizes all the costs.

TOTAL COSTS (INVESTMENT, OPERATING AND MAINTENANCE)	
Maintenance costs divided to years (a)	30
GEOTHERMAL HEATING	
Operating costs	1 459
Maintenance costs	73
Total operating cost for 1 year (€)	**1533**
Investment for 30 years (€)	**31700**
DISTRICT HEATING SYSTEM	
Operating costs	3 168
Maintenance costs	27
Total operating cost for 1 year (€)	**3168**
Investment for 30 years (€)	**20176**
WOOD FIRED BOILER	
Operating costs	1 729
Maintenance costs	30
Total operating cost for 1 year (€)	**1759**
Investment for 30 years (€)	**12700**

TABLE 10 Cost summary of different heating systems

In table 10 it is easy to see that investment of geothermal heating system is the most expensive investment. In operating costs geothermal heating and wood fired boiler are almost even, but wood fired boiler is much cheaper as an investment. In Finland people usually think that geothermal heating is expensive and the investment's pay-back time is long. This thinking is quite right. But the operation costs of this system are making it a very reasonable heating system together with the low maintenance needed, at least if it is compared to district heating system.

Wood-fired boiler is cheapest to invest and it seems that if there is possibility to take as hobby to make the wood and maintenance the boiler, it would be the cheapest system after all. In table 10 the maintenance costs are calculated to one year costs based on 30 year expected life-time, because it is interesting to see how much the owner should be prepared to spend on to spare parts in one year's time cycle. I think that just buying the wood ready to fire is not a good idea in Finland. With the wood-fired boiler, you have to get the wood from somewhere at a lower price than the market price. This applies to this kind of small boilers with a small heating power, the case is different if the boiler is big and supplying energy to a town or factory.

Anyway the maintenance costs are mainly my own assumptions, so they could make a big role if there are problems with equipment and machines. Geothermal heating system is quite a new way to make energy and there are no long term experiences of possible machine problems with them. Also earlier in Finland, the wood-fired boiler has been like a furnace, where the logs are put in manually, maybe once a day. In this kind of modern wood-fired boiler, the fuel feeding system is automatic, so the problems might be different with the automatic feeding system. With the wood-fired boiler the owner must make decisions with the size of the wood storage system, because in the cold time of the year the wood consumption is higher than in the warmer times of the year. This determines how often the owner must fill up the fuel storage.

4 INVESTMENT CALCULATIONS

In this kind of big investments the financial part is crucial which must be considered carefully in long-term. In this chapter I show different kind of calculations on how to estimate the economy of this kind of heating systems investments. This was a very interesting part in advance, because usually especially in Finland people think that geothermal heating is a very expensive investment.

In this chapter I will represent methods *annuity* and *net present value* to calculate some information of the investments.

4.1 Annuity

In the annuity method investment costs are divided into yearly based returns by using annuity factor. (Rahoitus, 2009, 15) (Energia Suomessa, 2004, 388)

Defaults to be selected in annuity calculations were that the loan interest is 5 % and the loan period is 20 years.

4.1.1 Annuity calculation of geothermal heating investment

ANNUITY

Interest (%)	5
Loan period (years)	20
Annuity	0,080243
Interest + repayment (€)	2543,69
Investment cost (€)	31 700

YEAR	INVESTMENT (€)	BALANCE (€)	INTEREST (€)	REPAYMENT (€)	INTEREST+REPAYMENT (€)
0	-31700,00	-31700,00	0,00	0,00	2543,69
1		-30741,31	1585,00	958,69	2543,69
2		-29734,69	1537,07	1006,62	2543,69
3		-28677,73	1486,73	1056,96	2543,69
4		-27567,93	1433,89	1109,80	2543,69
5		-26402,63	1378,40	1165,29	2543,69
6		-25179,07	1320,13	1223,56	2543,69
7		-23894,34	1258,95	1284,74	2543,69
8		-22545,36	1194,72	1348,97	2543,69
9		-21128,94	1127,27	1416,42	2543,69
10		-19641,70	1056,45	1487,24	2543,69
11		-18080,10	982,09	1561,61	2543,69
12		-16440,41	904,00	1639,69	2543,69
13		-14718,74	822,02	1721,67	2543,69
14		-12910,99	735,94	1807,75	2543,69
15		-11012,85	645,55	1898,14	2543,69
16		-9019,80	550,64	1993,05	2543,69
17		-6927,10	450,99	2092,70	2543,69
18		-4729,76	346,35	2197,34	2543,69
19		-2422,56	236,49	2307,20	2543,69
20		0,00	121,13	2422,56	2543,69

TABLE 11 Annuity calculation of geothermal heating investment

4.1.2 Annuity calculation of district heating investment

ANNUITY

Interest (%)	5
Loan period (years)	20
Annuity	0,080243
Interest + repayment (€)	1618,97
Investment cost (€)	20 176

YEAR	INVESTMENT (€)	BALANCE (€)	INTEREST (€)	REPAYMENT (€)	INTEREST+REPAYMENT (€)
0	-20176,00	-20176,00	0,00	0,00	1618,97
1		-19565,83	1008,80	610,17	1618,97
2		-18925,14	978,29	640,68	1618,97
3		-18252,43	946,26	672,72	1618,97
4		-17546,07	912,62	706,35	1618,97
5		-16804,40	877,30	741,67	1618,97
6		-16025,65	840,22	778,75	1618,97
7		-15207,95	801,28	817,69	1618,97
8		-14349,38	760,40	858,58	1618,97
9		-13447,87	717,47	901,51	1618,97
10		-12501,29	672,39	946,58	1618,97
11		-11507,38	625,06	993,91	1618,97
12		-10463,78	575,37	1043,61	1618,97
13		-9367,99	523,19	1095,79	1618,97
14		-8217,42	468,40	1150,57	1618,97
15		-7009,31	410,87	1208,10	1618,97
16		-5740,80	350,47	1268,51	1618,97
17		-4408,87	287,04	1331,93	1618,97
18		-3010,34	220,44	1398,53	1618,97
19		-1541,88	150,52	1468,46	1618,97
20		0,00	77,09	1541,88	1618,97

TABLE 12 Annuity calculation of district heating investment

4.1.3 Annuity calculation of wood fired boiler investment

ANNUITY

Interest (%)	5
Loan period (years)	20
Annuity	0,080243
Interest + repayment (€)	1019,08
Investment cost (€)	12 700

YEAR	INVESTMENT (€)	BALANCE (€)	INTEREST (€)	REPAYMENT (€)	INTEREST+REPAYMENT (€)
0	-12700,00	-12700,00	0,00	0,00	1019,08
1		-12315,92	635,00	384,08	1019,08
2		-11912,63	615,80	403,28	1019,08
3		-11489,19	595,63	423,45	1019,08
4		-11044,56	574,46	444,62	1019,08
5		-10577,71	552,23	466,85	1019,08
6		-10087,52	528,89	490,20	1019,08
7		-9572,81	504,38	514,71	1019,08
8		-9032,37	478,64	540,44	1019,08
9		-8464,91	451,62	567,46	1019,08
10		-7869,07	423,25	595,84	1019,08
11		-7243,45	393,45	625,63	1019,08
12		-6586,54	362,17	656,91	1019,08
13		-5896,78	329,33	689,75	1019,08
14		-5172,54	294,84	724,24	1019,08
15		-4412,09	258,63	760,45	1019,08
16		-3613,61	220,60	798,48	1019,08
17		-2775,21	180,68	838,40	1019,08
18		-1894,89	138,76	880,32	1019,08
19		-970,55	94,74	924,34	1019,08
20		0,00	48,53	970,55	1019,08

TABLE 13 Annuity calculation of wood-fired boiler investment

4.1.4 Summary of annuity calculations

As a summary of cost for different bank loans, annuity for different heating system loans for a 20- year period with a 5% interest rate are:

Geothermal heating	2544 € / year
District heating	1619 € / year
Wood fired boiler	1019 € / year

4.2 Net present value

In the net present value method, there the future incoming cash flow in its net present value is calculated by using inflation rate. Future cash flow's net present value is compared to costs caused by the investment. (Yrityksen rahoitus, 2002, 87)

Inflation rate in calculation was selected to be 3,7 %, which is estimation based on Statistic Finland statistics. (Statistic Finland web pages (Findicator), 2012)

In this method it is compared, how much savings is going to be between different systems against each other. The savings are operating and maintenance costs of different systems. In the calculation the payment occurs always at the end of the year.

4.2.1 Geothermal heating compared to district heating system

Operating costs and maintenance costs of geothermal heating system were calculated to be 1533 € in year, and district heating system's 3168 € in year. So in operation costs geothermal heating saves 1635 € every year compared to district heating system. In investment costs, the investment is 20 176 € - 31 700 € = - 11 524 €. (investment of district heating system – investment of geothermal heating)

NET PRESENT VALUE

Inflation (%)	3,7
Savings (€)	1635
Investment (€)	-11524

YEAR	GAIN (€)	PRESENT VALUE (€)	PRESENT VALUE OF GAIN (€)	CUMULATIVE GAIN (€)
0				-11524
1	1635	0,9643	1577	-9947
2	1635	0,9299	1520	-8427
3	1635	0,8967	1466	-6961
4	1635	0,8647	1414	-5547
5	1635	0,8339	1363	-4184
6	1635	0,8041	1315	-2869
7	1635	0,7754	1268	-1601
8	1635	0,7478	1223	-378
9	1635	0,7211	1179	801
10	1635	0,6954	1137	1938
11	1635	0,6706	1096	3034
12	1635	0,6466	1057	4091
13	1635	0,6236	1020	5111
14	1635	0,6013	983	6094
15	1635	0,5799	948	7042
16	1635	0,5592	914	7956
17	1635	0,5392	882	8838
18	1635	0,5200	850	9688
19	1635	0,5014	820	10508
20	1635	0,4835	791	11298
21	1635	0,4663	762	12061
22	1635	0,4496	735	12796
23	1635	0,4336	709	13505
24	1635	0,4181	684	14188
25	1635	0,4032	659	14848
26	1635	0,3888	636	15483

27	1635	0,3750	613	16096
28	1635	0,3616	591	16688
29	1635	0,3487	570	17258
30	1635	0,3362	550	17807
31	1635	0,3242	530	18338
32	1635	0,3127	511	18849
33	1635	0,3015	493	19342
34	1635	0,2908	475	19817
35	1635	0,2804	458	20276
36	1635	0,2704	442	20718

TABLE 14 Net present value calculation of geothermal heating with district heating system to be compared

In the table 14 it can be seen that geothermal heating system has saved it's investment back to the owner in 9 years.

4.2.2 Wood fired boiler compared to district heating system

The operating costs and maintenance costs of wood-fired boiler were calculated to be 1759 € in a year, and district heating system's 3168 € in a year. So in operation costs wood-fired boiler is saving 1409 € every year. In investment costs, the investment is 20 176 € - 12 700 € = 7 476 €. In this case the saving is starting already in positive value, compared to case shown in chapter 4.2.1.

NET PRESENT VALUE

Inflation (%)	3,7
Savings (€)	1409
Investment (€)	7476

YEAR	GAIN (€)	PRESENT VALUE (€)	PRESENT VALUE OF GAIN (€)	CUMULATIVE GAIN (€)
0				7476
1	1409	0,9643	1359	8835
2	1409	0,9299	1310	10145
3	1409	0,8967	1263	11408
4	1409	0,8647	1218	12627
5	1409	0,8339	1175	13802
6	1409	0,8041	1133	14935
7	1409	0,7754	1093	16027
8	1409	0,7478	1054	17081
9	1409	0,7211	1016	18097
10	1409	0,6954	980	19077
11	1409	0,6706	945	20022
12	1409	0,6466	911	20933
13	1409	0,6236	879	21811
14	1409	0,6013	847	22659
15	1409	0,5799	817	23476
16	1409	0,5592	788	24263
17	1409	0,5392	760	25023
18	1409	0,5200	733	25756
19	1409	0,5014	707	26462
20	1409	0,4835	681	27144
21	1409	0,4663	657	27801
22	1409	0,4496	634	28434
23	1409	0,4336	611	29045
24	1409	0,4181	589	29634
25	1409	0,4032	568	30202
26	1409	0,3888	548	30750
27	1409	0,3750	528	31279
28	1409	0,3616	509	31788

29	1409	0,3487	491	32279
30	1409	0,3362	474	32753
31	1409	0,3242	457	33210
32	1409	0,3127	441	33650
33	1409	0,3015	425	34075
34	1409	0,2908	410	34485
35	1409	0,2804	395	34880
36	1409	0,2704	381	35261

TABLE 15 Net present value calculation of wood fired boiler with district heating system to be compared

4.2.3 Geothermal heating system compared to wood fired boiler and all other comparisons

This chapter is just to show the idea of net present value method. Operating costs and maintenance costs of geothermal heating system were calculated to be 1533 € in a year, and for wood fired boiler 1759 € in year. So in operation costs geothermal heating is saving 227 € every year. The saving is so small that actually the saving does not give any savings to the investment going to be done due to the inflate rate. (investment never provides “pay back”)

	District heating system	Geothermal heating	Wood fired boiler
Geothermal heating	1635		227
District heating		-1635	-1409
Wood fired boiler	1409	-227	

TABLE 16 Operating and maintenance costs savings compared between different systems

In the table 16, positive value shows savings in euros compared to some other systems. Negative value shows, that savings are actually costing more compared to another system in the table, when we are calculating the investment by the net present value- method.

4.3 Summary of investment calculations

The annuity method gives an idea what are costs of the loan in the time period, where the loan is going to be paid back to the bank.

Net present value method shows more in common sense way what people think when they are thinking of replacing an old heating system with a new one, the word is in common language the “pay-back time”; the time in years when the savings of the investment reach a point that it “makes money” to the owner.

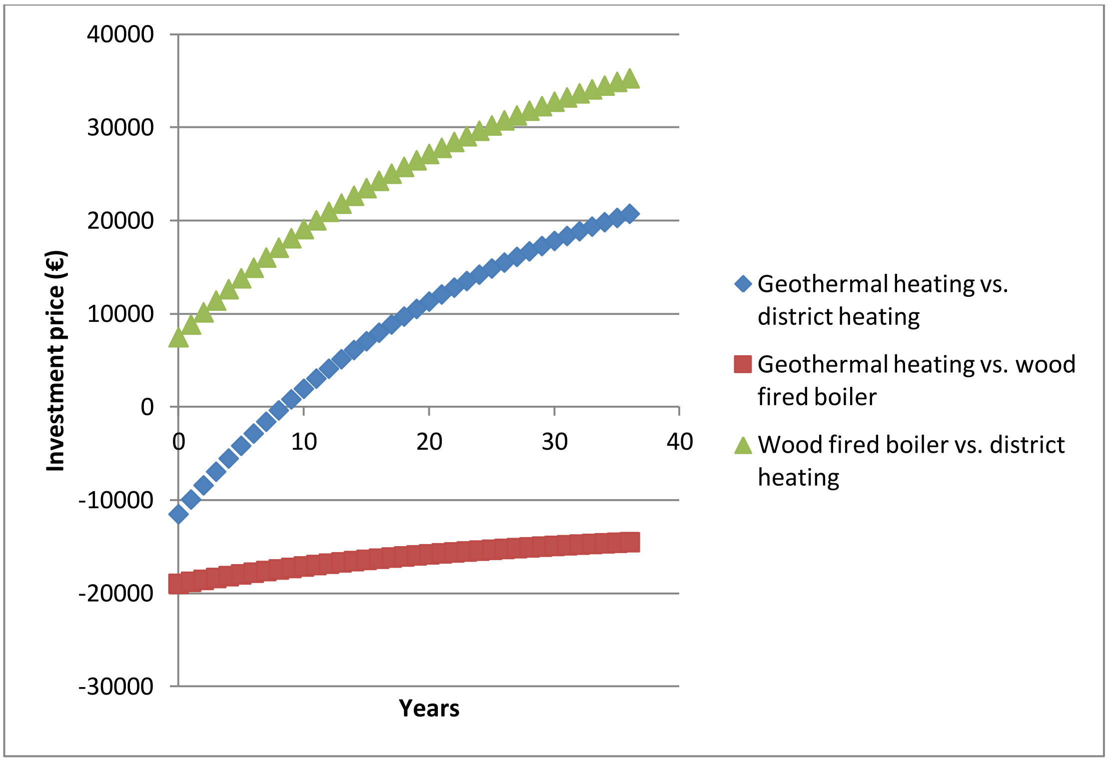

FIGURE 7 “Pay-back time” comparison

In figure 7 I made a graph, where a comparison of net present value comparison is shown. This gives a better look of how it looks like in this kind of big investment, when we take the inflation into account in the calculations. If we look at a trend of wood fired boiler vs. district heating, we could see that pay-back time is little bit over 10 years. If we compare geothermal heating system to wood fired boiler, due to the inflation, it never reaches the savings to the zero point so it is not actually paying it-self back. This is a theoretical comparison in this case anyway, because we are making calculations of a new heating system investment, but it gives a very good idea of the investment's economy!

5 SENSITIVITY ANALYSIS

The idea of this chapter was to find limits of operating costs by changing selected values in operating costs. The search was done by using Microsoft Excel add-on application, which is called *Solver.* Solver is what-if analysis tool for optimization. It helps to find optimal values by changing selected cell values in Microsoft Excel. (Office blogs web pages, 2012)

In this part of thesis the operating costs and annuity costs of loan are calculated together, when running the solver.

5.1 Changing electricity price

As it was stated earlier in chapter 4, the geothermal heating is the cheapest heating system when we look at the operating costs. So together with the teacher it was decided to analyze: What is the value of electricity price in €/kWh, where the operation cost in one year is the same with the district heating system?

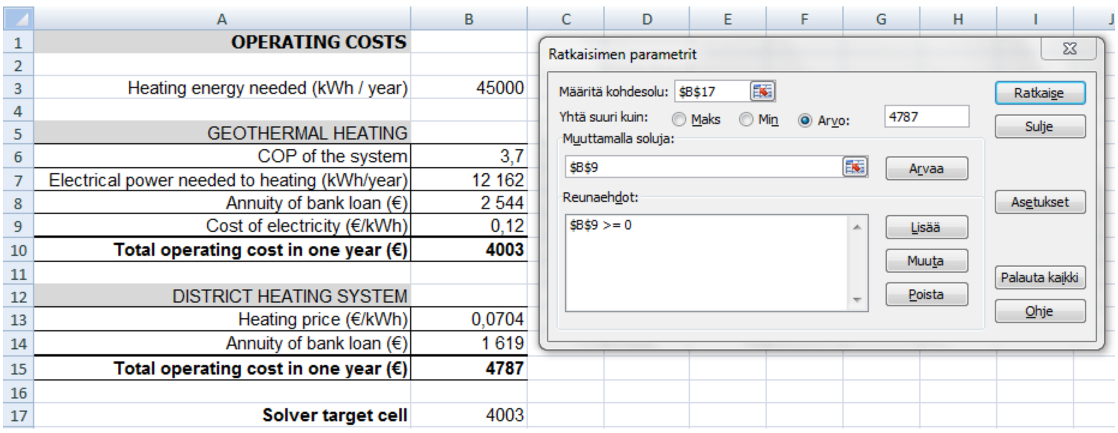

FIGURE 8 Solver parameters when finding limit price of electricity price

In solver target cell the total operating cost for one year is calculated, and it is set to be the same as the operating cost and annuity of district heating system (4 787 €). Then the solver is programmed to change value of cell B8 until the operation costs meets the limit.

The limit price of electricity is 0,18 €/kWh, where the operation cost is the same with the district heating system. Excel table is screenshot of result is shown below in table 17.

OPERATING COSTS	
Heating energy needed (kWh / year)	45000
GEOTHERMAL HEATING	
COP of the system	3,7
Electrical power needed to heating (kWh/year)	12 162
Annuity of bank loan (€)	2 544
Cost of electricity (€/kWh)	0,18
Total operating cost in one year (€)	**4787**
DISTRICT HEATING SYSTEM	
Heating price (€/kWh)	0,0704
Annuity of bank loan (€)	1 619
Total operating cost in one year (€)	**4787**
Solver target cell	4787

TABLE 17 Solver results when finding limit price of electricity price

5.2 Changing COP of geothermal heating system

Another limit I wanted to test was to find the lower limit of COP where the price of the operation cost is the same with district heating system.

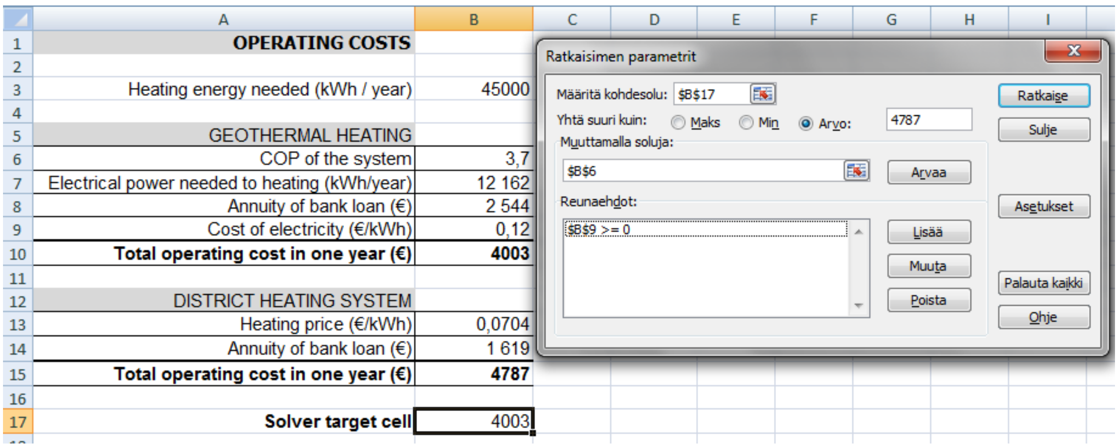

FIGURE 9 Solver parameters when finding limit of COP

In solver target cell it is calculated the total operating cost for one year, and it is to be set same as the operating cost of district heating system (4 787 €). Then the solver is programmed to change value of cell B6 until the COP of the geothermal pump is at the point, where electricity cost in one year is the same with the district heating cost.

When the limit value of geothermal heating pump COP is 2,4 the operation cost is the same with the district heating system. Excel table screenshot of result is shown below in table 18.

OPERATING COSTS	
Heating energy needed (kWh / year)	45000
GEOTHERMAL HEATING	
COP of the system	2,4
Electrical power needed to heating (kWh/year)	18 692
Annuity of bank loan (€)	2 544
Cost of electricity (€/kWh)	0,12
Total operating cost in one year (€)	**4787**
DISTRICT HEATING SYSTEM	
Heating price (€/kWh)	0,0704
Annuity of bank loan (€)	1 619
Total operating cost in one year (€)	**4787**
Solver target cell	4787

TABLE 18 Solver results when finding limit for the geothermal heating COP

6 CONCLUSIONS

At first I would like to say that when comparing to the start of the thesis, the content has changed quite a lot. It is explained by a lot of changes during the real-life project and I think that my thesis meets the needs of the project quite well.

I have also learned a lot of new thinking and methods to make economic calculations by using theories of investment calculations and thinking of different factors, which will cause operating and maintenance costs to heating system.

In summary I think that in Finland wood heating system is quite competitive, if the wood comes near and it is cheap. By this I mean a situation, where the wood chip could be made from the owner's own forest. Anyway, it needs more time and to be reasonable, wood chip silos are usually so small that it will require frequent wood chip filling to silos.

It was interesting to find out that with the parameters used in the calculation, the geothermal heating system was a very competitive option. In Finland people think that geothermal heating system is expensive because the high investment price but it is a very competitive option due the operational costs after the big investment.

I would also like to thank my supervising teachers (and work colleagues) Jukka Huttunen and Raija Lankinen for helping me out with the calculation part of this thesis.

LIST OF TABLES AND FIGURES

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