Viability of Improving Heating System Economicality and Efficiency

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Ohjaaja Kaisa Kontu

Tämän opinnäytetyön tavoitteena oli arvioida eri lämmitysjärjestelmätyyppejä ja mahdollisia säästöjä, joita voidaan saavuttaa vaihtamalla olemassa olevasta järjestelmästä kokonaan toisentyyppiseen lämmitysjärjestelmään. Yksi tavoitteista oli luoda laskurityökalu, jolla voi vertailla erilaisten lämmitysjärjestelmien käyttökustannuksien eroja.

Jatkuvasti nouseva energian hinta ja uusien teknologioiden saatavuuden parantuminen ajavat maailmaa parantamaan järjestelmien ja laitteiden energiatehokkuutta ja taloudellisuutta. Uudet uusiutuvat energialähteet pystyvät kilpailemaan uusiutumattomien lähteiden kanssa, sillä vaikka niiden käyttöön ottamisen hinta saattaa olla suurempi, niiden käyttökustannukset ovat yleisesti alhaiset. Hiilineutraalisuustavoitteet ja polttonesteiden hintojen nouseminen ovat tällä hetkellä uhkaavia ongelmia erityisesti jokseenkin epävakaan maailmantilanteen vuoksi.

Tämä opinnäytetyö sisältää yleiskatsauksen lämmitysjärjestelmien taustateoriasta ja tietoa joistakin tietyistä lämmitysjärjestelmätyypeistä, lämmitysjärjestelmien toteuttamiseen liittyviä seikkoja, sekä luvun, joka esittelee lämmitysjärjestelmien vertailulaskinta ja sen tulosten analysointia.

Lämmitysjärjestelmän vaihtaminen toiseen voi parantaa rakennuksen lämmityksen taloudellisuutta ja tehokkuutta. Parannuksen suuruus riippuu siitä, mikä korvattava lämmitysjärjestelmä on, mikä lämmitysjärjestelmä korvaa vanhan järjestelmän, mikä on uuden järjestelmän resurssien saatavuus sillä hetkellä ja kuinka hyvin alkuperäinen lämmitysjärjestelmä on loppuviimeksi toteutettu ja optimoitu. Joskus teoreettinen tehokkuuden parannus ei saata olla riittävä kattaakseen lämmitysjärjestelmän vaihtamisen kustannuksia järkevällä aikavälillä. Tällöin on suoritettava monitorointia, optimointia ja modernisointia olemassa olevan järjestelmän parantamiseksi.

Avainsanat lämmitysjärjestelmä, energiatehokkuus ja taloudellisuus, uusiutuvat energialähteet, vertailulaskin
Sivut 29 sivua

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Electrical and automation engineering Abstract
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Subject Viability of Improving Heating System Economicality and Efficiency
Supervisors Kaisa Kontu

The aim of this thesis was to evaluate different heating system types and the potential savings that could be achieved by switching from an existing system to a different type of heating system altogether. One of the objectives was to create a calculator tool that can be used to compare the operating costs of some different types of heating systems.

The ever-growing cost of energy and the increasing availability of new technologies are pushing the world to improve energy efficiency and economicality of systems and devices. New renewable sources are able to compete with non-renewable sources because even though the cost of implementing them might be greater, they have lower operating costs in-general. Carbon emission neutrality goals and the increased cost of fuels are pressing issues at current times, especially because of the somewhat unstable world situation.

This thesis contains an overview of the theory behind heating systems in-general and information about some of the specific heating systems types, considerations concerning the implementation of heating systems, and a chapter detailing a heating system comparison calculator and an analysis of its results.

Changing heating systems can definitely improve the economicality and efficiency of the heating in a building. The size of the improvement depends on what heating system is being replaced, what heating system is replacing the old system, what the availability of resources regarding the new system are at that time, and how well the original heating system was actually implemented and optimized. Sometimes the theoretical efficiency improvement may not be enough to repay the cost of the changing the heating system within a reasonable timeframe. In this case, monitoring, optimization, and modernization should be conducted in order to improve the existing system.

Keywords heating system, economicality and efficiency, renewable sources, comparison calculator
Pages 29 pages

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1 INTRODUCTION

With the ever-growing cost of energy and the increasing availability of modern technologies, finding solutions for improving the efficiency and cost-effectiveness of systems has become very important. Looking into the future, renewable sources are able to compete with non-renewable sources because of their low operating costs in-general. Carbon emission neutrality goals and the increased cost of fuels are pressing issues at current times, especially because of the somewhat unstable world situation.

The objective of this thesis was to evaluate the design considerations behind implementing a heating system and the potential savings that could be achieved by switching from an existing system to a different type of heating system altogether. The practicality and applicability of the improvements are also to be considered to evaluate the viability of the improvements in the real world. One of the objectives was to create a calculator tool that can be used to compare the operating costs of some different types of heating systems. The calculator uses hourly heating usage data from a specific target building in Helsinki. The building data and price data used are from 2020-2022, which was the best and newest data available.

The questions that this thesis aims to answer are:

1. Can changing to a different heating system improve economicality and efficiency?
2. What factors lead to an improved heating system efficiency?
3. Which heating systems are most resistant to possible future world events?

This thesis considers the heating systems that could be used by small individual residential or commercial buildings, or possibly by some larger residental or commercial buildings, like condomeniums, facilities, or apartment buildings. The focus is mainly on building specific heating systems and heating systems for some small area, not on large stations operated e.g, by the government.

The theory of heating systems and how the are implemented is analysed in the second and third chapters of the thesis. The fourth chapter is about the calculator tool and its principles. The fifth chapter and beyond are where the information from the theory and data calculations from the calculator are combined and analysed. The sixth chapter contains the conclusion.

2 IMPLEMENTATION OF HEATING SYSTEMS

2.1 Where is heating needed?

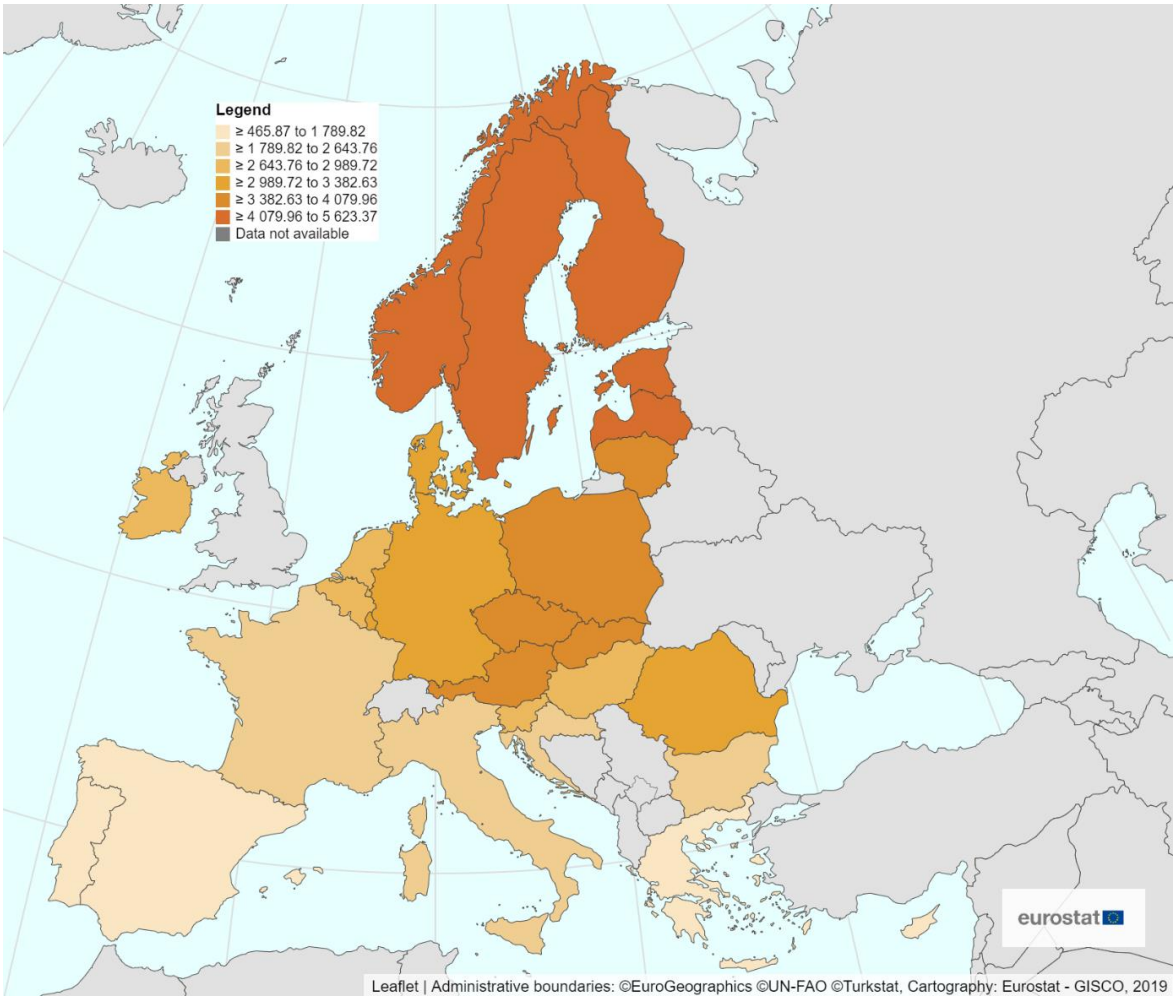
Many factors should be considered when implementing a heating system in a building. Perhaps the first factor is the location and type of building. Whether the building is located in an urban, suburban or a rural area. Whether the building is a residence, commercial space, office, public facility, or an industrial space. (Race, 2006)

Some places may be windy, sunny, arid, or experience low average temperatures where heating is needed much more than in warmer climates. In some warmer climates it is possible that heating may not even be required at all and they may require extensive cooling instead.

A heating degree day essentially indicates how much energy is needed for heating. The number of heating degree days is calculated by summing up the difference between the presumed indoor temperature and the average outside temperature of the day for each day within a certain time period. A map of heating degree days in European countries in can be seen in Figure 1. It visualizes an overview of which countries in Europe need the most heating for their buildings. (Ilmatieteen Laitos, (n.d.))

Using heating degree day as a unit, allows for standardization of the consumption of heating energy. Heating degree day allows for energy consumption comparisons of buildings in the climate conditions of different months or years as well as comparing buildings in different municipalities. (Ilmatieteen Laitos, (n.d.))

Figure 1: Heating degree days in European countries in 2021 (Eurostat, 2022)



2.2 When is heating needed?

The implementation and operation of the heating system also depends on the building type and when it is occupied. Some buildings, like residential buildings, may require continous heating and thus the efficiency and flexibility of the heating system is especially important. Buildings like offices and industrial buildings may be only occupied for specific times and vacant otherwise which can benefit from more controllable and scheduled heating. The time of year also significantly affects heating needs since heating is more needed during the cold months of the year.

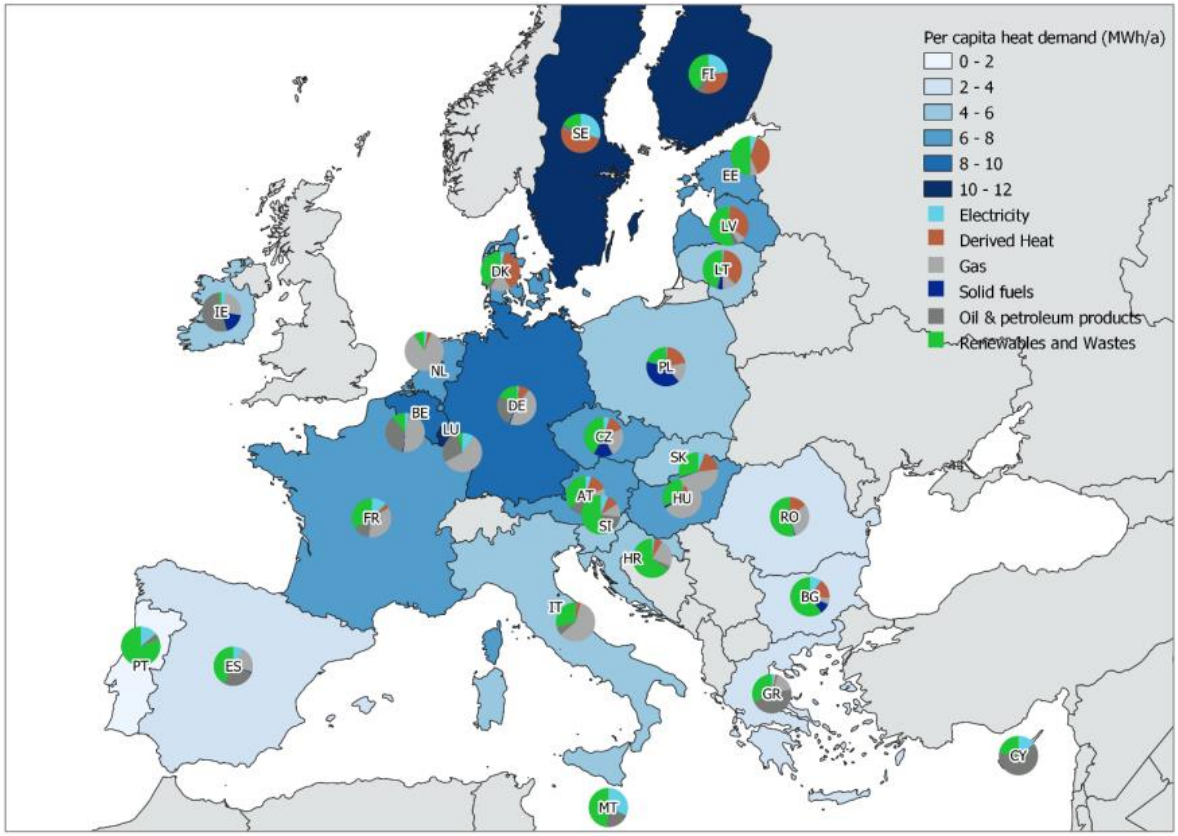
2.3 Restrictions, limitations and requirements

There are often regulations for factors such as the minimum energy efficiency of products and standards considering greenhouse gas emissions for fuel burning heating products. Some of the most common greenhouse gases are carbon and nitrous oxide (NOx) compounds. Each country has their own regulations for buildings and heating systems that can differ a lot between countries. Some countries or locations may even have regulations preventing the use of certain types of heating systems or products, or ones supporting the use of renewables and good energy efficiency planning. This affects what kind of heating systems can be possible to implement since some types of heating, such as fossil fuel based heating, may even be banned in newer buildings. (European Commission, 2018)

In Finland, the municipality may rule that new buildings built in certain district planning areas will be connected to a district heating system. The rule may be excepted if the new building is a low energy building or its main heating system is a low emissions heating system based on renewable energy sources. Some alternatives for district heating are geothermal heating and wood or wood pellet heating. (Motiva Oy, 2023)

In the European Union, decarbonization of the heating sector is a big part of the established climate goal for carbon neutrality for 2050. The share of different heat energy sources in EU countries can be seen in Figure 2. It shows that many countries still rely heavily on fossil-fuels. This means that in order to achieve the goal of carbon neutrality in the EU, a lot of countries will have to start making stricter regulations for the operation of existing heating systems, as well as for the heating systems of the future. (Braungardt, Keimeyer, Bürger, & Tezak, 2021)

Figure 2: Share of energy sources and per capita heat demand in EU countries (Braungardt, Keimeyer, Bürger, & Tezak, 2021)



“The EU Heating and Cooling Strategy is the first EU initiative addressing the energy used for heating and cooling in buildings and industry, which accounts for 50% of the EU's annual energy consumption. By making the sector smarter, more efficient and sustainable, energy imports and dependency will fall, costs will be cut and emissions will be reduced.” (European Commission, 2016)

2.4 Changing heating systems

There may be many reasons for changing your heating system to a different one altogether. Maybe the operating costs for the current system are high or have been increasing, the heating is uneven in different parts of the building, or the current system is just old and inefficient in other ways. (Sealed Inc, 2020)

The feasability of changing the heating system depends on multiple factors. It may not be possible to use certain types of heating systems depending on the building and the area it is

located in. For example, switching to geothermal heating in an apartment building may not be possible if the building is right in the heart of the city. Some heating systems may also have certain dependencies, for example, having good road connections for oil and gas deliveries.

3 THEORY OF HEATING SYSTEMS

3.1 Heating system definition and key elements

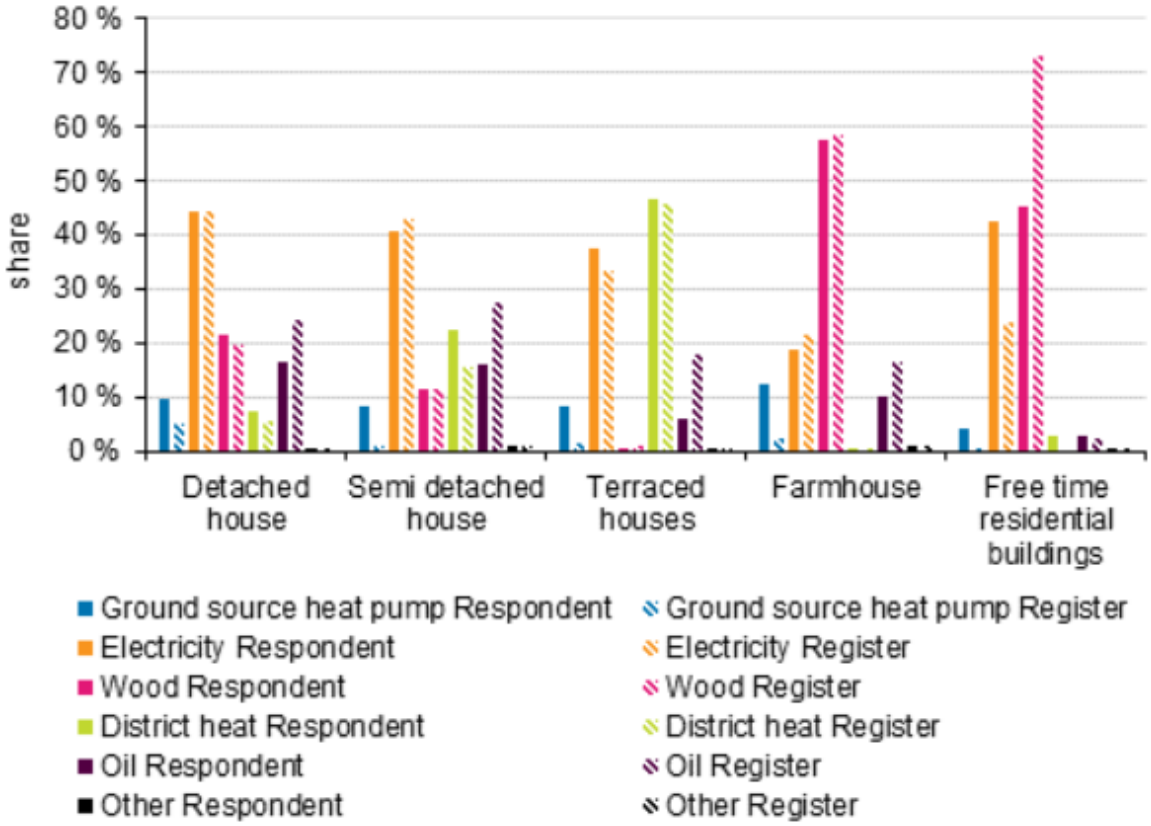
A heating system is by definition a system where heat is transferred through radiation, conduction, convection, or a combination of the three. The matter to which the heat energy is transferred to can be surrounding surfaces, air, or both. (Law Insider, (n.d.))

The main purposes of a heating system are to maintain a minimum temperature for a sustained climate and to create a habitable and comfortable place for people.

A heating system may include heat producing elements like boilers, radiators, floor heating, gas heaters, solid fuel heaters, and heat pumps. The heat from the producing elements is transferred through the air in vents and ducts. In heating systems like floor heating and radiators, the heat is more directly transferred into the surfaces of the building or heating panels. (American Council for an Energy-Efficient Economy, (n.d.))

The shares of heating source types in small buildings in Finland in 2018 can be seen in Figure 3. The solid colored bars are survey results and the rasterized bars are register information. The results show that oil heating is less common and geothermal heating is more common among the surveyed households than what the register shows. This could perhaps be because of recent changes to the heating systems of the surveyed households.

Figure 3: Main heat source for heating according to survey responses and register by type of detached and semi-detached house – unit-level comparison (Tilastokeskus, 2019)



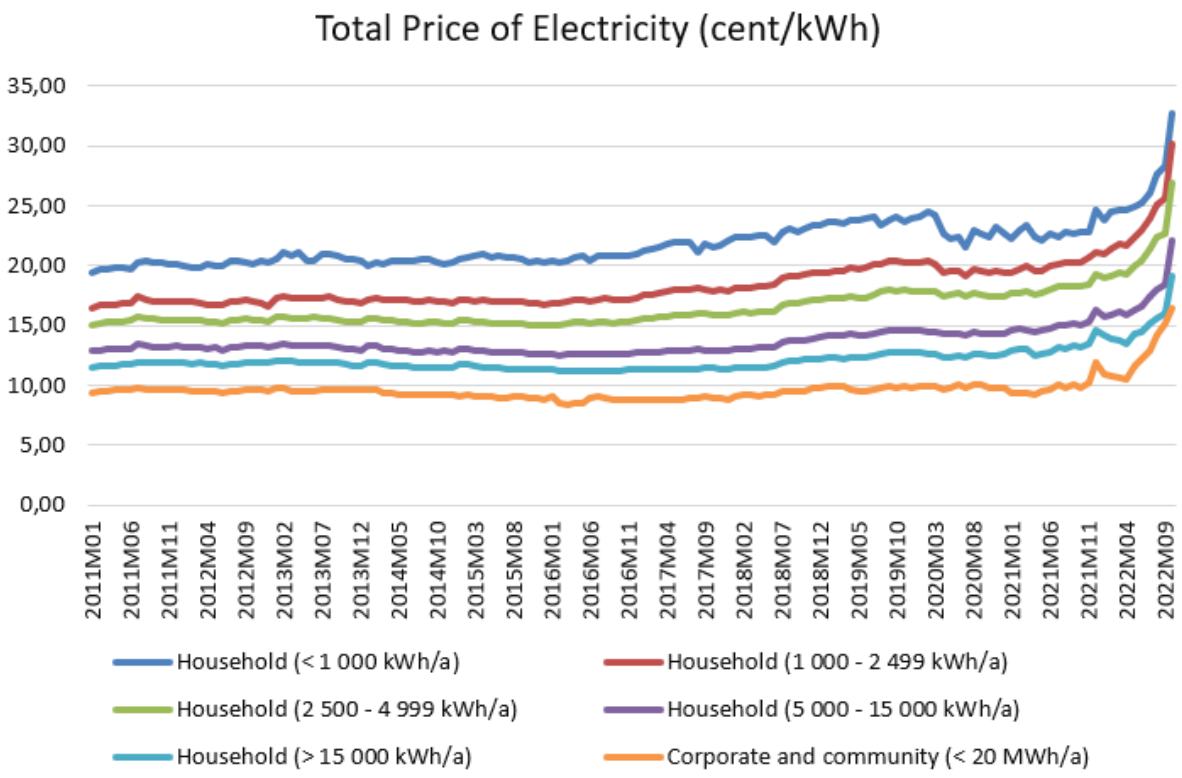
3.1.1 Electric heating

An electrical heating system is a heating system where the main source of heating energy is electricity. The electricity may come from the grid or for example from renewable sources like photovoltaics or wind turbines. The electric energy is converted to heat energy using various methods, including radiators, floor heating, and boilers.

Since electric heating uses electricity as the source of heating energy, the price of electric heating is essentially just the price of electricity. There are varying installation costs since radiators and other heating system devices need to be installed. Depending on the price of electricity, electric heating may be more expensive than oil or gas heating, but the distribution of it is generally easier.

The total consumer price for electricity in Finland, including all fees and taxes, can be seen in Figure 4. It shows a giant upwards spike in the price of electricity in late 2022, due to the currently ongoing world events.

Figure 4: Total consumer price of electricity in Finland 2011-2022 (Tilastokeskus, 2022)

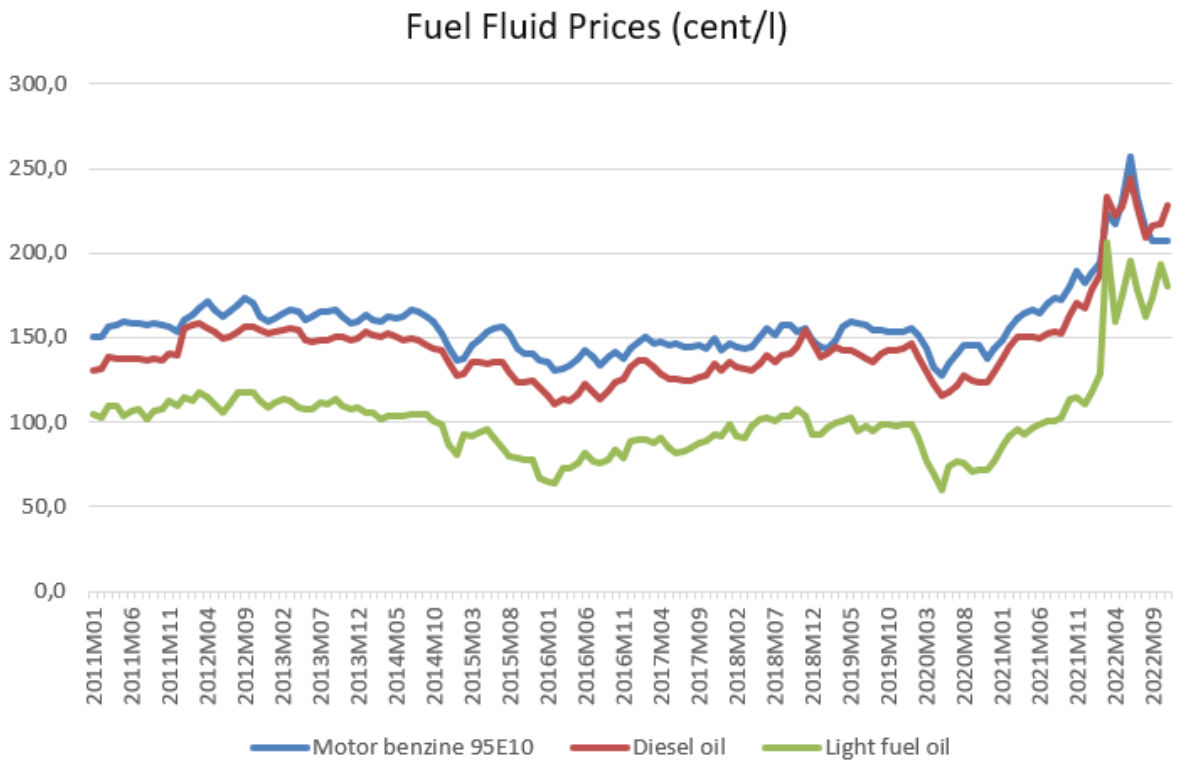


3.1.2 Oil and gas heating

Oil and gas heating systems burn an air-fuel mixture in order to generate heat energy. The heat energy of the burning reaction is used to heat a heat exchanger. The heat exchanger uses the energy to heat up air in the case of a furnace, or water in the case of a boiler. The heated fluid can then be trasferred using ducts or pipes. Modern oil and gas furnaces can reach up to 90% efficiency and utilize methods like condensing furnaces. (American Council for an Energy-Efficient Economy, (n.d.)) Both oil and gas are fossil fuels and thus produce carbon dioxide and other undesirable byproducts when burned. Small-scale gas heating systems are fairly uncommon in Finland.

A problem with oil and gas heating systems is that fossil fuels can also be prone to large price fluctuations and their future prices are really hard to predict. Recently the price of oil has been increasing because of the current world situation. The price increase can be seen in Figure 5.

Figure 5: Consumer prices of fuel fluids 2012-2022 (Tilastokeskus, 2022)



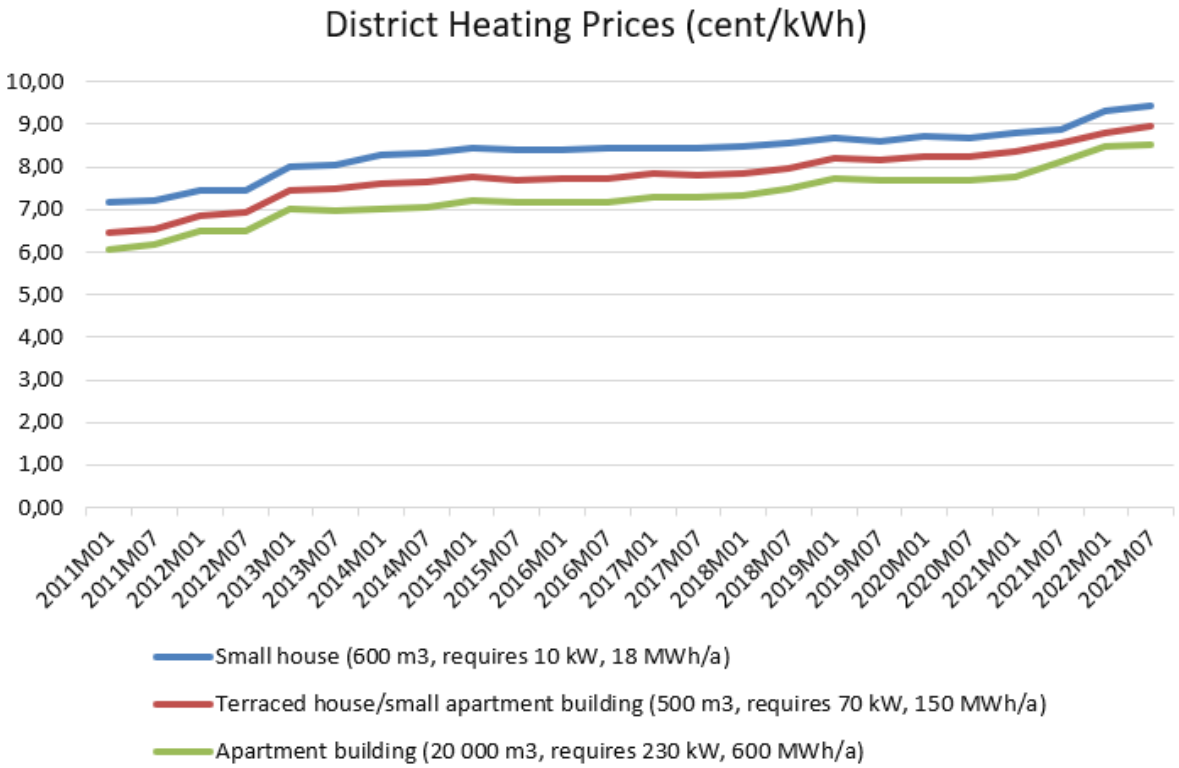
3.1.3 District heating

District heating is utilized to heat several buildings from a centralized heat energy plant, that typically use boilers to produce the energy. Combined heat and power (CHP) plants can also be used as the source for district heating. The heat is then tranferred to the destination through a fluid that travels in underground pipes. District heating is best utilized in areas where there is constant local demand for power and heat. Such areas include urban residential and commercial buildings, as well as facilities such as schools and hospitals. (International District Energy Association, (n.d.))

The consumer price of district heating by building type in Finland can be seen in Figure 6. What can be deduced from the figure, is that the price of district heating has slowly and steadily

been rising, but not as sharply as the prices of other heating types. In comparison to Figure 4 about oil prices, there was not as sharp of an increase in district heating price in 2021. The data points are only bi-annual since it was the only usable data that could be found about district heating prices.

Figure 6: Prices of district heating by building type in Finland 2011-2022 (Tilastokeskus, 2022)



3.1.4 Solar heating

A solar heating system absorbs heat energy from solar radiation into a fluid and transfers the heated fluid elsewhere where it can be used to heat spaces and surfaces. The heat energy from the solar collector is transferred to its desired destination through pipes, tanks and heat exchangers. The system can also be used for a form of heat storage as the fluid can store the heat energy for some time. (U.S. Department of Energy, (n.d.))

Solar heating is a renewable heat energy source, so the operating costs are lower overall since it doesn’t require a fuel to be burned. The average purchase prices for different sizes of typical

solar heating systems in 2014-2015 and their heat production prices for 30 years without, interest, taxes, household deductions and investment subsidies can be seen in Figure 7.

Figure 7: Average purchase prices for solar heating systems in 2014-2015 (Auvinen, 2016)

System size collector - m^2	Purchase price of equipment and installation €/collector- m^2	Maintenance costs % of initial investment / collector m^2	The production price of solar heat €/MWh, when the yield is 0.4 MWh/ m^2	The production price of solar heat €/MWh, when the yield is 0.5 MWh/ m^2
Small systems 4 – 20 collector squares	500 – 1000 €/collector square	10%, 50 – 100 €/collector square	46 – 92 €/MWh	37 – 73 €/MWh
Medium-sized systems 20 – 100 collector squares	€500 – €750/collector square	8%, 40 – 60 €/collector square	45 – 68 €/MWh	36 – 54 €/MWh
Large systems 100 – 1000 collector squares	400 – 500 €/collector square	5%, about €20 – €25/collector square	35 – 44 €/MWh	28 – 35 €/MWh
Industrial systems, 15,000 collector squares	280 – 340 €/collector square	About €20/collector square	–	20 – 24 €/MWh

3.1.5 Geothermal heating and heat pumps

A geothermal heating system utilizes the solar heat that has been captured by the ground or water, and the natural heat radiating from the Earth's core. The temperature stays at a nearly constant temperature just a few meters underground. The temperature increases with depth and volcanic and tectonic activities may also create higher temperatures closer to the surface. Nowadays, the majority of geothermal heating systems in Finland operate by utilizing a thermal well. The well has a diameter is 115-165 mm and contains piping where the heating fluid cycles. Geothermal energy is a renewable energy source. (U.S. Environmental Protection Agency, 2022) (Motiva Oy, 2022)

According to electric and heat company Helen's website, the initial investment cost in an example case of a small terraced house was 25000€ and in a large apartment building it was 602000€. Their payback times were 11,3 years and 10,7 years, respectively. Both cases are located in Helsinki. (Helen Oy, 2022)

A heat pump is a device that captures heat from natural surroundings like air, ground or water. The heat pump then convects or circulates the captured heat into the building through air. Reversible heat pumps can be used for the purpose of cooling a building as well as heating it. (Law Insider, (n.d.))

The three main types of heat pumps are air-to-air, geothermal and water source. Their main operation principle is pretty much the same but the source for heat collection is different for each of them: (U.S. Department of Energy, (n.d.))

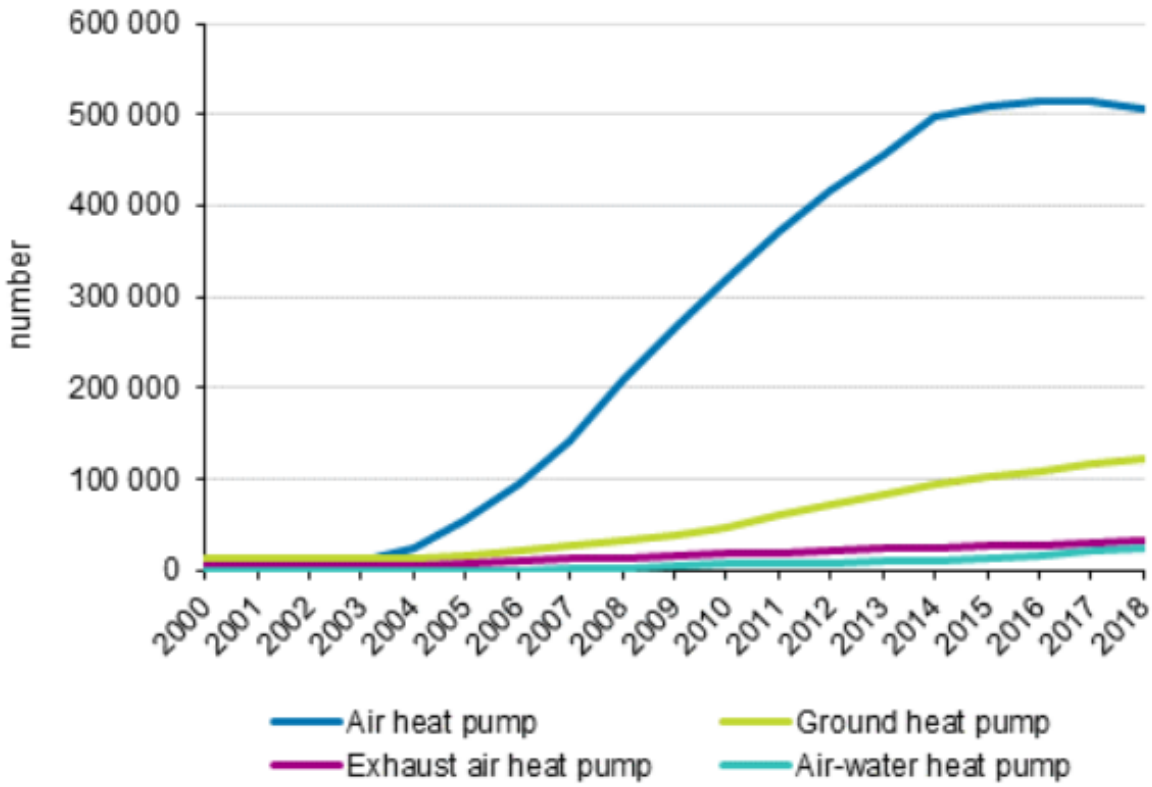
- Air-to-air heat pumps generates heat by collecting heat energy from the outside air as well as utilizing the temperature difference to create a potential. Air-to-air is the most common heat pump type.

- Geothermal heat pumps collect heat energy from underground using pipes buried a under the ground. They work because there is a constant temperature underground, provided by the Earth's core.

- Water source heat pumps are in a way similar to geothermal heat pumps but their main heat source is water instead of ground. Water sources may include lakes, rivers, and wells.

The popularity of heat pumps has been in the last decade, especially within Finland. This can be seen from Figure 8, which shows the development curve for the number of heat pump installations in Finland.

Figure 8: Development of the number of heat pumps in the 2000s estimated from sales volumes (Tilastokeskus, 2019)



3.2 Efficiency in heating systems

The efficiency of a heating system consists of multiple factors. These factors include how much energy is lost in the conversion from fuel to heat, appropriate sizing for the transport pipes or ducts, how much heat energy is lost during transmission, and how efficiently the heat is radiated and how the radiation sources are placed. Renewable energy sources increase the

efficiency since they do not require consumable fuels and it allows for the production to be located close to the place of demand. (Race, 2006)

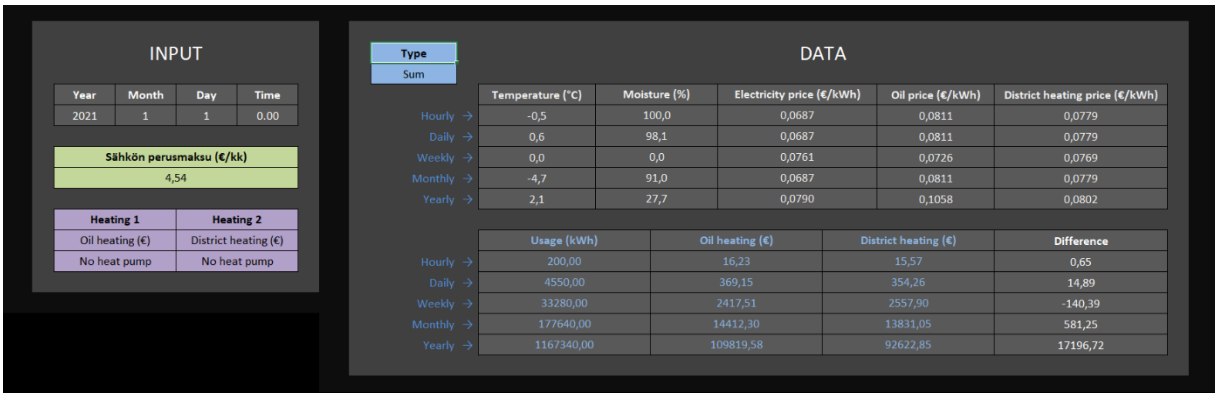
4 COMPARISON CALCULATOR

4.1 Implementation and operation

The objective of the calculator was to create a method for comparing the efficiency of the different heating systems through calculating their operating costs using real data. It was made in Microsoft Excel using the formulas and functions features. These essentially create programmatic functions that retrieve data from tables and calculate formulas.

The calculator has a user interface for selecting input values and displaying retrieved data. It is of note that some of the input fields were unused in the final version. The user interface of the calculator can be seen in Figure 9. It allows the user to select a specific date and time for which the model data is selected. Then using that data the operating costs are calculated for each heating system and can be compared.

Figure 9: User interface of the calculator



INPUT

Year	Month	Day	Time
2021	1	1	0.00

Sähkön perusmaksu (€/kk)
4,54

Heating 1	Heating 2
Oil heating (€)	District heating (€)
No heat pump	No heat pump

DATA

Type
Sum

	Temperature (°C)	Moisture (%)	Electricity price (€/kWh)	Oil price (€/kWh)	District heating price (€/kWh)
Hourly →	-0,5	100,0	0,0687	0,0811	0,0779
Daily →	0,6	98,1	0,0687	0,0811	0,0779
Weekly →	0,0	0,0	0,0761	0,0726	0,0769
Monthly →	-4,7	91,0	0,0687	0,0811	0,0779
Yearly →	2,1	27,7	0,0790	0,1058	0,0802

	Usage (kWh)	Oil heating (€)	District heating (€)	Difference
Hourly →	200,00	16,23	15,57	0,65
Daily →	4550,00	369,15	354,26	14,89
Weekly →	33280,00	2417,51	2557,90	-140,39
Monthly →	177640,00	14412,30	13831,05	581,25
Yearly →	1167340,00	109819,58	92622,85	17196,72

The calculator finds the model data from the selected heating systems according to the selected date in the time and date input fields and retrieves the data to be calculated and displayed in the user interface. It calculates the operating cost for the heating system for a user-specified time period using the formula: heat energy price (€/kWh) * heat energy usage (kWh). It is worth noting that this cost does not include initial installation costs or additional occasional costs, like maintenance. The calculator displays the operating cost difference

between the heating systems in the user interface by just subtracting the value of the second selected heating system (“Heating 2”) from the first one (“Heating 1”) and displaying the result in the “difference” column. Additionally, the user can select whether to show the operating cost data as an average or a sum of the time period from the “type” field.

4.2 Data sources

All of the data is stored in separate Excel sheets from the user interface for simplicity and aesthetics. The model data used in the calculator is from 1.1.2020 to 31.10.2022 and from the following sources:

- Hourly heating energy usage data from Helsinki Region Infoshare (Helsinki Region Infoshare, 2020)
- Hourly temperature and moisture data from Ilmatieteen Laitos (Ilmatieteen Laitos, 2021)
- Monthly electricity and heating oil price data from Tilastokeskus (Tilastokeskus, 2021)
- Bi-annual district heating price data from Tilastokeskus (Tilastokeskus, 2021)

The price data used for electric and district heating includes all fees according to Tilastokeskus. The price data for oil heating is calculated by approximation from oil price data. The weather data from Ilmastolaitos was retrieved for only the year 2021 when their data download site still worked. The calculator source data was later expanded to include data from 2020 and 2022. However, as of 2023, the download site is not working and thus the weather data couldn’t be retrieved and is missing for years 2020 and 2022. The calculator will show the temperature and moisture as zero if the date selected is not within 2021. This is not a big concern though, since the temperature and moisture are only displayed for reference and not used in calculations.

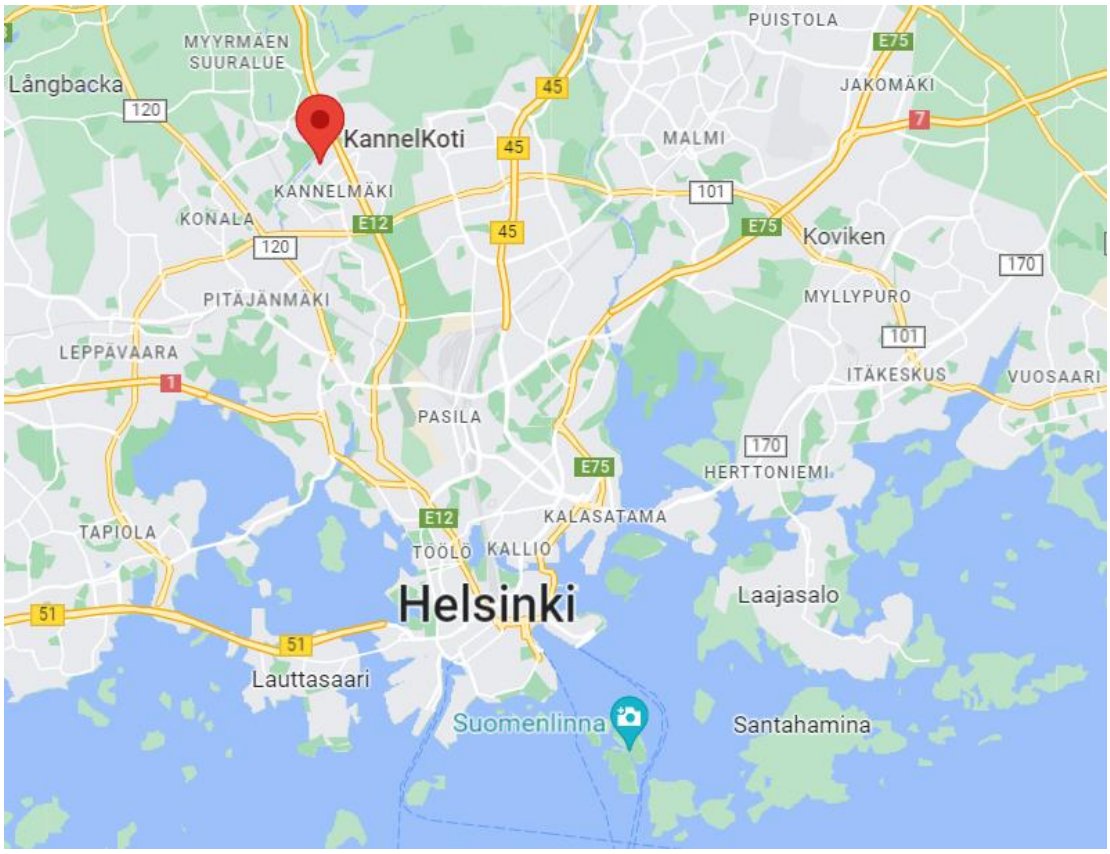
4.3 Heating data source building

A specific building was selected for the heating energy usage data. The usage data is used in calculating the operating cost using a €/kWh value for each heating system. As mentioned

before the data source was Helsinki Region Infoshare and is from 1.1.2020 to 31.10.2022. It is of note that some data points were missing from the year 2022.

The target building is an elderly person care center in Helsinki called Kannelkoti. Its street address is Vanhaistentie 15, Helsinki and its location within Helsinki can be seen in Figure 10. They have about 85 employees and a total capacity of 100 patient places, of which 80 are long term care and 20 short term care. There are rooms for one and two people, as well as two three-person rooms. (Helsingin Seniorisäätiö, 2021)

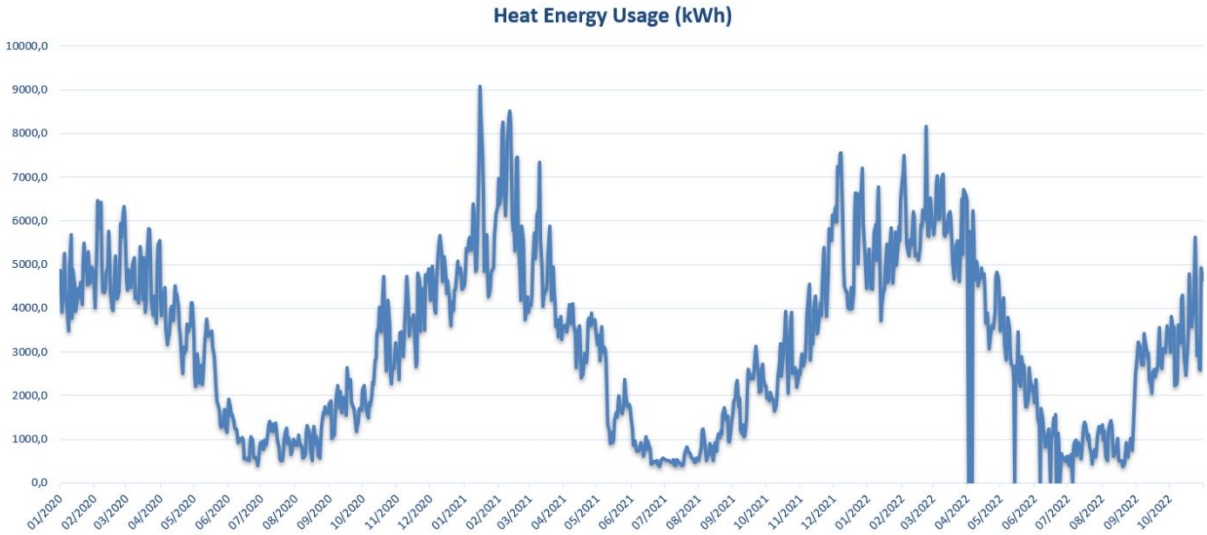
Figure 10: Location of Kannelkoti in Helsinki (Google, 2022)



The target building is quite large and has a rather large heat energy usage since it is a service building and they have the capacity to accommodate 100 people. A graph showing the trend of heat energy usage throughout the year in 2021 can be seen in Figure 11. As it is possible to see from the graph, the colder times of year obviously demand more heating. The graph spikes down to zero a few times in 2022 because of missing data points. Peak usage was around February-March for each year. The highest usage peak was in 15.1.2021 and it was 9080,0

kWh. The lowest usage was around June-July and the lowest value, excluding the zero values caused by missing datapoints, was 380,0 kWh reached in 27.6.2021 and 20.8.2022.

Figure 11: Heat energy usage graph of the target building 2020-2022



5 RESULTS AND DISCUSSION

5.1 Analysis of comparison calculator results

The following comparisons were made using the calculator and the pictures are screenshots from the comparison table section of the calculator. A positive difference value means that the operating cost of the first heating system is that much higher than the operating cost of the second one; a negative one means that the operating cost is that much lower for the first heating system. The values calculated are estimations, since it wouldn’t be possible to calculate very accurate or exact values using the data available.

5.1.1 2020

As can be seen from Figures 12 and 13, at the start of the year in 2020, the operating cost for the target building could have been be lower with electric heating than with both oil and district heating. However the cost difference between electric and district is significantly less than for electric and oil. Figure 14 shows that oil heating would have been more expensive than district heating. In 2020, heating energy usage of the target building was at lowest 400 kWh in July and at highest 6460 kWh in February.

Figure 12: Heating cost difference between electric and oil heating in January 2020

Type
Sum

DATA

	Temperature (°C)	Moisture (%)	Electricity price (€/kWh)	Oil price (€/kWh)	District heating price (€/kWh)
Hourly →	0,0	0,0	0,0689	0,0934	0,0768
Daily →	0,0	0,0	0,0689	0,0934	0,0768
Weekly →	0,0	0,0	0,0689	0,0934	0,0768
Monthly →	0,0	0,0	0,0689	0,0934	0,0768
Yearly →	0,0	0,0	0,0790	0,1058	0,0802

	Usage (kWh)	Electric heating (€)	Oil heating (€)	Difference
Hourly →	240,00	16,54	22,42	-5,88
Daily →	4860,00	334,85	453,91	-119,05
Weekly →	17800,00	1226,42	1662,45	-436,03
Monthly →	141680,00	9761,75	13232,38	-3470,63
Yearly →	1110660,00	79634,51	82253,00	-2618,49

Figure 13: Heating cost difference between electric and district heating in January 2020

	Usage (kWh)	Electric heating (€)	District heating (€)	Difference
Hourly →	240,00	16,54	18,42	-1,89
Daily →	4860,00	334,85	373,10	-38,25
Weekly →	17800,00	1226,42	1366,51	-140,09
Monthly →	141680,00	9761,75	10876,77	-1115,02
Yearly →	1110660,00	79634,51	85306,69	-5672,17

Figure 14: Heating cost difference between oil and district heating in January 2020

	Usage (kWh)	Oil heating (€)	District heating (€)	Difference
Hourly →	240,00	22,42	18,42	3,99
Daily →	4860,00	453,91	373,10	80,80
Weekly →	17800,00	1662,45	1366,51	295,95
Monthly →	141680,00	13232,38	10876,77	2355,60
Yearly →	1110660,00	82253,00	85306,69	-3053,69

As can be seen from figures 15 and 16, at the warmest time of year in 2020, the operating cost for the target building could have still been be lower with electric heating than with both oil and district heating. Unlike at the start of the year, the cost difference is greater for electric and district than electric and oil. Since it is such a warm time of year, heating is not required as much. This means that the cost differences are much less significant between all of the heating systems, since heating cost scales with the amount of heating that is required.

Figure 15: Heating cost difference between electric and oil heating in July 2020

Type	DATA				
Sum					
	Temperature (°C)	Moisture (%)	Electricity price (€/kWh)	Oil price (€/kWh)	District heating price (€/kWh)
Hourly →	0,0	0,0	0,0719	0,0726	0,0769
Daily →	0,0	0,0	0,0719	0,0726	0,0769
Weekly →	0,0	0,0	0,0728	0,0706	0,0768
Monthly →	0,0	0,0	0,0719	0,0726	0,0769
Yearly →	0,0	0,0	0,0790	0,1058	0,0802

	Usage (kWh)	Electric heating (€)	Oil heating (€)	Heating cost difference
Hourly →	40,00	2,88	2,91	-0,03
Daily →	780,00	56,08	56,66	-0,58
Weekly →	4720,00	343,41	333,33	10,09
Monthly →	30430,00	2187,92	2210,48	-22,56
Yearly →	1110660,00	79634,51	82253,00	-2618,49

Figure 16: Heating cost difference between electric and district heating in July 2020

	Usage (kWh)	Electric heating (€)	District heating (€)	Heating cost difference
Hourly →	40,00	2,88	3,07	-0,20
Daily →	780,00	56,08	59,95	-3,87
Weekly →	4720,00	343,41	362,48	-19,06
Monthly →	30430,00	2187,92	2338,85	-150,93
Yearly →	1110660,00	79634,51	85306,69	-5672,17

Figure 17: Heating cost difference between oil and district heating in July 2020

	Usage (kWh)	Oil heating (€)	District heating (€)	Heating cost difference
Hourly →	40,00	2,91	3,07	-0,17
Daily →	780,00	56,66	59,95	-3,29
Weekly →	4720,00	333,33	362,48	-29,15
Monthly →	30430,00	2210,48	2338,85	-128,37
Yearly →	1110660,00	82253,00	85306,69	-3053,69

5.1.2 2021

As can be seen from Figures 18 and 19, electric heating could have been cheaper than both oil and district heating at the start of the year in 2021. Figure 20 shows that district heating could have been sligthly less expensive overall than oil heating throughout the month of January.

It is of note that, as can be seen from the weekly heating cost difference in Figure 18, there were some brief periods when oil heating was actually less expensive than electric and district heating. However, the price of oil started to increase significantly during the year 2021 and it would keep increasing at least until 2023.

Figure 18: Heating cost difference between electric and oil heating in January 2021

Type	DATA				
Sum					
	Temperature (°C)	Moisture (%)	Electricity price (€/kWh)	Oil price (€/kWh)	District heating price (€/kWh)
Hourly →	-0,5	100,0	0,0687	0,0811	0,0779
Daily →	0,6	98,1	0,0687	0,0811	0,0779
Weekly →	0,0	0,0	0,0761	0,0726	0,0769
Monthly →	-4,7	91,0	0,0687	0,0811	0,0779
Yearly →	2,1	27,7	0,0790	0,1058	0,0802

	Usage (kWh)	Electric heating (€)	Oil heating (€)	Heating cost difference
Hourly →	200,00	13,74	16,23	-2,49
Daily →	4550,00	312,59	369,15	-56,57
Weekly →	33280,00	2532,61	2417,51	115,10
Monthly →	177640,00	12203,87	14412,30	-2208,43
Yearly →	1167340,00	87809,45	109819,58	-22010,13

Figure 19: Heating cost difference between electric and district heating in January 2021

	Usage (kWh)	Electric heating (€)	District heating (€)	Heating cost difference
Hourly →	200,00	13,74	15,57	-1,83
Daily →	4550,00	312,59	354,26	-41,68
Weekly →	33280,00	2532,61	2557,90	-25,29
Monthly →	177640,00	12203,87	13831,05	-1627,18
Yearly →	1167340,00	87809,45	92622,85	-4813,40

Figure 20: Heating cost difference between oil and district heating in January 2021

	Usage (kWh)	Oil heating (€)	District heating (€)	Heating cost difference
Hourly →	200,00	16,23	15,57	0,65
Daily →	4550,00	369,15	354,26	14,89
Weekly →	33280,00	2417,51	2557,90	-140,39
Monthly →	177640,00	14412,30	13831,05	581,25
Yearly →	1167340,00	109819,58	92622,85	17196,72

Figures 21 and 22 show that electric heating could have been less expensive around July of 2021. Once again, the cost differences are suppressed by the fact that heating is not required as much during this warm time of year.

Figure 21: Heating cost difference between electric and oil heating in July 2021

Type
Sum

DATA

	Temperature (°C)	Moisture (%)	Electricity price (€/kWh)	Oil price (€/kWh)	District heating price (€/kWh)
Hourly →	18,5	61,0	0,0765	0,0953	0,0814
Daily →	21,4	62,1	0,0765	0,0953	0,0814
Weekly →	23,1	72,9	0,0699	0,0934	0,0779
Monthly →	20,9	63,1	0,0765	0,0953	0,0814
Yearly →	2,1	27,7	0,0790	0,1058	0,0802

	Usage (kWh)	Electric heating (€)	Oil heating (€)	Heating cost difference
Hourly →	10,00	0,77	0,95	-0,19
Daily →	540,00	41,31	51,45	-10,14
Weekly →	3240,00	226,48	302,60	-76,13
Monthly →	16720,00	1279,08	1593,13	-314,05
Yearly →	1167340,00	87809,45	109819,58	-22010,13

Figure 22: Heating cost difference between electric and district heating in July 2021

	Usage (kWh)	Electric heating (€)	District heating (€)	Heating cost difference
Hourly →	10,00	0,77	0,81	-0,05
Daily →	540,00	41,31	43,98	-2,67
Weekly →	3240,00	226,48	252,27	-25,79
Monthly →	16720,00	1279,08	1361,68	-82,60
Yearly →	1167340,00	87809,45	92622,85	-4813,40

The cost difference between oil and district heating can be seen in Figure 23. During July district heating is a little more economical than oil heating. Considering the scale energy usage in the target building, the difference is not that great.

Figure 23: Heating cost difference between oil and district heating in July 2021

	Usage (kWh)	Oil heating (€)	District heating (€)	Heating cost difference
Hourly →	10,00	0,95	0,81	0,14
Daily →	540,00	51,45	43,98	7,48
Weekly →	3240,00	302,60	252,27	50,34
Monthly →	16720,00	1593,13	1361,68	231,46
Yearly →	1167340,00	109819,58	92622,85	17196,72

5.1.3 2022

At this point in time, the price of oil has started to sharply climb which is why the cost differences between oil heating and the other heating systems has grown in Figures 24 and 26. The cost difference of electric and district heating is rather small, but now district heating has become the least expensive heating system. Throughout the year, oil heating was significantly more expensive than both electric and district heating, and it would stay that way until at least 2023.

Figure 24: Heating cost difference between electric and oil heating in January 2022

Type
Sum

DATA

	Temperature (°C)	Moisture (%)	Electricity price (€/kWh)	Oil price (€/kWh)	District heating price (€/kWh)
Hourly →	0,0	0,0	0,0873	0,1113	0,0848
Daily →	0,0	0,0	0,0873	0,1113	0,0848
Weekly →	0,0	0,0	0,1076	0,1047	0,0814
Monthly →	0,0	0,0	0,0873	0,1113	0,0848
Yearly →	0,0	0,0	0,0790	0,1058	0,0802

	Usage (kWh)	Electric heating (€)	Oil heating (€)	Heating cost difference
Hourly →	180,00	15,71	20,04	-4,32
Daily →	5150,00	449,60	573,30	-123,71
Weekly →	41150,00	4427,74	4309,10	118,64
Monthly →	160480,00	14009,90	17864,75	-3854,85
Yearly →	1003290,00	86943,61	155077,34	-68133,73

Figure 25: Heating cost difference between electric and district heating in January 2022

	Usage (kWh)	Electric heating (€)	District heating (€)	Heating cost difference
Hourly →	180,00	15,71	15,26	0,45
Daily →	5150,00	449,60	436,67	12,93
Weekly →	41150,00	4427,74	3351,26	1076,48
Monthly →	160480,00	14009,90	13607,10	402,80
Yearly →	1003290,00	86943,61	85171,51	1772,10

Figure 26: Heating cost difference between oil and district heating in January 2022

	Usage (kWh)	Oil heating (€)	District heating (€)	Heating cost difference
Hourly →	180,00	20,04	15,26	4,78
Daily →	5150,00	573,30	436,67	136,63
Weekly →	41150,00	4309,10	3351,26	957,85
Monthly →	160480,00	17864,75	13607,10	4257,66
Yearly →	1003290,00	155077,34	85171,51	69905,83

The same trends from the start of the year appear in July as well. The differences are suppressed by the fact that less heating is required at this warm time of the year. Oil heating is still clearly the most expensive one.

Figure 27: Heating cost difference between electric and oil heating in July 2022

Type
Sum

DATA

	Temperature (°C)	Moisture (%)	Electricity price (€/kWh)	Oil price (€/kWh)	District heating price (€/kWh)
Hourly →	0,0	0,0	0,1059	0,1679	0,0852
Daily →	0,0	0,0	0,1059	0,1679	0,0852
Weekly →	0,0	0,0	0,0963	0,1840	0,0848
Monthly →	0,0	0,0	0,1059	0,1679	0,0852
Yearly →	0,0	0,0	0,0790	0,1058	0,0802

	Usage (kWh)	Electric heating (€)	Oil heating (€)	Heating cost difference
Hourly →	10,00	1,06	1,68	-0,62
Daily →	610,00	64,60	102,43	-37,83
Weekly →	7590,00	730,92	1396,27	-665,36
Monthly →	26130,00	2767,17	4387,87	-1620,70
Yearly →	1003290,00	86943,61	155077,34	-68133,73

Figure 28: Heating cost difference between electric and district heating in July 2022

	Usage (kWh)	Electric heating (€)	District heating (€)	Heating cost difference
Hourly →	10,00	1,06	0,85	0,21
Daily →	610,00	64,60	51,97	12,63
Weekly →	7590,00	730,92	643,56	87,36
Monthly →	26130,00	2767,17	2226,28	540,89
Yearly →	1003290,00	86943,61	85171,51	1772,10

Figure 29: Heating cost difference between oil and district heating in July 2022

	Usage (kWh)	Oil heating (€)	District heating (€)	Heating cost difference
Hourly →	10,00	1,68	0,85	0,83
Daily →	610,00	102,43	51,97	50,46
Weekly →	7590,00	1396,27	643,56	752,72
Monthly →	26130,00	4387,87	2226,28	2161,59
Yearly →	1003290,00	155077,34	85171,51	69905,83

The following figures show data from the end of October 2022, which is the newest data that was available at the time. As can be seen from Figures 30, 31 and 32, at this point of the time, district heating was the least expensive heating system and oil heating was clearly the most expensive.

Figure 30: Difference between electric and oil heating cost at the end of October 2022

Type
Sum

DATA

	Temperature (°C)	Moisture (%)	Electricity price (€/kWh)	Oil price (€/kWh)	District heating price (€/kWh)
Hourly →	0,0	0,0	0,1069	0,1821	0,0852
Daily →	0,0	0,0	0,1069	0,1821	0,0852
Weekly →	0,0	0,0	0,1069	0,1821	0,0852
Monthly →	0,0	0,0	0,1069	0,1821	0,0852
Yearly →	0,0	0,0	0,0790	0,1058	0,0802

	Usage (kWh)	Electric heating (€)	Oil heating (€)	Heating cost difference
Hourly →	210,00	22,45	38,24	-15,79
Daily →	4650,00	497,09	846,65	-349,57
Weekly →	29520,00	3155,69	5374,87	-2219,18
Monthly →	108980,00	11649,96	19842,58	-8192,62
Yearly →	1003290,00	86943,61	155077,34	-68133,73

Figure 31: Difference between electric and district heating cost at the end of October 2022

	Usage (kWh)	Electric heating (€)	District heating (€)	Heating cost difference
Hourly →	210,00	22,45	17,89	4,56
Daily →	4650,00	497,09	396,18	100,91
Weekly →	29520,00	3155,69	2515,10	640,58
Monthly →	108980,00	11649,96	9285,10	2364,87
Yearly →	1003290,00	86943,61	85171,51	1772,10

Figure 32: Difference between oil and district heating cost at the end of October 2022

	Usage (kWh)	Oil heating (€)	District heating (€)	Heating cost difference
Hourly →	210,00	38,24	17,89	20,34
Daily →	4650,00	846,65	396,18	450,47
Weekly →	29520,00	5374,87	2515,10	2859,76
Monthly →	108980,00	19842,58	9285,10	10557,49
Yearly →	1003290,00	155077,34	85171,51	69905,83

5.2 Analysis of calculator data

The great increase of oil price around 2022-2023 has to do with the currently ongoing Russian invasion of Ukraine. A major part of the oil imports to Europe and Finland came from Russia, and now that great sanctions have been placed on Russia, European countries and Finland are buying oil from countries that are further away. The situation has had additional effects, such as affecting the cost and amount of electricity imports and the overall cost of living.

From the data of the comparison calculator, we may see that during certain periods of time the operating cost differences between heating systems may be negligible. This is mostly during times when heating is not required as much and when the situation regarding the availability of resources is stable.

On the other hand, large differences may appear quickly when the availability of resources for that heating system diminishes. This is one situation where well-implemented renewable energy sources can shine because renewable energy is not dependent on a constant input of highly-refined external resources. The operation of renewable energy sources can be self-dependent. Another possible way of managing an increase in the heating system operating costs could be to have a solid contingency plan and to stay up to date on developments regarding energy sources. For example, designing and implementing a heating system that is flexible and can be converted to utilize another resource when a situation arises.

6 CONCLUSION

Changing heating systems can definitely improve the economicality and efficiency of the heating in a building. The size of the improvement depends on what heating system is being replaced, what heating system is replacing the old system, what the availability of resources regarding the new system are at that time, and how well the original heating system was actually implemented and optimized. Sometimes the cost of changing the efficiency improvement may not be enough to justify the cost of the changing the entire heating system to a new one. In this case, monitoring, optimization, and modernization should be conducted in order to improve the existing system.

The efficiency of a building's heating system can further be improved by installing a heat pump. Heat pumps augment the primary heating system and have low operating costs. Heat pumps are considered a renewable source which means that they can also lower the carbon footprint of the primary heating system.

Another way of improving a heating system is to use smart heating strategies. Smart heating solutions operate by using various sensors in a building to analyze heating trends in buildings and to optimize which areas are heated and when they are heated. For example an office building may not require as much heating at times when it is not occupied, thus it could be possible to scheduling the heating to not heat as much in unoccupied parts of the building. Sometimes even lowering the heating target temperature can be used to improve energy efficiency. However, this strategy depends on the climate charasteristics of the area and the time of year, among other things.

The heating systems that are most resistant to possible world events are ones that use renewable energy and do not depend on resources with volatile availability. Renewable energy can be very powerful, especially if it is paired with energy storing capabilities and an energy efficient heating system. Heating systems that utilize locally available resources are also more resistant than those depending on highly-refined external resources.

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