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BUSINESS MODELS FOR CONSTRUCTION COMPANIES IN PROMOTING GROUND SOURCE HEAT PUMP SYSTEMS

Master of Science Thesis
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ABSTRACT

Eetu Virtanen: Business Models for Construction Companies in Promoting Ground Source Heat Pump Systems

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Purpose of this thesis is to suggest a business model for construction companies that can be used for ground source heat pump (GSHP) systems. Thus far, only a few GSHP systems have been installed in apartment buildings during the construction phase of the building. The use of GSHP systems is expected to increase in the future; however, there are currently many challenges that hinder a wider application of GSHP systems. A major reason why so few GSHP systems have been installed is that construction companies have not seen business benefits for GSHP systems. In addition, third-party business models were found to be challenging when integrated into the new apartment building sector.

This thesis consists of a literature review and empirical study. The literature study presents the energy markets in Finland and the energy companies that use the business models for the energy generated with renewable sources. The study also covers the customer typology of construction companies in GSHP markets. The empirical part of the study consists of two interview rounds. The aim of the first interview round was to determine whether it is possible to use the GSHP system possible in Marinranta and what are GSHP system's costs in one of the housing cooperatives in Marinranta. The aim of the second interview round is to obtain information for answering the research questions.

Based on literature and interviews results, this thesis recommends construction companies to develop a GSHP system's design and build concept to construct GSHP systems for the real estate investors. There are already existing concepts to build GSHP systems for small attached houses, but there are no such concepts yet for the apartment buildings. Second recommendation for the construction companies are that they should study which are economically best options to lower apartment buildings lifecycle CO₂ emissions. There were no studies found which would study, which are the most cost-effective ways to reduce apartment buildings lifecycle CO₂ emissions. This area requires further research in the future.

Keywords: Ground source heat pump system, distributed energy, heat generation

The originality of this thesis has been checked using the Turnitin OriginalityCheck service.

TIIVISTELMÄ

Eetu Virtanen: Maalämpöjärjestelmään perustuva liiketoimintamalli rakennusliikkeelle edistämään maalämpöjärjestelmien hyödyntämistä rakennusliikkeen omassa liiketoiminnassa
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Tämän tutkimuksen tarkoituksena on ehdottaa maalämpöjärjestelmään perustuvaa liiketoimintamallia rakennusliikkeelle. Tällä hetkellä vain muutama maalämpöjärjestelmä on asennettu kerrostaloon rakennusvaiheessa. Maalämpöjärjestelmien odotetaan yleistävän tulevaisuudessa. Monet haasteet hidastavat kuitenkin maalämpöjärjestelmien laajempaa käyttöä. Suurin syy miksi niin vähän maalämpöjärjestelmiä on asennettu kerrostaloihin rakennusvaiheessa, on että rakennusliikkeet eivät ole nähneet taloudellista hyötyä maalämpöjärjestelmissä. Lisäksi, kolmansien osapuolien harjoittama liiketoimintamalli on nähty haasteelliseksi uudiskerrostalo puolella.

Tämä tutkimus käsittää kirjallisuuskatsauksen ja empiirisen tutkimuksen. Kirjallisuustutkimus esittelee energia markkinat Suomessa ja erilaisia liiketoimintamalleja, joita energiyhtiöt ovat käyttäneet uusiutuvan energiantuotannossa. Tutkimus käsittää myös rakennusliikkeen asiakastypologian maalämpö markkinoilla. Empiirinen osuus käsittää kaksi haastattelu kierrosta. Ensimmäisen haastattelu kierroksen tavoite oli arvioida, onko maalämpöjärjestelmä teknisesti mahdollinen lämmitysjärjestelmä Marinrannassa ja mitkä ovat maalämpöjärjestelmän investointi kustannukset taloyhtiölle Marinrannassa. Toisen haastattelu kierroksen tavoitteena hankkia tietoa haastattelukysymyksiin vastaamiseen.

Kirjallisuuteen ja haastatteluiden tuloksiin perustuen, tutkimus suosittelee rakennusliikkeitä kehittämään suunnittele- ja rakenna -konseptin maalämpöjärjestelmien toteuttamiseen. Omakotitaloille on jo olemassa konseptit maalämpöjärjestelmien toteuttamiseen, mutta kerrostalopuolelle tällaista konseptia ei ole vielä olemassa. Toinen suositus rakennusliikkeelle on että, rakennusliikkeiden tulisi tutkia mitkä ovat taloudellisesti parhaimmat vaihtoehdot pienentää kerrostalojen elinkaaren CO₂ päästöjä. Tässä tutkimuksessa ei löydetty yhtään olemassa olevaa tutkimusta, joka olisi tutkinut, mitkä ovat kustannustehokkaimmat tavat vähentää kerrostalojen elinkaaren aikaisia CO₂ päästöjä. Tämä alue vaatii lisää tutkimusta.

Avainsanat: Maalämpöjärjestelmä, hajautettu energian tuotanto, lämmöntuotanto

Tämän työn alkuperäisyys on tarkastettu Turnitin OriginalityCheck palvelulla

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LIST OF SYMBOLS AND ABBREVIATIONS

CO ₂	Carbon dioxide
DH	District heating
EU	European Union
ESCO	Energy service company
GH consultant	Ground heat consultant
GSHP	Ground source heat pump

1. INTRODUCTION

1.1 Background of this research

In dealing with the current climate crisis, the European Union (EU) and Finland have ambitious goals with their policies in relation to the environment. For instance, Finland's energy policy target is to phase out the use of coal in energy production by 2030 and increase the use of renewable sources in energy production. (Huttunen 2017, 11, 31-32). Energy generation requires the diversification in energy sources and the use of local energy sources so that such generation could support sustainable development (Ediger et al. 2007, 2974-2975).

Most of the new apartment buildings are connected to the district heating (DH) network in Finland. DH production uses almost 60% of the coal in the Helsinki metropolitan area (Helen n.d.). With such a high usage, there is the need to find a replacement for coal. In addition, the price for DH has increased over the past few years, and it is assumed that its price will increase in the future (Lauttamäki 2018, 159). At this moment, the price for DH is approximately €75/MWh (Motiva, 2019a). The ground source heat pump (GSHP) system is an attractive heating system for housing cooperatives. Right now, GSHP systems' operation costs are more affordable than DH systems operation costs. On the other hand, GSHP system investment costs are more expensive than DH system's connection fee. (Appendix A, 13, 17.)

Over the years, customers have become more environmentally conscious, and therefore companies are focusing more on developing their own environmental image. In the real estate sector, international real estate investors are more aware of environmental friendly processes; investors usually request for buildings to fulfil at least one green building rating system, and the most widely used green building rating system is LEED. Some investors view certain buildings as a future risk if they have not been assessed by any green building rating systems. They are concerned that buildings without any green rating systems can decrease in value. (Lauttamäki 2018, 169-170.)

GSHP systems are also more environmentally friendly than DH systems. The GSHP's emissions come from the heat pump's consumed electricity. GSHP system provide building's space heating and cooling as well as water heating. (Lucia et al. 2016, 867; Omer 2008, 352; Sarbu & Sebarchievici 2013, 442, 444). With GSHP systems, it is possible to reduce CO₂ emissions, gain economic advantage, and decrease fossil fuel consumptions (Self et al. 2012, 348).

Construction companies are usually the ones that decide the heating system to be installed in the apartment buildings during the development stage of the property. Generally, the construction companies have not seen GSHP systems as profitable and have always connected apartment buildings to the DH network. In the case when real estate investors invest in a housing cooperative, they have more authority to decide on which heating system to use. Heating cost can be significant for the real estate investors, as they typically own many apartment buildings. It is possible that some real estate investors view GSHP systems as a viable investment, but thus far it is not clear why so few GSHP systems have been installed during the construction phase of the buildings.

Energy service companies (ESCOs) practise third-party business models, and in the case with GSHP systems, ESCOs can use these business models to lease the GSHP system to housing cooperatives or they can also own the GSHP system and sell ground heat to housing cooperatives. In third-party ownership, there are certain risks in design, construction, and financing with GSHP systems that would be borne collectively by the owners, but the system's benefits are also shared by them.

It is clear that there are currently no business models that could attract construction companies to invest in GSHP systems for new apartment buildings. Therefore, this thesis aims to create a business model that could attract construction companies to install the GSHP system in new apartment buildings. The objective here is to determine how construction companies could use GSHP systems and the heat generation from GSHP systems in the business of the company.

1.2 Research limitations

This thesis focuses only on the new housing areas, namely those that consist of several apartment buildings. The main assumption in this thesis is that if the GSHP system is profitable in one apartment building, it is profitable also in other buildings that are also within the same area of the building. For GSHP systems, it is possible to create either a centralised or distributed system; this thesis focuses only on a distributed GSHP system.

It is possible to construct GSHP systems that are horizontal, vertical, or even in spiral, but this research focuses only on vertical loop systems. Such systems need less space and therefore is not the best option in areas where properties are small, such as those in the Helsinki metropolitan area.

This thesis is written with construction companies as the target audience. Business models need to be profitable for a construction company, but they also need to attract real estate investors. In this thesis, real estate investors include housing cooperatives, private

residential real estate investment companies, and real estate private equity investors. These investor types are chosen because they are considered as important clients to the construction company that is the core case of this research.

The main business models studied in this thesis concerning the business of heat generation are the third-party business models used by ESCOs and the utility-side and customer-side business models used by energy companies. If the GSHP system generates extra heat, it is possible to sell this heat to other DH companies, such as Fortum (Fortum, 2019). However, this thesis does not examine this revenue model where housing cooperatives would sell their own generated energy to a DH company.

1.3 Research method

The research methods used in this thesis include a literature review and interviews. In the literature review, the main focus is on Finland's heat markets and the business models of energy companies. The theory part introduces the present state of Finland's heat markets. This part also presents the GSHP system, the heat consumption of new apartment buildings, the clients of DH, and the possible development in prices of DH companies. The third-party business model is also presented as well as the business models of the utility-side and customer-side of energy companies. The empirical part identifies how the respondents view the future of GSHP systems and how they see third-party business models in the area of new apartment building construction. In this empirical part, the research uses interviews, particularly those conducted with expert interviews.

A ground heat (GH) consultant conducted a prestudy for GSHP systems using the housing cooperative Espoo's Apollo as the example. The prestudy is also found in this thesis; the report presents the GSHP system's investment costs and energy saving calculations, and it also describes how much the housing cooperative could save in heat energy compared to having a DH housing cooperative. This information is used for analysing how high the investment costs would be for the GSHP systems and how much housing cooperatives can benefit from the GSHP system.

1.4 Thesis overview

This rest of the thesis is as follows. Chapter 2 covers the literature review on the GSHP system and the energy markets in Finland. Chapter 3 describes the two business models that are explored in this paper. Chapter 4 presents the methodology of the research along with the interviews that were conducted. Chapter 5 describes the customer typology of construction companies in the GSHP market. Following this, Chapter 6 presents the findings from the interviews, while Chapter 7 presents an investment analysis of a few specific cases. Chapter 8 discussion the findings of the study and presents the reliability of the study and future research. Finally, the study concludes with Chapter 9 which answers the research questions and gives recommendations.

2. GROUND SOURCE HEAT PUMP SYSTEMS AND HEATING MARKETS IN FINLAND

2.1 Ground source heat pump system

GSHPs are typically classified as open or closed systems. Groundwater heat pumps are usually called open systems, and ground-coupled heat pumps are called closed systems. Surface-water heat pumps has open and closed system variations. Sometimes the systems cannot be classified exactly as open or closed systems (Omer 2008, 356).

In a closed system, the heat exchangers are located underground. In heating systems, heat is transported from the underground to the heat pumps, while in cooling systems, the opposite takes place. Heat exchangers can be used for installations in a horizontal, vertical, or oblique fashion. Heat exchangers are used in a closed circuit, which is the reason why this is called as a closed system. A heat carrier (i.e., mixture of water and antifreeze) is pumped around the pipe without any direct contact with rock, soil, and groundwater (Omer 2008, 352, 356). The vertical loop system is presented in Figure 1.

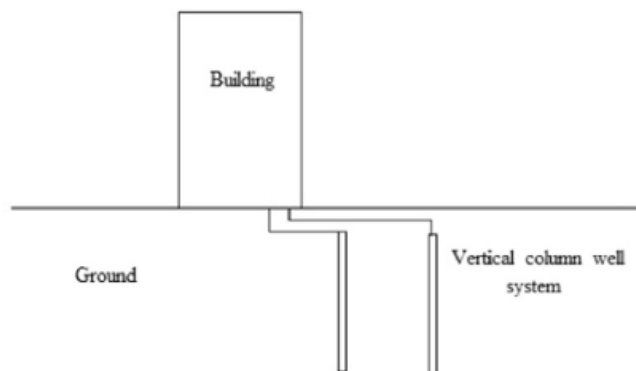


Figure 1. Vertical loop system (Lucia et al. 2017, 868).

Unlike in open systems, the quality and availability of the groundwater in a closed system does not affect the system (Lucia et al. 2017, 868). Another advantage of a closed system is that it uses less energy than an open system. (Lucia et al. 2017, 868; Sarbu & Sebarchievici 2013, 444).

GSHP systems are more cost-effective in places where there are high temperature changes and where the winters are cold. GSHP systems with a cooling system tend to be more profitable than GSHP systems without the cooling system (Sarbu & Sebarchievici 2013, 444).

2.2 Market shares of different heating types in Finland

In 2016, the market share for DH was over 60% in new building construction (Energiateollisuus ry, 2018a). DH's market share in new building construction has grown approximately 20% in ten years. The production of DH totalled 38.3 TWh in 2017 (Official Statistics of Finland 2018a). At the same time, electricity has decreased its market share (Energiateollisuus ry, 2018a).

GSHP systems has grown approximately 13% in four years alone between 2010 to 2014 for the construction of new buildings (Energiateollisuus ry, 2018a). Ground heat is a very common heat source in single family houses (Official Statistics of Finland 2018b). Approximately 15% of the existing buildings are heated with heat pumps (Energiateollisuus ry, 2018a). It seems that the development of oil prices has influenced the popularity of GSHPs (Lauttamäki 2018, 174).

In 2016, there were 410 apartment buildings that use GH as a heat source (Tilastokeskus 2017 as cited Lauttamäki 2018, 31). The energy consumption for apartment buildings is relatively steady all year round, and there are typically no high consumption peaks. Therefore, the GSHP system is a viable choice as a heating system for apartment buildings (Lauttamäki 2018, 253). According to Lease Green's CEO Tomi Mäkipelto, every third housing cooperative could change their heating system from DH to ground heat. DH's market share would still be around 60 to 70% if this change were to happen (Mäkipelto 2019). The use of ground heat is expected to grow mostly in row buildings, apartment buildings, and service buildings (Lauttamäki 2018, 253).

Market shares of different energy sources in existing residential buildings and public service buildings, the latter of which have been classified by the Official Statistics of Finland (n.d.) as educational buildings, health care buildings, and social service buildings (Figure 2). Most of the buildings in Finland in 2017 were residential buildings, and only 4% of the residential buildings were apartment buildings, which are also referred to as blocks of flats (see Table 1). It was found that 1.2 million household-dwelling units lived in apartment buildings; this number is nearly half of all Finnish household-dwelling units (Official Statistics of Finland 2018c).

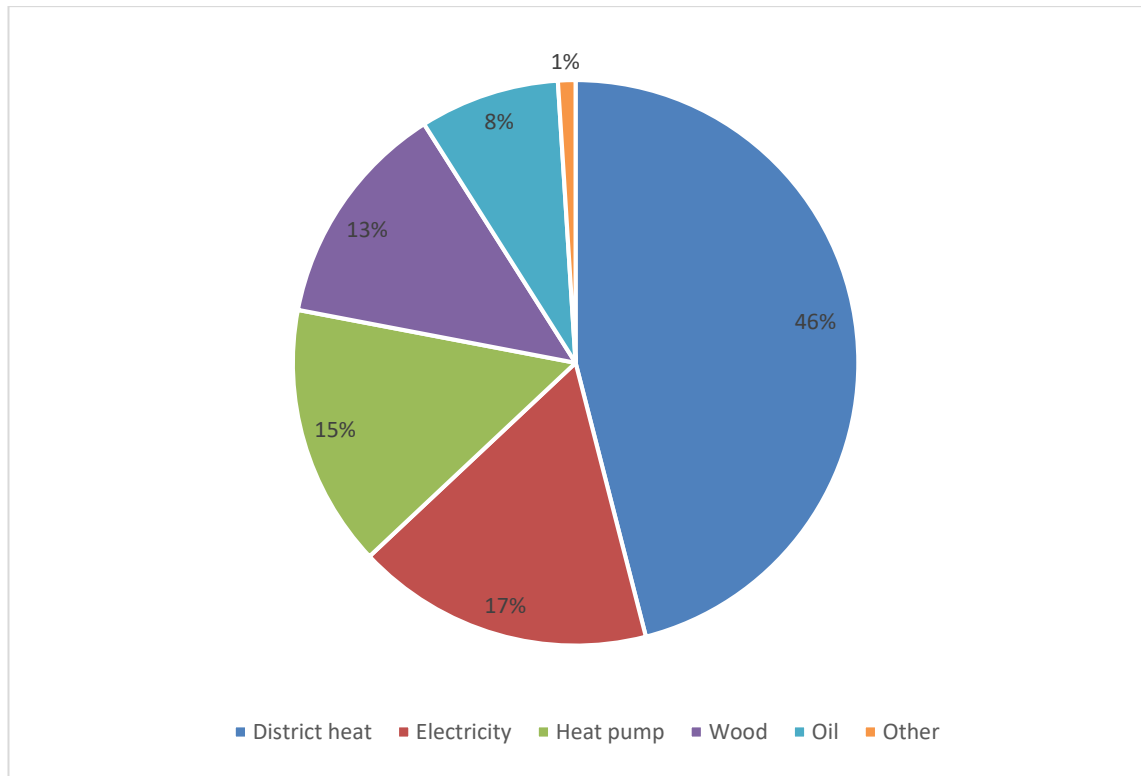


Figure 2. *Housing and service heat market share 2016 in Finland by energy (Energiateollisuus ry, 2018a).*

DH companies' market share in housing and service sector was 46% in 2016 (Figure 2). Approximately 2.84 million people live in district-heated buildings in Finland (Energiateollisuus ry 2018b, 4), and 2,310 new customers joined the DH network in 2017 (Energiateollisuus ry, 2018a). DH is a common heating system in other parts of Europe, such as Iceland, Denmark, Sweden, Estonia, Latvia, Lithuania, and Poland (Werner 2017, 619).

Table 1. Building stock 2017 (Official Statistics of Finland 2018d).

	Buildings	Per cent of total buildings (%)
Buildings total	1523196	100
A1-A3 Residential buildings	1294426	85
A1 Detached houses	1152489	75,7
A2 Attached houses	81293	5,3
A3 Block of flats	60644	4
C-X Other buildings	228770	15
C Commercial buildings	43868	2,9
D Office buildings	10834	0,7
E Traffic buildings	57760	3,8
F Institutional buildings	9077	0,6
G Buildings for assembly	14510	1
H Educational buildings	8987	0,6
J Industrial buildings	45870	3
K Warehouses	32408	2,1
X Other buildings	5456	0,4

The largest heat markets in the building and service sector are in Germany, the United Kingdom (UK), France, and Italy, although Finland's average heat consumption was the second largest in European member states in 2010. Compared to these countries, Finland's heat markets are relatively small (Persson & Werner 2015, 4, 7, 9). The heat markets of the European member states in the residential and service sectors in 2010. Fossil fuel suppliers dominated the European building heat markets in 2010. (Figure 3.) DH markets and the electric heat markets each accounted for approximately 12% of the European member state countries in 2010 (Persson & Werner 2015, 9).

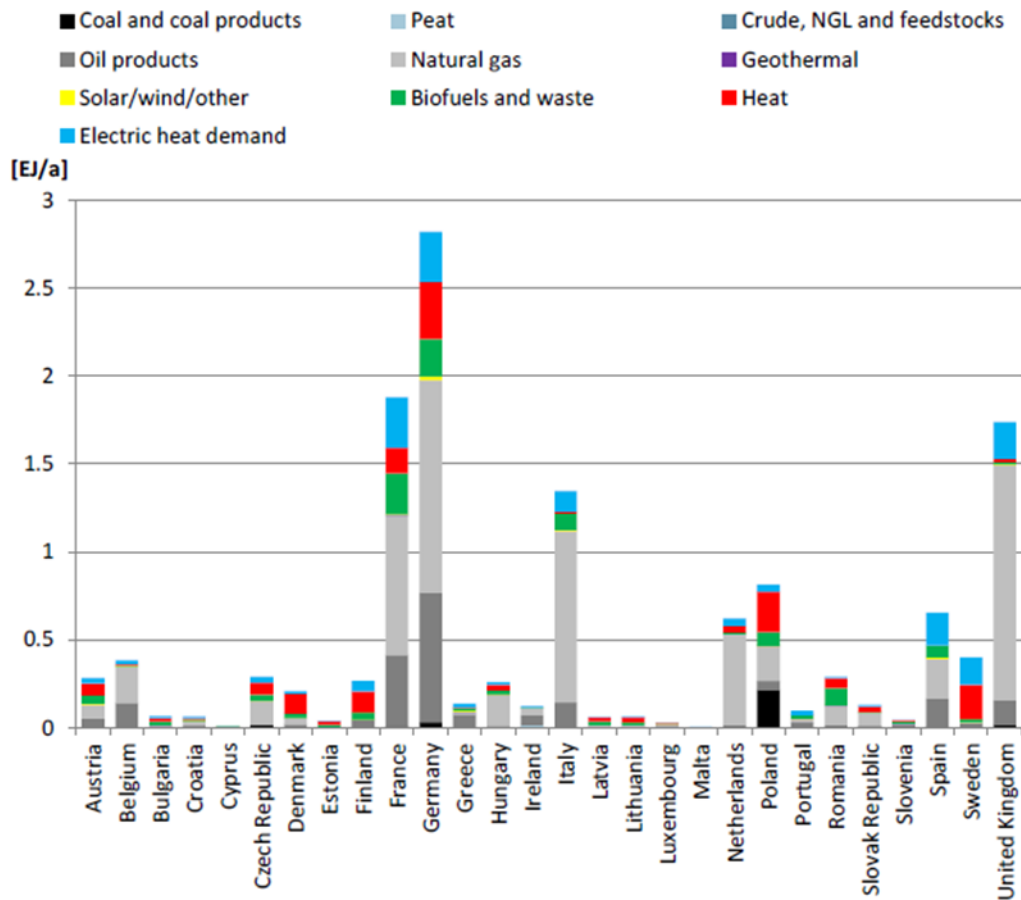


Figure 3. Heat markets of European member states in the residential and service sector buildings in 2010, including fuel supply sources and energy carriers (Persson & Werner 2015, 9).

DH has a dominant market position in Finland in both new building construction and existing building stock (Energiategollisuus ry, 2018a; Figure 2). Almost every new apartment building in Finland are DH buildings (Vainio et al. 2015, 24). According to the Finnish Energy's Chief Executive Officer Jukka Leskelä, construction companies choose DH as the heating system for buildings because it is cost-effective, environmentally friendly, and reliable (Energiategollisuus ry 2017a).

2.3 Heat consumption of buildings

According to the Official Statistics of Finland (2018b), space heating consumed 45 TWh, and the heating of domestic water consumed 10 TWh in residential buildings in 2017. This indicates that space heating consumed most of the heating energy in residential buildings. However, the calculation by the Official Statistics of Finland (2018b) included buildings that are built in different periods of time. The maximum U-values of the building components are decreased over time (Paiho & Reda 2016, 918; as cited Ministry of Environment 2015a, 2015b), which means that the energy efficiency of building components has increased (Ministry of Environment 2008, 3).

Most of the Finnish buildings were built in 1970s (see Figure 4). Vainio et al. (2015, 14) noted that evidently some older existing buildings are no longer in use. Every year, 1% of the existing buildings disappear from the housing stock; this could be for different reasons, such as a fire or demolition. At the same time, every year a new building stock is constructed from 8 to 10 million m², and the new stocks are more energy efficient. On the other hand, most of the buildings that disappear from the existing building stock are located in the dispersed settlements, and the new building construction is mainly centralised in cities where there is an existing DH network. This can increase DH consumption in cities. If economic growth slows down, it would affect building construction and consequently the building of a new DH network (Vainio et al. 2015, 9-10, 16, 37).

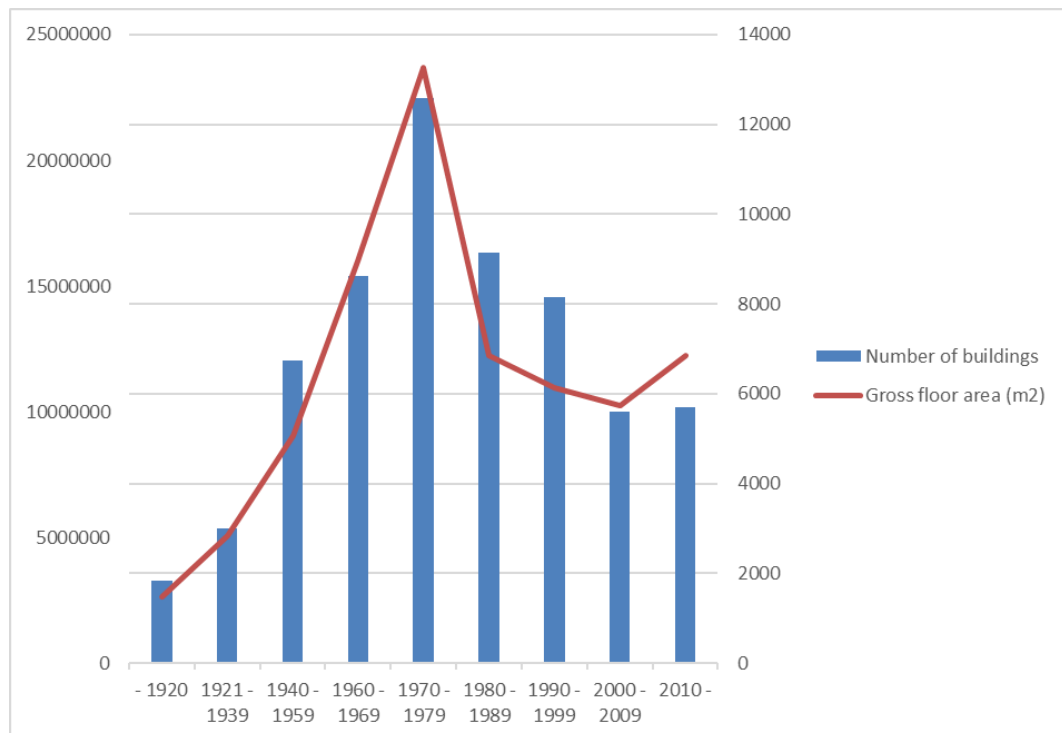


Figure 4. Apartment buildings in Finland listed by the year of construction (Official Statistics of Finland 2018e).

It is important to note that the energy performance certificate and the data from the Official Statistics of Finland do not give precise information on the energy consumption of new buildings. Energy performance certificate calculations are only appraisals of buildings energy consumption (Paiho & Saastamoinen 2018, 13), and therefore it does not determine the actual energy consumption of a building.

2.4 Clients of district heating

The number of clients for DH companies have grown almost linearly since the 1970s (Figure 5). By the end of 2017, DH companies in Finland had 151,500 customers; 81% of these clients were residential buildings, and it was found that residential buildings use 54.6% of the entire DH production (Energiateollisuus ry 2018b, 1, 4). It was estimated that the population will grow in locations where a DH network is already available (Vainio et al. 2015, 24; Paiho & Saastamoinen 2018, 669). MDI's appraisal is that there will be an approximate 18.1% population growth in the Helsinki metropolitan area from 2018 to 2040. This means that 1.8 million people will live in the Helsinki metropolitan area in 2040. Tampere and Turku are also growing cities, and their population are expected to grow by 11.1 % and 9 % respectively (MDI 2019).

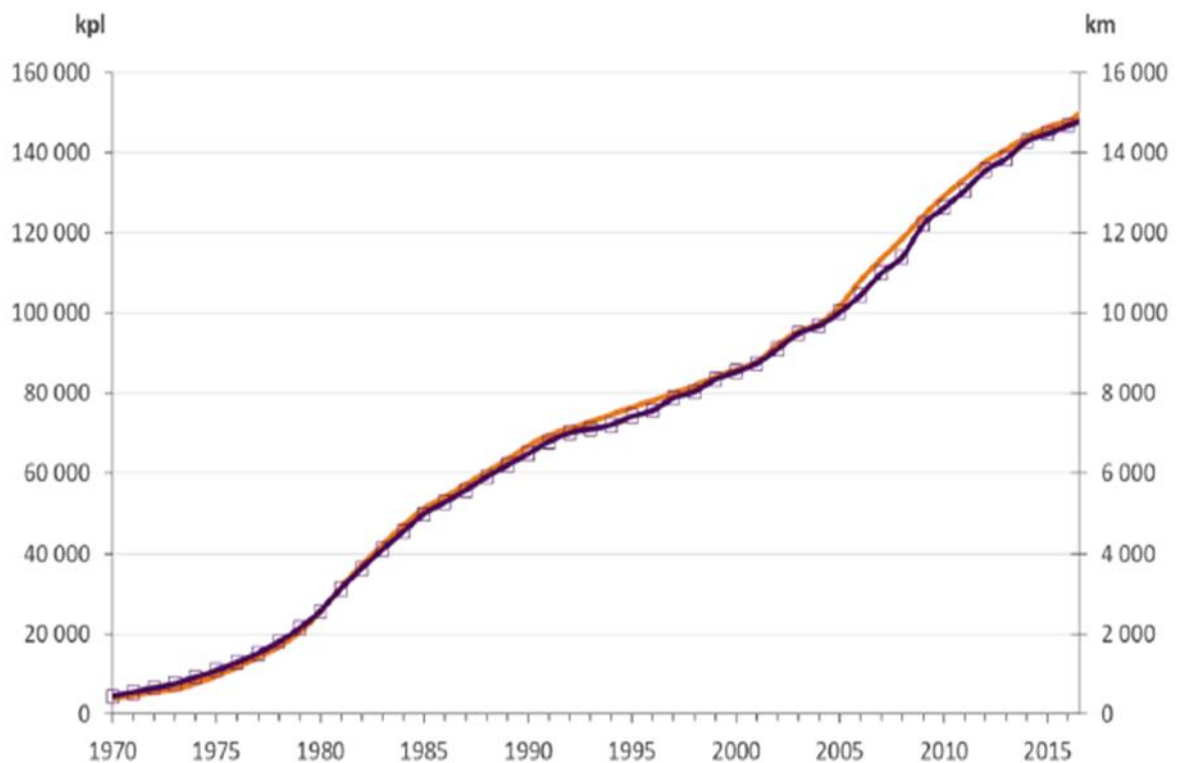


Figure 5. Number of district heating customers and district heating networks from 1970 to the present (Energiateollisuus ry 2018b, 4)

Apartment buildings can be owned by housing cooperatives, real estate companies, corporations, individuals, states, municipalities, congregations, or other types of cooperatives. Owners can invest their own capital in a construction project, and the outcome of their investment can either be for their own use, for making profit, or for fulfilling the needs of the community (Kiiras & Tammilehto 2014, 25).

According to Lauttamäki (2018, 218), the DH that was produced by combined heat and power (CHP) technology has retained the DH market share especially in dense areas where DH infrastructure already exists and where buildings consume more energy. However, the DH consumption in buildings has decreased over time (Figure 6). The demand for DH is expected to decrease even more because of an increase of energy efficiency in buildings (Koljonen et al. 2014, 51). However, the demand for domestic heating is not expected to decrease at the same rate in relation to the demand for space heating (Lauttamäki 2018, 226).

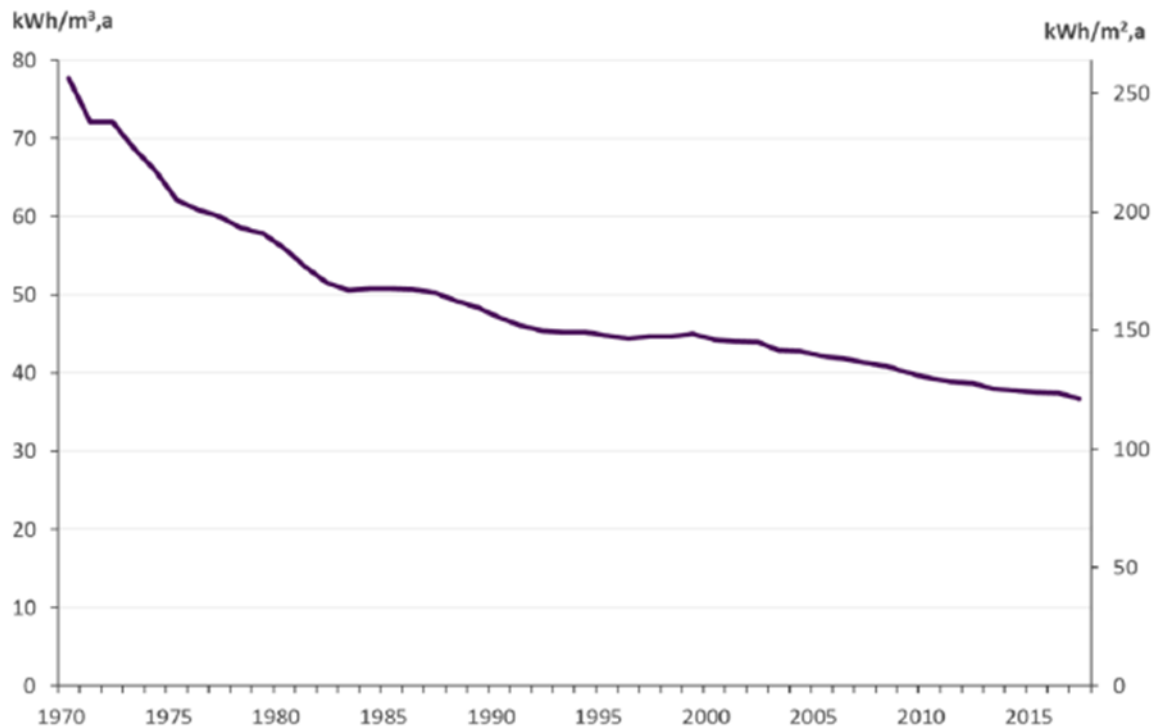


Figure 6. Timeline of district heating consumption in apartments (Energiateollisuus ry 2018b, 6).

2.5 Price of district heating

The price of DH can be divided by three parts, namely a connection fee, a power fee and an energy fee. The connection fee covers the construction costs of DH networks; the cost of the power fee depends on the size of the connection, while the energy fee depends on how much DH was used. The average taxable price of DH was €75/MWh in 2016 (Motiva 2019a). According to data from the Official Statistics of Finland, DH prices has risen every year since 2011 (Figure 7). DH prices can vary greatly between different DH companies. Differences between DH prices depend mainly on what types of energy sources were used in DH production (Lauttamäki 2018, 159). Koljonen et al. (2014, 51) expected that the annual average price for DH will vary between €90 to €120/MWh in 2030, depending on various scenarios.

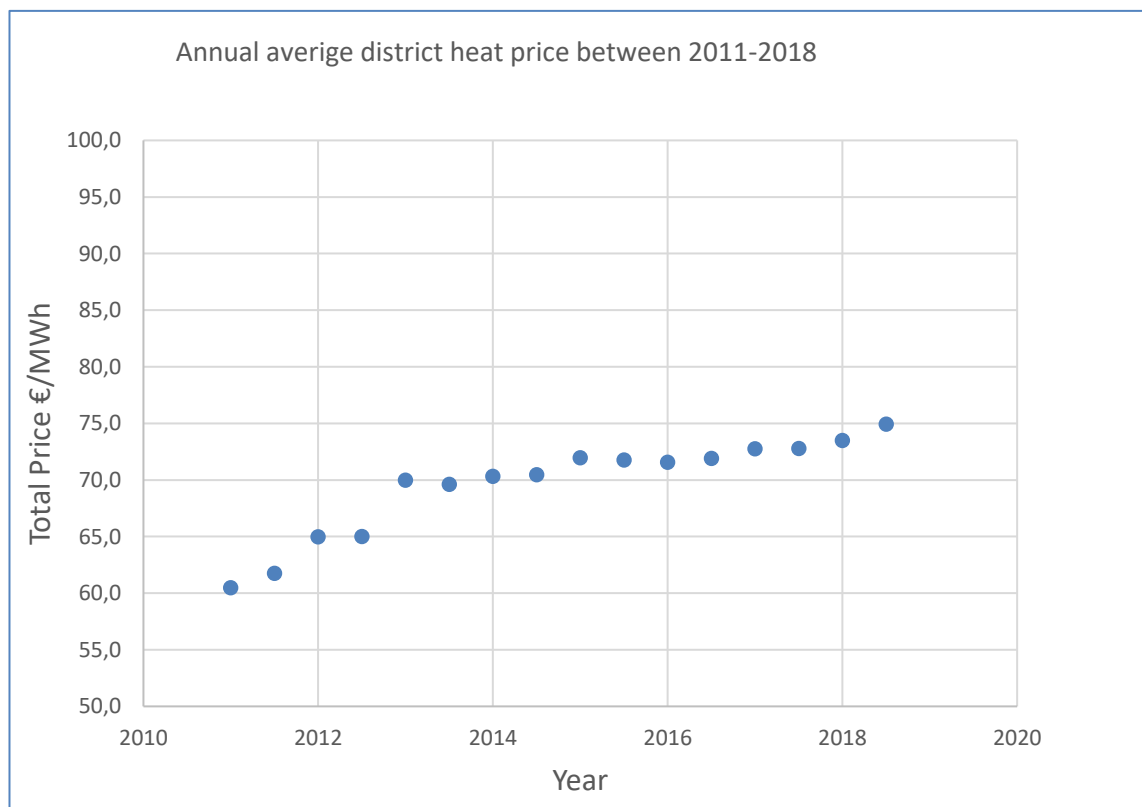


Figure 7. Annual average district heating price between 2010 and 2019 (Official Statistics of Finland 2019).

2.6 Future challenges in heating markets related to renewable energy and sustainable policy

Energy companies have been facing many challenges that are driven by the energy policies set by Finland and the EU. The emissions in Finland's energy sector were 75% of the total amount of emission in 2018 (Official Statistics of Finland 2018f). Finland's energy policy target is to phase out the use of coal in energy production by 2030. Finland's target is to increase the use of renewable sources. By the end of 2020s, renewable energy should cover 50% of the Finland's final energy consumption. (Huttunen 2017, 11, 31-32).

Business managers are generally concerned with the rising costs of energy and material sources around the world. At the beginning of the 21st century, prices started to increase rapidly (Weetman 2016, 1-11). Fuel prices have developed in the last 15 years. Price of coal has increased significantly for the past 15 years. (Energiateollisuus ry 2019.)

There has been massive investments in renewable energy power plants, and the ratio of return is not as large as it is for coal or gas. However, renewable energy projects can be seen as more profitable and less risky than coal or gas power plants (Richter 2013, 1231).

Fossil fuels consumption in DH production has decreased since 2010, and renewable fuels consumption has increased at almost the same rate. This indicates that energy companies have made significant investments in renewable energy (see Figure 8). This will lead to the decrease of coal consumption (Energiateollisuus ry 2017b). At the moment, coal still has a significant role in Finland's DH production (see Figure 8).

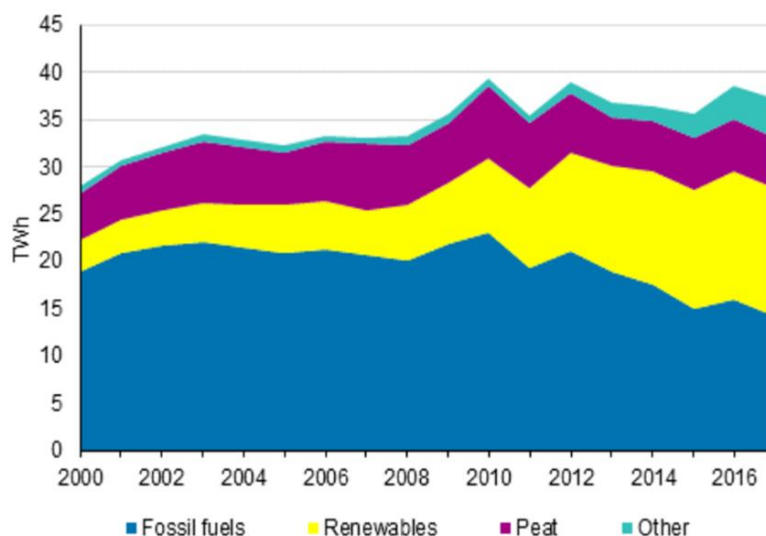


Figure 8. District heating production by fuels from 2000 to 2017 (Official Statistics of Finland 2018g).

Political factors have driven energy companies to increase their biofuel share in energy production in Finland (Lauttamäki 2018, 206). In many situations, biomass has been proposed to replace coal for electricity and heat production (Wahlroos 2019, 29). The renewable energies that are used in the generation of DH are largely biofuels (18%) and industries wood waste (11%). There is still the uncertainty regarding the availability of biofuels or their price development (Lauttamäki 2018, 206). This is a risk for energy companies, and this can hinder investments in new biomass capacity (Wahlroos 2019, 29).

Figure 9 shows waste heat as an important renewable fuel in DH production. Waste heat has significant potentials to reduce carbon dioxide emissions. However, the needed investments are significant, and this can be risky for some companies. In addition, the rate of return is sometimes too long for some companies. These factors cause waste heat systems to be less attractive for companies (Yle 2019).

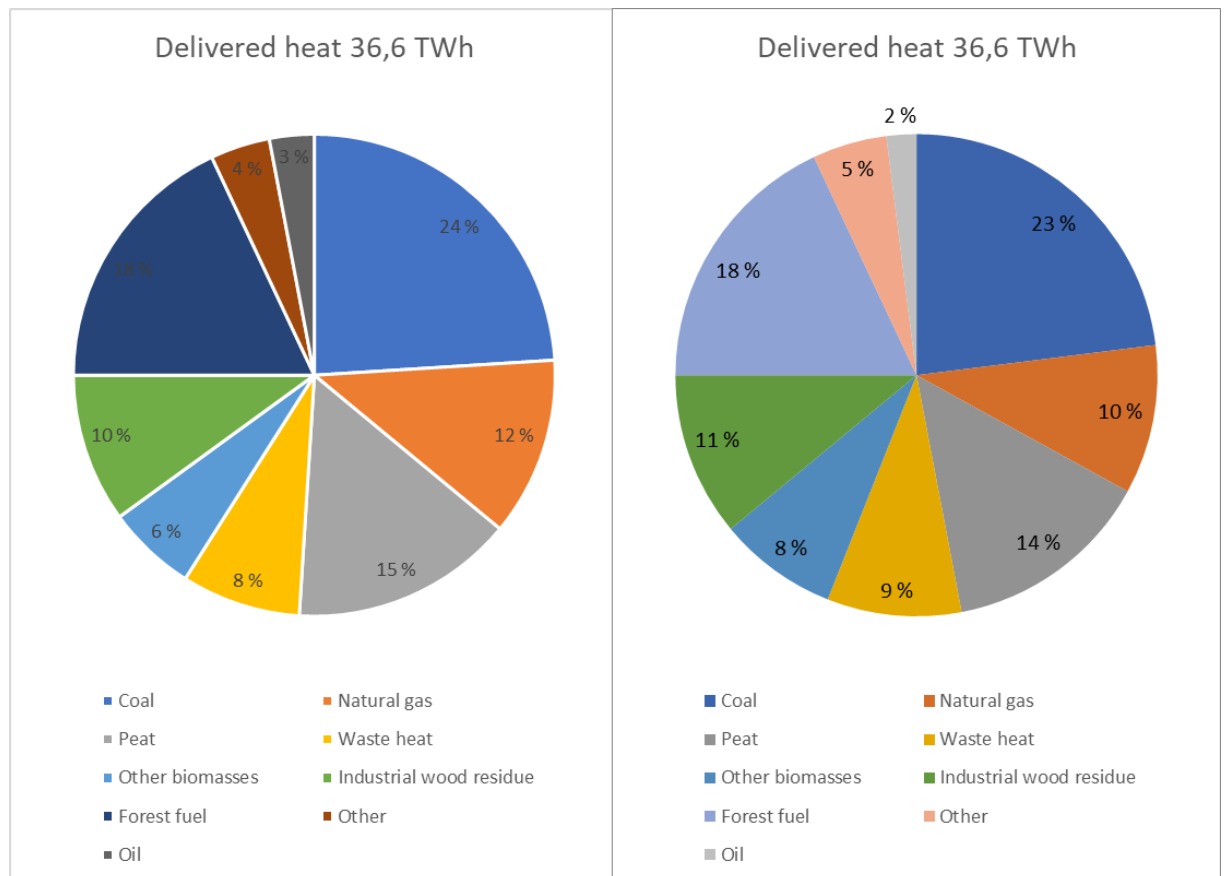


Figure 9. Energy sources in Finland's district heating production in 2016 (left) and 2017 (right) (Energiateollisuus ry 2018, 4)

Peat has a 14% share of DH production in 2017 (Figure 8). However, there has been much discussion in Finland on the environmental impacts of peats (e.g., Suomen luonnonsuojeluliitto n.d.; Turveinfo n.d.). Almost 20 years ago, there was research claiming that the rate of Finland's peat consumption was greater than the rate of peat growing; therefore, the use of peat was seen as not sustainable (Schilstra 2001, 291). Use of peat in DH production was almost the same in 2000 and 2017 (Figure 8).

There has been a great amount of political pressure placed on energy companies to increase the use of renewable sources in heat production. However, it is not clear which energy sources should be calculated as a renewable energy source, and not all renewable sources are always sustainable.

2.7 Heat generation in the future

Energy generation can be divided in three types of generation models: centralized, decentralised, and distributed energy generation. Energy that is generated with large power plants is referred to as centralised energy generation. However, distributed generation and decentralised generation are argued to be more efficient, reliable, and environmentally friendly than traditional centralised generation (Alanne & Saari 2006, 540, 542). Still, energy companies seem to be more interested in centralised renewable energy generation, and they seem to be more interested of large-scale renewable energy projects and see more new business opportunities in this business field (Richter 2013, 1234).

The definitions for centralised, decentralised, or distributed generations are not unambiguous, and it is difficult to define which energy generation network is centralised, decentralised, or distributed. The energy generation is hardly ever completely centralised or decentralised. There has not been a situation where a single power plant could cover the entire country's total energy consumption (Alanne & Saari 2006, 540, 542, 545). Table 2 presents the average sizes of power plants in different regions in decentralised and centralised energy generation.

Table 2. Average size of power plants referring to centralised and decentralised energy generation in terms of different regions (Alanne & Saari 2006, 547)

Region	Decentralised	Centralised
Country	< 2MWe	> 1000 MWe
Territory	< 250 kWe	> 100 MWe
Municipality, city, or town	< 100 kWe	> 2 MWe
Village or group of houses	< 25 kWe	> 100 kWe
Residential building	1-5 kWe	> 25kWe

Centralised energy generation is typically the generation where few energy plants are located within a large area to provide energy to a large group of customers. (Alanne & Saari 2006, 541). An example of a centralised energy system is seen in Figure 10.

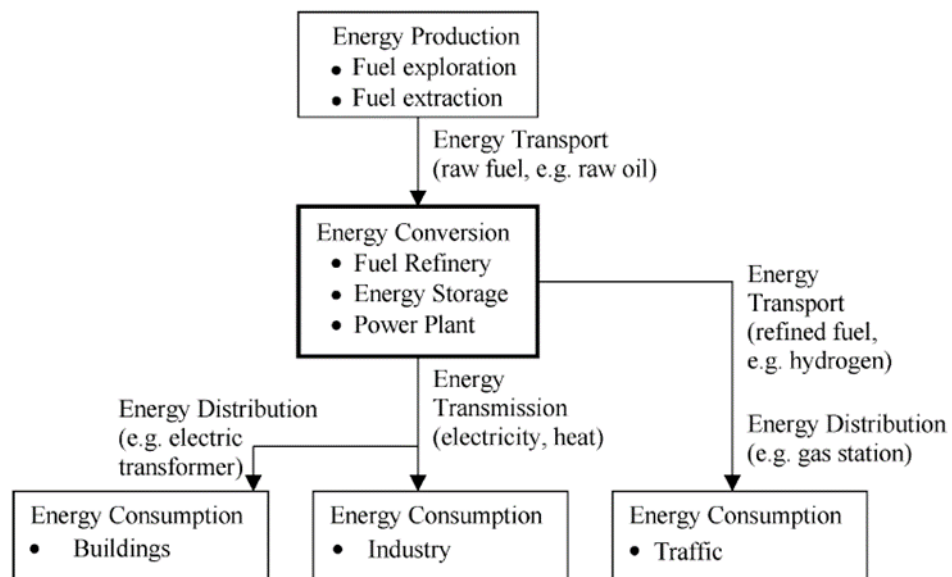


Figure 10. Example of a centralised energy system (Alanne & Saari 2006, 542).

Distributed energy generation can be seen as the opposite of a centralised energy generation. In distributed generation, a large number of small-scale power plants are located within a small area to provide energy to a small group of customers (Alanne & Saari 2006, 541-542). An example of a distributed energy system is seen in Figure 11.

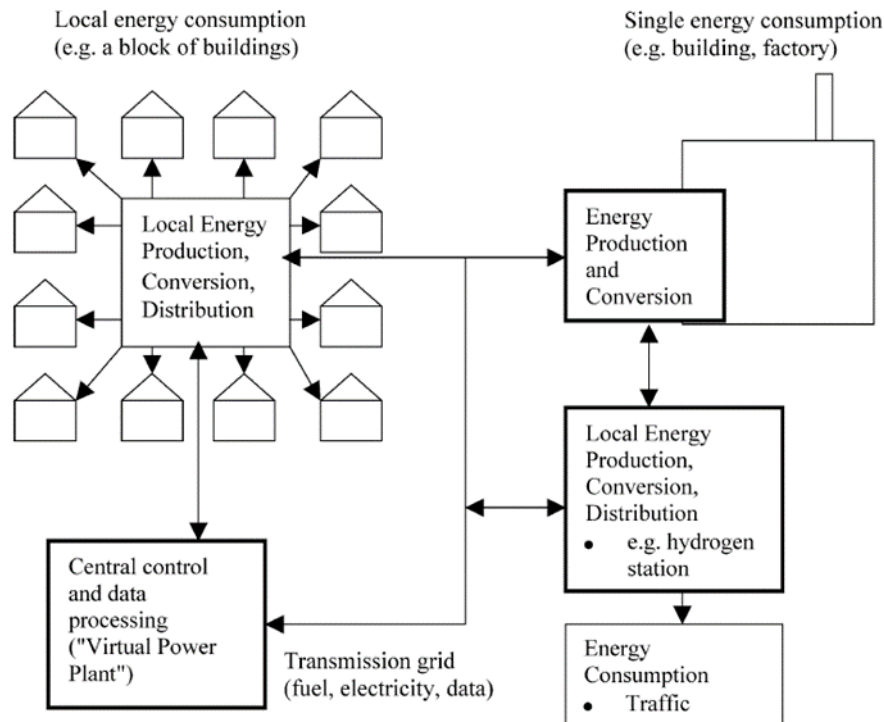


Figure 11. Example of a distributed energy system (Alanne & Saari 2006, 544).

According to Alanne and Saari (2006 543), decentralised energy systems “consist of small-scale energy generators that are placed in the same location with an energy consumption point and that are used by a small number of people.” An example of a decentralised system is presented in Figure 12.

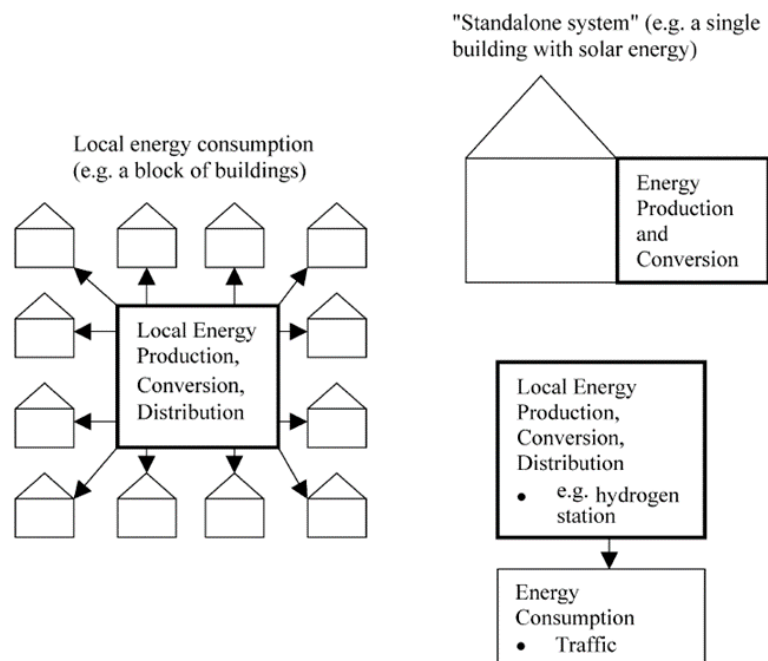


Figure 12. Example of a decentralised energy system (Alanne & Saari 2006, 543).

It is estimated that future DH companies will increase distributed generation; the current DH generation is mainly based on centralised generation. Increases in the share of renewable energy sources are expected in the future (Paiho & Reda 2016, 922). DH in the future requires more production diversity (Wahlroos 2019, 39-40). New renewable technologies that could be considered for DH in the future include solar thermal collectors, thermal heat storages, and heat pumps (Paiho and Reda 2016, 922).

3. BUSINESS MODEL OPPORTUNITIES FROM ENERGY MARKETS

3.1 Definition of business model and green marketing

To obtain a real competitive advantage, a company's business model must be serving particular customer's need (Teece 2010, 191). According to Teece (2010, 172), "a business model is about defining the manner by which the enterprise delivers value to customers, entices customers to pay for value, and converts those payments to profit".

According to many studies, a business model is based on four basic elements, namely value proposition, customer interface, infrastructure, and a revenue model (e.g., Osterwalder & Pigneur 2009; Ballon 2007; Richter 2012; Richter 2013). The term *value proposition* is defined by Osterwalder (2004, 43) as "a value Proposition is an overall view of company's bundle of products and services that are of value to the customer". A customer interface relates closely to the value proposition, as explained by Osterwalder (2004, 43) "the customer interface covers all customer related aspects. This comprises the choice of firm's target customers the channels through which it gets in touch with them and the kind of relationships the company wants to establish with its customers. The customer interface describes how and to whom it delivers its value proposition, which is the firm's bundle of products and services." According to Osterwalder (2004, 79) the term *infrastructure* "describes what abilities are necessary to provide its value propositions an maintain its customer interface" (Osterwalder 2004, 79). The revenue model is company's way to make money (Osterwalder 2004, 43)

Environmental performance has positive effects on a company's financial performance. For this reason, many companies are more interested in environmental issues within the context of their business activities (Molina-Azorin et al. 2009, 1093). Green marketing is important factor when companies are trying to increase their green products sales.

According to Chen and Chang (2012, 503), "Green marketing activities involve developing, differentiating, pricing, and promoting products and services that satisfy customers' needs without a hurtful in-fluence on the environment." Green marketing can increase a corporation's green image and bring competitive advantage (Chen 2008, 541).

3.2 Business model for centralised heat generation and customer-side renewable energy business model

Richter (2013) examined the business models of energy utilities in Germany in the context of renewable energy. The business model used is close to a large-scale business model of traditional utilities where electricity is generated with a small number of large-scale assets. The main technologies in this business model involve renewable energy systems. (Richter 2013, 1228.)

Energy companies view renewable energy as more attractive than power plants, which are based on fossil fuels today. Managers of energy companies believe that the rise in price for coal and gas price is a significant risk. Coal and gas power plants are slightly more profitable than renewable power plants; however, power projects are long-term investments, and it is difficult to predict the profitability of coal or gas power plants in the long run. (Richter 2013, 1231.) As Richter (2013, 1231) noted, renewable projects have the “feed-in tariff guaranteed for 20 years on the sell side” with no risk for the price on the input side.

Richter (2013, 1234) found that most of the utility managers saw large-scale renewable energy projects as an attractive new field of business. Energy managers understand that the rate of return is slightly higher for coal or gas power projects, but it is hard for energy companies to predict which price they can sell electricity at because of prices for coal and gas rising in the future (Richter 2013, 1231).

The value proposition in a utility-side renewable business model does not differ from a traditional business model where energy is produced with large coal or gas power plants. The value proposition for both types is in the bulk generation of electricity that is fed into the grid (Nimmons & Taylor 2008, 5; Richter 2012, 2489; Richter 2013, 1229). Generally speaking, the value proposition does not change, but there can be more opportunities when companies obtain a greater green value. When the quality of the value proposition changes, the utility could be seen as more valuable for environmentally-sensitive customers (Richter 2012, 2489).

The customer relationship in this business model consists of a business-to-business relationship. Energy companies' customers are enterprises that transport and distribute the electricity to the end customer. Because utilities mainly conduct business with enterprises, they have not seen a reason to improve their relationship toward the end customer (Richter 2012, 2489-2490). However, utility managers are aware that end custom-

ers are willing to change their suppliers, and hence these managers see renewable technologies to have a positive effect on their relationship to the end customers (Richter 2013, 1230)

The key partnerships are the networks of suppliers and partners, and such a network makes the business model work. Key partnerships can provide knowledge, experience, and financial strength to the utilities in the field of renewable energy. Richter provided the following example in his work:

Juwi is one of the leading German project developers in the field of wind and solar energy as well as biomass. Juwi brings in its expertise in project development and operations management of the projects and the utilities bring in their financial strength to finance the projects and use the electricity. (Richter 2012, 2490)

The investment decisions made by utilities regarding power projects are based on the profitability and return expectations of the projects. Large-scale renewable projects have higher construction and maintenance costs, but their “revenues come from regulated feed-in-tariffs for electricity or tax- or investments credit” (Richter 2012, 2491).

Utility managers believe that there is no need to change the traditional business model (Richter 2013, 1230), but researchers such as Frantzis et al. (2008, 56) and Nimmons and Taylor (2008, 48) found that changes to renewable energy require new business models. For example, utilities have potential to create new revenue streams through project developments or service and maintenance. Another interesting note is that most utility managers do not see renewable energy as a threat to their current business model. However, a number of third parties have grown their business in Germany. If utilities are not able to change their way of conducting business in a changing environment, their loss of market share will increase (Richter 2013, 1235-1236).

The energy generation of a customer-side business model for renewable energy is distributed where energy is generated in small-scale systems which are located close to the point of consumption. This means that the value chain of a customer-side business model is different. The value chain of a utility-side business model for renewable energy is in generation and the value chain of the customer-side is in consumption (Richter 2012, 2486; Richter 2013, 1228-1229).

Utility managers see distributed generation as a major threat, but they are not able to find an economically sustainable value proposition in this field. The costs for small-scale electricity production are too high compared to large power plants, and this makes it difficult for them to make enough profit for large utilities (Richter 2013, 1232). One utility manager explained this situation in the study by Richter (2013, 1232):

It is a severe threat to our business model. Today you can already see it in the field of heat and gas supply. Due to better insulation houses use significantly less energy for heating, A similar effect could occur in the electricity sector through distributed generation.

According to another utility manager, “Distributed electricity generation will become more important. Either we enter this market, or others will do” (Richter 2013, 1232). However, Richter (2013, 1232) pointed out that “the strategic value of customer-side generation for utilities lies not in being a new technology with cheaper production costs per kilowatt hour, but in the possibility to make a first step into a new distributed energy market”.

It is clear that large-scale utility projects are more profitable for utilities than small-scale customer-side projects in reaching the renewable energy portfolio of utilities. Still, customer-side business model can bring competitive advantage for utilities in the future. Customer-side business model is fairly new type of business model and utilities need to thoroughly consider the value propositions, customer interfaces, infrastructures and revenue models for this business model (Richter 2012, 2492).

In addition, utility managers need to create new value propositions for the customer-side business model (Richter 2013, 1232). For example, the Dutch green energy provider Greenchoice’s value proposition is price stability. They install PV system’s for customers and offer a fixed electricity price for the next 20 years and can therefore build a relationship with their customer that lasts for 20 years (www.greenchoice.nl as cited Richter 2013, 1232). Policymakers also have an important role in the development of customer-side business models. They have the power to set new regulatory frameworks for a truly sustainable energy future (Richter 2012, 2492; Richter 2013, 1236).

In addition, there is a belief that customers who can finance a building by themselves would prefer to make their own investments and earn the return themselves. However, some utilities offer customer-side generation even though they do not see it to be economically profitable (Richter 2013, 1233). Customer relationship management and political goodwill seems to be the main drivers for this kind of business and not customer demand (Richter 2013, 1233).

3.3 Third-party business model

Many studies have noted that the third parties practice third-party business model in energy sector is harmful for utility businesses, as they will likely lose their market share and profit to third parties (Klose et al. 2010, 10; Frantzis et al. 2008, 63). Third-party business models have become popular among ESCOs and investors of solar photovoltaic businesses (Lam & Yu 2016, 856). This involves ESCO companies conducting a service business when third-party energy experts make investments to lower buildings energy costs on behalf of the customers, and the service is paid by the saved energy. Usually, some energy is guaranteed to be saved (Lam & Yu 2016, 856; Saarivirta n.d.). The main idea is that a third-party makes the investment, installs the system, and operates it instead of the building owner. Third-party ownership can be based on a power purchase agreement or on the lease of the equipment. The building owner would either pay the power output generated from the energy system every month or pay a fixed monthly rent to the third-party for leasing the energy system to the building owner (Lam & Yu 2016, 856, 861).

Third-party ownership has become more common in the United States than in the EU (Burger & Luke 2017, 242). The financing model for third-party ownership is expected to become more common in the EU when feed-in-tariff policies wane in Europe and customers purchase debt products when they become more common (Sharma et al. 2015, 9).

Third-party business models are also used in the GSHP business for the residential sector. ST1 offers a business model where they invest in the GSHP system and construct the system on the customer's property. The customer pays a fixed monthly price for the system, which is combined with real estate maintenance costs; the customer is also responsible for the GSHP system's consumed electricity (ST1 n.d.).

However, the third-party business model is challenging in the residential sector (Suhonen & Okkonen 2013, 787). Some utility managers admitted that there is no economic sense with residential generation (Richter 2013, 1233). The energy savings of customers are rather small, and therefore the cash flow of the ESCOs is also small. Another problem for the ESCO business model is that the interests between the customer and the ESCO can differ. Customers could prefer longer service periods and cheap energy cost at the beginning of the investment, and ESCO companies may want short payback times and shorter contracts (Suhonen & Okkonen 2013, 787).

4. METHODOLOGY

4.1 Research questions

The empirical part of this study consists of two expert interview rounds. The first interview round was a pair interview conducted with a GH consultant and a heat pump manufacturer. The second interview round consists of eight interviews, and one of these interviews was a pair interview. (Hirsijärvi et al. 2009, 210.) These experts and companies were chosen either because they either have a wide experience in designing, contracting, or constructing GSHP systems or the companies have a significant role in deciding the heating systems of apartment buildings.

The purpose of the first interview round is to determine whether it is possible to use the GSHP system in the Marinranta housing area and how profitable the GSHP system is for the housing cooperative. After this interview, the interviewed GH consultant agreed to conduct a prestudy for one of the apartment buildings in the Marinranta housing area. The heat pump manufacturer also agreed to suggest a suitable heat pump for the chosen apartment building. The apartment building's energy certificate was sent to the GH consultant and the heat pump manufacturer. The prestudy presents the costs of the GSHP system and the investment calculations of the heating system; this information is presented in Appendix A.

Prestudy was used in this thesis because, there was possible to get the GSHP system's investment costs. Without prestudy, the GSHP system's investment costs would be difficult to get. GH consultant presented the GSHP system's cashflow calculations which are presented in this thesis. Cashflow calculation is presented in this thesis to illustrate, how much surplus the GSHP system could bring to the housing cooperative's operating costs.

The purpose of the second interview round is to examine how interviewees think about the current market of GSHP systems and what are future expectations for GSHP systems in the apartment building sector. Interview questions were chosen and prepared in a way where interviewees could answer the four research questions:

RQ1: How is ground heat currently used in the energy generation of new apartment buildings?

RQ2: What are the future expectations for GSHP systems?

RQ3: What business models have energy companies used in Finland and in other countries when the energy comes from renewable distributed energy generation?

RQ4: How can construction companies benefit from the identified business models in their own business?

4.2 Expert interviews

Interview's subject and theme areas are known but question's precise order and structure are missing in theme interview. A theme interview was chosen as the method for the interviews; this method was chosen because interviewees could answer the questions in their own words, and the interview questions did not restrict the experts' own opinions on the subject. Only a few interviews were conducted, but the theme interviews provided much material for this thesis. In the theme interviews, there was a great amount of information that could be obtained, and if needed there was the possibility to ask more precise questions on the subject. The questions in the second interview round were presented in the same order to every interviewee. Interviews were compared with one another, and this allowed interviewees to provide different opinions. Questions for the interviews were open ended, and most of the interviewees answer the questions as fully as they can. (Hirsijärvi 2009, 208-210.)

It is important to record interviews especially in theme interviews (Mäkinen 2006, 94). Every interview was recorded and transcribed; there was no need to transcribe interviews word by word as the language and tone was not seen as important for this thesis. Recording capture interviews talk word by word and expression of emotions (Hirsijärvi ja Hurme 2000, 92)

Interview questions were sent to the interviewees by email before interviews. The theme subjects for the first interview round are presented in Appendix B, and those from the second interview round are in Appendix C. Most of the interviewees had prepared for their interview beforehand.

4.2.1 Interview process

The first interview round was conducted in May 2019 with the GH consultant and the heat pump manufacturer. The GH consultant conducted a prestudy for this thesis in cooperation with the heat pump manufacturer. The purpose was to see whether the GSHP system could be used in Marinranta, and thus there was the need to involve a GH consultant and a heat pump manufacturer. A pair interview was chosen as the method for this interview. A pair interview is group interview's subtype and it is concerning the same guidelines as group interview (Hirsijärvi et al 2009, 210). Interviewees are more relaxed and open when other interviewees are present (Grönfors 1982, 109). Interview type depends on who are the interviewers and what is study's subject (Hirsijärvi et al 2009, 210).

The second interview round consists of eight interviews that were conducted between September and October 2019. One of the interviews was a pair interview. Some interviews were made through Skype, and some interviews were conducted in the interviewee's office.

Interviews were open-ended conversations, and interviewees could answer the questions freely. The reason for this was to motivate the interviewees to answer the questions more broadly and accurately. However, open interviews are more demanding and need more skills than other interview types. (Hirsijärvi et al. 2009, 205-209.) Because the experts work in different business fields, the interviews gave a broad view of the GSHP markets in the sector of new apartment building construction.

4.2.2 Profiles of interviewees

As mentioned, interviewees were chosen either because they know about GSHP systems or they have a significant role in their company's strategic decision-making process. The interviews were conducted with a number of experts, including the construction company of this case study, two real estate investors, a student housing foundation, a real estate private equity investor, an ESCO, two designers for a GSHP system, a heat pump manufacturer, and a GH consultant. All interviewees were familiar of GSHP systems, and they are familiar about benefits of GSHP systems.

Real estate investors companies, the real estate private equity and student housing foundation were chosen because GSHP systems can lower the heating costs of their apartment building's portfolio. Heating costs are a significant expense item for these companies. They also need to decide the heating system of their housing cooperative, which could be either invested or contracted. Therefore, this group was seen as an important interviewee group. An ESCO was interviewed because ESCOs typically have a wide

knowledge on contracting GSHP systems. However, ESCOs mainly focus on existing apartment buildings. In this study, an ESCO was interviewed to see what they think about the use of GSHP systems, specifically whether this use will increase in the sector of new apartment building construction in the future.

In addition, the GSHP system designers, heat pump manufacturer, and GH consultant were interviewed because they have a wide knowledge of today's GSHP markets. They also have an understanding on how GSHP system markets have developed in the past few years, as well as how many new apartment buildings have installed the GSHP system during the construction phase. Finally, the company which is the case of this thesis was interviewed because the purpose of this thesis is to suggest a business model to this construction company; therefore, it was important to also obtain their opinion on GSHP systems.

4.2.3 Theme areas and questions

4.2.3.1 First interview round

Interview questions based on theory and research questions. The background of the companies and organisations were studied by visiting their websites before the interviews. The interviewees gave a brief presentation of their company either before or after interviews.

The first interview round contained two main themes. The first theme was the GSHP system in the Marinranta housing area. The GH consultant and the heat pump manufacturer were both asked to discuss whether it is possible to use GSHP system in the Marinranta housing area. The second theme was on the costs and profitability of GSHP systems. In this part of the interview, the GH consultant and the heat pump manufacturer were asked where the costs for the GSHP system come from and how much housing cooperatives would save from heating costs compared to DH. To obtain more precise answer to the questions, the GH consultant agreed to make prestudy for one of the housing cooperatives in the Marinranta housing area.

4.2.3.2 Second interview round

The second interview round was conducted with eight experts. One of the interviewees was the same GH consultant who performed the prestudy for one of Marinranta housing area's housing cooperative named Apollo.

The questions were designed to gain a clear view of GSHP markets. The purpose of the interviews was to see how different parties could benefit from GSHP systems and

whether there are there business opportunities that could cause GSHP systems to be more appealing.

Table 3. Interview questions and question objectives

Questions	Objective
Q1: What is the present state of the GSHP market in the sector of new apartment building construction?	To obtain a clear view of the present state of the GSHP market in the sector of new apartment building construction
Q2: What are the challenges of GSHP systems and what factors restrict a wider use of the GSHP systems in new apartment building construction?	To understand what the challenges of GSHP systems are and what factors restrict a wider use of the GSHP systems in new apartment building construction
Q3: What are the factors that could increase the use of GSHP systems in new apartment building construction?	To investigate the different factors that could increase the use of GSHP systems in new apartment building construction
Q4: What are the key business opportunities that GSHP system could bring to other parties?	To investigate the key business opportunities that GSHP system could bring to other parties
Q5: Why there are not many parties that either lease the GSHP system to housing cooperatives or own the GSHP systems themselves and then sell the heat to housing cooperatives?	To find out from interviewees why they think there are not many parties that either lease the GSHP system to housing cooperatives or own the GSHP systems themselves and then sell the heat to housing cooperatives
Q6: How GSHP investments from third parties could become more attractive to construction companies?	To find out from interviewees their opinion on how GSHP investments from third parties could become more attractive to construction companies
Q7: How interviewees view the future of GSHP systems in the sector of apartment buildings?	To clarify how interviewees view the future of GSHP systems in the sector of apartment buildings
Q8: What could be the role of construction companies in the energy generation of apartment buildings?	To examine what could be the role of construction companies in the energy generation of apartment buildings

The purpose of having open questions was to give interviewees a way to freely speak on the subject; they could also bring up topics themselves if there was a subject that the interviewer did not think of before the interview (Hirsijärvi et al. 2009, 209).

5. INTERVIEW RESULTS

5.1 Use of ground heat in new apartment buildings and future of ground source heat pump systems in new apartments

According to all interviewees, the GSHP system used in new apartment buildings in Finland is a rear heating system. Interviewees 7 and 8 stated they were aware that GSHP systems are constructed in some new apartment buildings in Finland. Two interviewees mentioned that most GSHP systems are installed in existing apartment buildings (Interviewee 1 & 5). All interviewees stated that GSHP systems are becoming more popular in new apartment building construction in Finland; they also felt that the GSHP system is a reliable and eco-friendly heating system (Interviewees 1–8).

All interviewees mentioned that GSHP systems are becoming more popular for new apartment building construction in Finland. According to the interviewees, the biggest reason for this is that people and companies are increasing their environmental awareness. Interviewee 8 said that the apartment building sector has the biggest growing potential in GSHP markets. It was mentioned that the GSHP system would become a more attractive heating system if the GSHP systems could be integrated with a cooling system (Interviewee 5 & 7).

Most of the interviewees said that there is a great amount of information on GSHP systems that are available. They viewed the GSHP system as a technically reliable heating system, and it is considered to be an economical system for housing cooperatives. These were the reasons why the interviewees felt that GSHP systems could become more common in the future.

5.2 Factors that restrict the use of ground source heat pump systems

5.2.1 Lack of financial benefits for the property developers

According to the interviewees, the main factor that restricts the use of GSHP systems in new apartment building construction is the fact that construction companies have not seen financial benefits from GSHP systems. Other challenging factors include town planning and the size of properties. At this moment, there are only a few designers and contractors who can design and contract GSHP systems in apartment buildings.

The main reason why GSHP systems are not constructed in apartment buildings is that construction companies have not seen any financial benefits for GSHP systems. DH systems lower construction costs; this attracts construction companies to connect the apartment buildings to the DH network, and customers usually see the cheaper option as the better option (Interviewee 5). Construction companies are not interested in the apartment building's heating costs after the apartments are sold to the private apartment buyers. According to Interviewee 1, the most important point from the view of the construction companies is that the system is reliable. However, this should not be the case. Heating systems should be comparable to lifecycle investment calculations, and construction companies should choose the heating system that is best for the customer. As mentioned by Interviewee 3, there is a challenge in how construction companies could sell the GSHP system with extra costs to the customers. However, some housing cooperatives changed their apartment building's heating system from a DH system to a GSHP system just few years after the building was completed because they saw the GSHP system as a more profitable heating system. By changing to the GSHP system, the investment that was put into installing a DH system investment became unnecessary. As noted by Interviewee 8, in these cases it would have been better to install the GSHP system in the apartment building straight away in the construction phase.

For some actors, the investment costs of a GSHP system can be too high. Interviewee 8 stated that for some real estate investors, it can be a challenge when 1% of apartment building's entire investment comes from the heating system. As noted by Interviewee 3, the investment in a GSHP system is a problem when the costs of the GSHP system are too high and when the payback time is too long. According to Interviewee 5, usually a 10-year payback time is seen as too long, and it is hard to imagine any other investments where the yearly profit would be 10 to 15%, which is what the GSHP system has. Interviewee 2 saw the investment cost of the GSHP system investment cost problematic in a situation where invested property is purpose to sell before GSHP system have time to pay the investment back. GSHP system's payback time needs to be short, or the investment needs to get back in exit-phase, when the property is going to sell (Interviewee 2).

5.2.2 How district heat and electricity price will change in the future?

Practically, DH companies are in monopoly situation although they are not monopolies. If DH companies increase their prices, there are no many options to heat the buildings, especially if it is not possible to drill energy wells in the property. In addition, the DH company and the energy company can be a same company. According to Interviewee 5, if the number of GSHP systems increase in apartment buildings, it is possible that the energy company switch their pricing model so that the profitability of the GSHP system decreases.

Energy companies can also increase the price of the electricity. Currently, GSHP systems are most profitable if GSHPs cover 70% of the power demand. As noted by Interviewee 5, if the electricity costs 100 times more on the coldest day of the year, it may no longer be profitable to design the GSHP system this way.

If it is possible to predict how legislators, DH companies, and energy companies would act, it would be easier to calculate the lifecycle costs. These uncertainties decrease the attractiveness of the GSHP system. In the end, the volume of the GSHP systems will decide how much DH and electricity prices will differ in the future. The electricity price would need to be nearly tripled in order for the GSHP system to become unprofitable. However, this would affect the industry sector so strongly that it is not likely for this to happen. Overall, DH companies are in a very tough situation; they have to increase the use of renewable sources for heat generation. In addition, the infrastructure of DH is in a bad condition, and at the same time they have to renew the entire energy generation. According to Interviewee 5, the DH business is based on centralised generation, but their business models are not suitable for distributed generation. Interviewee 1 also noted that energy companies would need to invest billions of euros in renewable sources, and it is not likely that the price of DH will decrease. As noted by Interviewee 5, the decrease in price for heat pumps will attract investors for GSHP systems in the future.

5.2.3 Size of properties and town planning

All interviewees viewed location as a challenge for a wider application of the GSHP systems. Properties are small, and it is possible that all the needed energy wells would not fit inside the property. Town planning can also be a problem. The interviewees all commented that in Helsinki especially, existing tunnels are a problem because they restrict drillings. According to Interviewee 5, cities used to restrict energy well drillings more strongly in the past than in the present day. The interviewee also mentioned that town planning used to make it mandatory for construction companies to connect apartment buildings to a DH network, but now the construction companies are no longer forced to do this.

Both Interviewees 7 and 8 did not consider small properties and town planning as major challenges as much as the other interviewees did. However, as Interviewee 8 mentioned, every drilling must be planned case by case. In Helsinki, there are many properties where it is possible to drill energy wells (Interviewee 7 & 8).

5.2.4 Lack of designers and contractors for ground source heat pump systems

The GSHP system is not a well-known heating system in the apartment building sector. It can be a challenge to find competent contractors and designers for GSHP systems. The GSHP system is a more complex heating system than the DH system. Therefore, the GSHP system needs to be looked after so that it can be ensured that the system will work as it should. According to Interviewees 5 and 7, it can also be hard to find a GSHP systems designing and contracting in a reasonable price because there is less competition between designers and contractors. (Interviewee 5, 7.)

Interviewee 5 mentioned that there are few GSHP system's designers and contractors because GSHP systems are contracted only few in the apartment buildings. When there are paying customers, it will be easier to find designers and contractors (Interviewee 5).

GSHP system's designing is an equipment specific design. It is common that when GSHP is tendered out, there is a completely different heat pump than the designs were made. GSHPs can work very differently, and designed plans are useless if the GSHP is different. Contractors should create the designs and choose the equipment that is best for them. The contract used is a design-and-build contract, which is often separated from the HVAC-contract. According to Interviewee 5, the mechanics for the equipment in GSHPs are so different from each other that there is no point to make any principal plans for the GSHP system. On the other hand, Interviewee 8 believed that the

main problem with a design-and-build contract is that the cheapest option is typically chosen, and usually the cheapest option is not the cheapest in operational costs. Currently, there are ways to design more cost-efficient GSHP systems, but it can be hard to find the right persons and companies who want the operational costs as low as possible (Interviewee 8).

5.3 Factors that increase the use of ground source heat pump systems

5.3.1 Increased environmental awareness

The increased environmental awareness is the main reason why construction companies and real estate investors have started to examine the use of GSHP systems in the construction of new apartment buildings in Finland. New business models, such as the third-party business model, can decrease the investment costs of GSHP systems, which can make GSHP system more attractive to construction companies. However, these new business models are seen to be at a start-up phase right now. Most interviewees felt that real estate investors should make the GSHP investments by themselves.

The growing environmental awareness in customers and in construction companies is one major driver for examining the usability of GSHP systems in the heating system of apartment buildings. Companies have ambitious goals to decrease their produced emissions. Interviewee 1 mentioned that their company aims to reduce carbon emissions significantly for their own construction projects by 2030. Interviewee 4 noted that international stockholders in particular are interested in the environmental goals of the company and how the company plans to reach these goals. Even larger cities have published different “carbon neutral” programs, and ground heat was mentioned for the first time in Helsinki’s own program. As mentioned by Interviewee 1, even the large cities have noted that every possible way to reduce emissions must be taken into account.

According to Interviewee 8, the GSHP system is an attractive heating system for environmentally-aware customers, investors, and construction companies because with the GSHP system, it is possible to produce almost CO₂-free heat. Interviewee 1 explained that if the electricity that is consumed by heat pumps is freely produced by CO₂, the generated heat is completely CO₂ free. As stated by Interviewee 2, real estate private equity investors are more interested in the “greenness” of their invested apartment buildings. Interviewee 1 noted that if real estate private equity investors decided to invest in more eco-friendly apartment buildings, they need to put the pressure on the construction companies, and construction companies have to be prepared to point out all the benefits

of the designed options. Interviewee 1 stated that it would be an advantage if construction companies could highlight the fact that the lifecycle emissions and operation costs of the apartment building are lower with a GSHP system than the DH system.

Interviewees mentioned that in rental business, tenants do not typically ask about the apartment's greenness, and they are not willing to pay more rent for the apartments in which heat comes from renewable sources (Interviewee 2, 5). Interviewee 4 felt differently and said that tenants are more environmentally aware. As mentioned by the interviewee, climate change has been featured so strongly on the media that this message could affect consumers choices.

On the other hand, it was noted that investing in solar panels and GSHP systems in new buildings is a rather new idea (Interviewee 8). Interviewee 2 also mentioned that new apartment buildings are designed and built with the latest requirements. According to Interviewee 1, the main problem is not new construction but the existing buildings. Interviewee 5 stated that thus far the usability of GSHP systems has been examined mainly in existing buildings.

5.3.2 Innovative business models

5.3.2.1 Creating design and building concepts

The interviewees pointed out a couple of business models for GSHP systems. They mentioned that it is hard to find a contractor who knows how to contract and build a GSHP system in a new apartment building, and if there are such contractors, these contractors do not market themselves properly. One business model that was discussed is the third parties that offer leasing and operating models of GSHP systems. Some interviewees felt that this business model is not suitable for real estate investors who can invest in the system on their own. On the other hand, all the risks in the GSHP systems that comes from designing and contracting are also shared with the third-party.

Some interviewees stated that construction companies should familiarise themselves with how to construct a GSHP system for the apartment buildings (Interviewees 4, 7, & 8). At this moment, it is not certain whether there are any successful design and building concepts for the apartment building sector. GSHP contractors have such concepts for small attached houses, and their systems are easy to install in small attached houses. GSHP systems consist of different components, and they are more complex to install (Interviewee 4).

5.3.2.2 Involving third-party businesses

In Finland, there are only a few companies that offer a leasing service with GSHP systems and a few GSHP system operators that offer “heat as a service” business. Interviewee 6 stated that this business model type is rare because there are only few GSHP systems that are contracted in new apartment buildings. According to some interviewees, it seems that these third parties do not market their business enough to construction companies or real estate investors (Interviewee 1, 2, & 4). The board members of housing cooperatives or real estate investors do not necessarily have the experience and knowledge for GSHP systems. Therefore, it was mentioned that it would be beneficial to have third-party who would operate the GSHP system and ensure, that the GSHP systems cost-effectively whole year round. (Interviewee 1 & 4).

Some interviewees shared that from the view of companies that practice rental business, there is no economical reason to share the benefits of GSHP systems (Interviewees 2, 3, & 4). These same interviewees also noted that the investment cost of the GSHP system was not considered as too large. The benefits of having a third-party who operates the GSHP system, is that they share the GSHP system’s investment risks. (Interviewee 5).

Interviewee 1 mentioned that the third parties have not seen business opportunities for the new apartment building sector. These third parties need business partners who can either own or contract many apartment buildings. The existing building stock consumes more heat energy, and the operating time of heat pump is longer in existing apartment buildings. Therefore, third parties are more interested in the older building stock and not new apartment buildings. Third parties cannot receive as large of a profit in new apartment buildings. It was mentioned that the third parties would need a larger volume in order for their business to be profitable, and this also needs huge investments in order to run this business (Interviewees 1 & 5).

It is easier to sell the GSHP system to a housing cooperative board than to construction companies. Construction companies view the GSHP system as an investment that is too large compared to a DH system. Construction companies do not yet believe that their customers would pay more for the apartments heated with ground heat (Interviewee 5).

Interviewee 3 mentioned that companies which offer a leasing service or “heat as a service” business for GSHP systems are in a start-up phase. It was stated that these companies need to improve their business model so that they could be a good fit for the companies who practice rental business (Interviewee 3 & 4). In a long run, companies

that practice rental business usually do not see an economical reason to have third parties invest in a GSHP system. According to Interviewee 3, it would make more sense if a third party would target a specific cover ratio.

There might be practical challenges why these models are rare in Finland. For example, as mentioned by Interviewee 5, the heating system is an integral part of an apartment buildings, and it is impossible for the business model to succeed if the housing cooperatives do not pay the agreed payment for the system.

6. CUSTOMER TYPOLOGY IN GROUND SOURCE HEAT PUMP MARKETS

6.1 Housing cooperatives as real estate investors

Housing cooperatives can benefit from a GSHP system when the system lowers the heat costs of the housing cooperative, as heat costs are part of the maintenance fee. Real estate investors that invest in housing cooperatives can also benefit from the heating system when the system lowers the maintenance costs of their invested housing cooperative.

A housing cooperative is considered to be a real estate investor in real estate developing, as it is a limited liability company whose purpose is to own one or more buildings (Asunto-osakeyhtiölaki 1599/2099, 2 §). In real estate development, the real estate developer forms a housing cooperative. The term *real estate development* means a business where construction companies design, markets, constructs, and sell apartments to the buyer, and thus the buyer obtains the right to control the apartment's spaces when buying housing cooperatives stocks (Savander & Salakka 2018 cited Kirjanpitolaautakunnan yleisohje 5.6.2017).

From a legal perspective, a real estate developer is a construction company that purchases the property on behalf of the formed housing cooperative. The construction company makes all the needed designs for the apartment building and then markets the building to the end users. After the housing cooperative is registered into the trade register, the construction company transfers the property to the housing cooperative. The construction company is responsible for making all the agreements that concern the construction project. It also needs to organise the needed funding for the housing cooperative, and it also makes all the agreements that are mentioned in apartment deal law with financial institution and insurance company. The construction company sells the stocks that provide access to control the housing cooperative's apartments (Savander & Salakka 2018 cited Kirjanpitolaautakunnan yleisohje 5.6.2017).

From the financial side, the revenue of the real estate developer comes from selling the stocks of the apartment building. Expenses are primarily the construction and property expenses (Savander & Salakka 2018 cited Kirjanpitolaautakunnan yleisohje 5.6.2017).

Shareholders of housing cooperatives need to pay a maintenance fee to the housing cooperative. The maintenance fee covers the management fee and financing fee (Re/max n.d.). A significant part of the housing cooperative's maintenance fee is spent

to cover energy and water fees. In 2017, 22% of the total maintenance fee from apartment buildings came from heating (Motiva 2019b). GSHP systems can lower the maintenance fee of housing cooperatives and therefore increase their rental profit (Appendix A, 20). Therefore, GSHP systems can be a viable investment for housing cooperatives and their shareholders. Construction companies can decide on the heating system of the apartment buildings in real estate development. According to two interviewees, GSHP systems need to increase the stock value of apartment buildings so that the system could be profitable for the construction company (Interviewee 1 & 2).

6.2 Real estate investors of housing cooperatives

There can be different kinds of buyers for housing cooperatives, such as private residential real estate investment companies, a student housing foundation, or even the city. Buyers can invest their capital in a construction project, either for their own use, for making profit, or for servicing the needs of the community. Real estate investors can focus on investing in different building types, such as offices or apartment buildings (Kiiras & Tammilehto 2014, 25). This thesis focuses on real estate investors that invest in housing cooperatives of apartment buildings.

It is clear that real estate investors want to make a profit from their investments; to do this, they can either construct apartment buildings themselves or buy ready cashflow. Real estate investors can lower their investment risks when they take part only in the later stage of the construction project (Kiiras & Tammilehto 2014, 25). This thesis examines the situation where real estate investors buy ready cashflow.

In this thesis, private residential real estate investment companies and real estate private equity investors are defined as real estate investors. They invest in housing cooperatives and practice rental business in the apartment building sector. However, their businesses differ from each other: private residential real estate investment companies practice long-term rental business, whereas real estate private equity practice short-term rental business.

6.2.1 Private residential real estate investment companies

Private residential real estate investment companies are those that invest in housing cooperatives and practice long-term rental business. They can either construct apartment buildings by themselves or buy ready cashflow. Private residential real estate investment companies can also sell their housing cooperatives (Interviewee 4 & 5). At this moment, most of the Private residential real estate investment companies apartment buildings are connected to the DH network. Heating costs are a large portion in maintenance costs for a private residential real estate investment company. As mentioned by two interviewees, investments that lowers the maintenance fee for housing cooperatives are worth considering (Interviewee 4 & 5)

Interviewee 4 noted that tenants' environmental awareness has grown significantly in the past few years. According to Interviewee 4, tenants are more interested in the environment. However, both Interviewees 2 and 5 mentioned that environmental aspects are not most important thing to tenants. Interviewee 5 mentioned that environmental aspects seem to be more important to apartment buyers than tenants.

Some studies have shown that energy efficient residential buildings tend to be positive associations to the rental price (Brounen & Kok, 2011, 177; Fuerst & Mcallister 2011, 65, 66). However, Feige et al. (2013, 331) noted that "it is also important to acknowledge that the price effect of various sustainability attributes are likely to be dynamic and variable between assets and markets".

6.2.2 Real estate private equity

A real estate private equity fund or a closed-end fund is a fund where the amount of collected capital and the number of investors is limited. The investor's withdrawal of the fund is also limited (Hallituksen esitys 94/2013).

A real estate private equity is the preferred indirect real estate investing method by institutional investors, and this investing method is becoming more common in Finland. Typically, real estate funds of limited partnership are closed after the aimed capital has been collected from investors, and it is not possible afterwards to make any more investments (Hallituksen esitys 94/2013).

Real estate private equity investors earn their profit by convincing capital holders to give them capital and by charging agreed amount on these pools. They also earn a profit from generating returns on their investments (Wall Street Prep n.d.). The operational time of real estate private equity is usually specified in advance; typically, their operational time is around 10 years (Hallituksen esitys 94/2013).

GSHP could lower maintenance costs of real estate private equities. However, because real estate private equities have a short operational time, the GSHP system should pay itself back before the exit phase so that it could be an attractive heating system for real estate private equities. Another option is that the GSHP system could increase the real estate private equity's value, and there would be the possibility to earn more profit in the exit phase. Interviewee 2 mentioned that heating costs are a significant cost for real estate private equities.

Most of the investors are Finnish pension insurance companies (Hallituksen esitys 94/2013). According to Interviewee 2, their environmental awareness has increased recently. In addition, a number of international investors have grown significantly (Kiiras & Tammilehto 2014, 26). This point was also noted by Interviewee 2, who mentioned that international investors are one investor group for real estate private equities.

7. INVESTMENT ANALYSIS

7.1 Background information on the Marinranta case project

Marinranta is a new housing area in Espoo Kivenlahti, and there are plans for this area to have 11 housing cooperatives (see Figure 13). Two housing cooperatives were in the constructing phase at the time while this thesis was written. Construction started in 2019, and the whole area project should be ready in 2025.



Figure 13. Marinranta housing area.

Apollo has 52 apartments, and its heated net floor area is 3303 square meters. The housing cooperative has a similar number of apartments and a similar heated net floor area as most of the other housing cooperatives. The information for other housing cooperatives are presented in Table 4. Heated net floor areas were only calculated for Apollo and Neptunus when this thesis was written.

Table 4. Living area and number of apartments for the housing cooperatives in the Marinranta housing area

Housing cooperatives	Living area (htm ²)	Number of apartments
Neptunus	3829	68
Apollo	2376	52
Selene	1905	38
Helios	2274	46
Kronos	2426	49
Poseidon	2435	49
Vesta	2401	48
Ceres	2189	44
Euros	2033	41
Notos	1615	32
Athene	1811	36

7.2 Ground source heat pump systems in the housing area

According to the first interview round, there are two possible ways to make investments in GSHP systems in the housing area, namely either a distributed GSHP system or a centralised GSHP system. A centralised system needs 1 to 3 industrial scale heat pumps which generate heat to the whole housing area. Industrial scale heat pumps are mainly used in larger buildings such as shopping centres; these heat pumps are usually custom designed and made for the project. The disadvantages are that the GSHPs are more expensive, and there is a long delivery time for the heat pumps. It was stated that third parties could make more profit from investing in a centralised GSHP system in new housing areas (First interview round)

In a distributed GSHP system, every apartment building has its own heat pump unit. The benefits of a distributed system are that the investment costs are incurred during the construction phase, and there is no need to made drillings for the entire area at the beginning of the project (First interview round)

This thesis focuses only on the distributed GSHP system. It is hard to estimate the real costs for the industrial scale heat pump system; there might also be some regulations, which could lead to unexpected challenges. A centralised GSHP system is not explored

here because so few GSHPs have been installed in new apartment buildings. The distributed system is only presented here given that this would be more technically possible to realize. It is not sure whether there would be other restrictions and what restrictions a centralised GSHP system has.

7.3 Details of the prestudy

The prestudy calculations were made by the GH consultant for the housing cooperative Espoo's Apollo (also called Apollo). GH consultant made prestudy was used in this thesis to get GSHP system's investment costs. Cashflow calculations were also presented in prestudy. Cashflow calculations are presented in this study to clarify how much housing cooperative could lower operating costs with GSHP system. These calculations presented the energy savings for the housing cooperative and the costs of the GSHP system.

The prestudy calculations that were made in this thesis are directional and can differ from the costs of the actual GSHP system. The GSHP system was not implemented in Apollo in the end; this study only used Apollo as a model example for building the system and for making the calculations. The cost of the GSHP system includes tax price, which is 24%.

The purpose of the prestudy is to provide the property owner with some basic knowledge on what ground heat is. The calculations of the report only provide directional results. The distance of the energy wells from one another and their location can affect how much energy could be obtained from the wells. To know the locations of the energy wells more precisely, calculations should be made using a modelling program, such as the Earth Energy Designer (EED) program (see Appendix A).

In the first interview round, it was decided that prestudy would be conducted on the Apollo housing cooperative. Apollo was chosen for these calculations because it already has a building permit and therefore there was possible to obtain more information from Apollo than from the other housing cooperatives. Also, Apollo's energy certificate has already been issued. The energy certificate indicates Apollo's net heated area and its DH purchase energy (kWh/a). The prestudy uses a value that is slightly higher than the value of the DH purchase energy on the certificate. The certificate's DH purchase energy is only a theoretical approximation of what the apartment building needs in terms of heat energy consumption. Therefore, the GH consultant used a value that is slightly above the estimated value on the energy certificate.

It was also agreed that the GSHP would be designed so that the GSHP would produce 70% of apartment building's peak heat energy in the coldest day of the year. The rest of the heat would be produced with electrical resistance. An approximate value was given for the coldest day of the years.

After the GH consultant received the information on Apollo's heated net floor area and its DH purchase energy, the consultant and the heat pump manufacturer decided how large the heat pump needs to be for Apollo. It was decided that Nibe's 2 x F1345 40kW heat pumps would be a good choice.

When the calculations were ready, they were sent to the researcher. The GH consultant made sure that are the costs and borrowed capital's interest rate for the DH system were correct. The figures given were accurate enough for the purpose of this thesis.

Rough calculations were possible with the information given. The prestudy mainly presents the results of the calculations and not how these calculations were made. Therefore, these calculations needs to looked at critically.

7.4 Cost of a ground source heat pump system for Apollo

According to Rototec's prestudy, the investment costs for a GSHP system are €138,000, including a tax cost of 24%. When a GSHP system is installed in an apartment building, there is no need to connect the building to the DH network. When the costs for the heating system of ground heated apartment building are compared to those of a DH building, the equipment and connection fees of DH should not be taken into account for the investment calculations. Otherwise, the costs for a DH system would be calculated twice for the investment calculations. Therefore, prestudy's calculation do not include the costs for DH's equipment and connection.

In the prestudy, the update of the electricity connection was also calculated, and the cost is €6290. Because the calculation of the investment involves comparing the investment cost of a GSHP system to the costs of a DH system, these calculations assume that the electricity connection should be higher in a GH apartment building. Therefore, the total costs for a GSHP system are the total costs of the entire investment made for the apartment building:

GSHP systems total costs for housing cooperative = €138,000 – €32,360 + €6290 = €111,930 (see Table 5)

Table 5. Investment costs for a GSHP system (Appendix A, 13)

Investment time	20 years
Investment costs of a GSHP system	€138,000
Costs of a DH system	–€32360
Water cooler	0
Updating the electricity connection	6290
Total costs of the GSHP system for the housing cooperative	€111,930
Updating the GSHP system in 15 years	€22,000

The GSHP and the energy wells are two-thirds of the system's total investment costs. In addition, the GSHP system needs to be updated after 15 years, and this cost was estimated to be €22,000. (Table 6.)

Table 6. Share of the costs for the GSHP and the technical life of the systems (see Appendix A, 13)

	Share of the costs for a GSHP system	Technical life of the systems (years)
GSHP	33%	15
Automation	11%	15
Internal pipes and installation	11%	30
Energy wells	31%	100
Energy tubes and installation	13%	40
Total	100%	25

Energy wells are practically long lasting. The costs for the GSHP system include automation costs and the internal pipes as well as installation costs. Automation, internal pipes, and installation is also required for DH apartment buildings.

7.5 Cost comparison

The total costs of the GSHP system was estimated to be €111,930. In these calculations, it was assumed that the GSHP system investment was paid with borrowed capital. The loan period was 15 years, and the interest rate was assumed to be 2% (see Table 7).

According to the data from the Official Statistics of Finland, the cost for DH will increase approximately every year by 4.4%, and the cost for GH will increase approximately 3.0% every year (see Appendix A, 17). These figures were used for the prestudy.

When these calculations were made, the cost for DH was €87.11/MWh in Espoo. The average cost for DH in Finland during this time was around €75/MWh; the cost for GH was €39.74/MWh. Apollo's heat energy consumption was calculated to be 245.08 MWh/year (see Table 7).

Table 7. Values for costs, time period, interest rates, and energy consumption (Appendix A, 16)

GSHP systems' total costs	€111,930
Loan period	15 years
Borrowed capital's interest rate	2 %
DH costs in Espoo (Fortum)	€87.11/MWh
Ground heat's cost	€39.74/MWh
Heat energy consumption in Apollo	245.08 MWh/year
Geo-energy's interest	3%
DH's interest	4.4%

The cashflow calculations for the GSHP system that is created based on the information from Apollo. The GSHP investment is compared to DH investment; the time cap is set to be 10 years. (Table 8)

The borrowed capital is subtracted every year with amortisation. The surplus is the energy savings that are left for the housing cooperative after the interest expenses and amortisation. After the 15 year loan period, the housing cooperative will have finished paying off the loan for the GSHP system, and the housing cooperative will receive higher savings from the GSHP system.

Table 8. Cashflow calculations (Appendix A, 17)

Year	1	2	3	4	5	6	7	8	9	10
Bor- rowed capitol (€)	111,9 30	105,4 34	98,81 2	92,06 0	85,1 77	78,15 9	71,00 5	63,71 1	56,27 5	48,69 4
Interest (%)	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Cost of DH	21,34 9	23,40 0	24,18 9	24,97 9	25,7 68	26,55 8	27,34 7	28,13 6	28,92 6	29,71 5
Cost of GH	9,740	11,15 3	11,40 4	11,65 4	11,9 05	12,15 5	12,40 5	12,65 6	12,90 6	13,15 7
Energy savings	11,60 9	12,24 7	12,78 5	13,32 5	13,8 63	14,40 3	14,94 2	15,48 0	16,02 0	16,55 8
Interest ex- penses	2,183	2,056	1,927	1,795	1,66 1	1,524	1,385	1,242	1,097	950
Cash- flow	9,426	10,19 1	10,85 8	11,53 0	12,2 02	12,87 9	13,55 7	14,23 8	14,92 3	15,60 8
Amorti- sation	6,496	6,622	6,752	6,883	7,01 8	7,154	7,294	7,436	7,581	7,729
Surplus	2,930	3,569	4,106	4,647	5,18 4	5,725	6,263	6,802	7,342	7,879

The energy savings are almost half compared to the DH costs. For the first year, the energy savings for the GSHP system will be small, but over time the system will start to pay itself back more quickly, and the housing cooperative will have more savings from the GSHP system. The energy cost calculations from the prestudy, and the costs are projected for the next 20 years. The table shows that the price for DH is expected to greatly increase in 20 years. In Apollo, the price for DH is expected to increase to €16,261. Ground heat's expected energy cost increase is only €5,921. (Table 9.)

Table 9. Energy cost calculations (Appendix A, 16)

	Year 1	Year 5	Year 10	Year 15	Year 20
DH's energy costs	21349	25768	29715	33663	37610
GH's energy costs	9740	11905	13157	14409	15661
Saved energy costs	11609	13863	16558	19254	21949

8. DISCUSSION

8.1 Present and future states of the ground source heat pump market

As mentioned, there are only a few apartment buildings in Finland that have installed a GSHP system during the construction phase. The GSHP system as a building's heating system has recently become an important topic, but there are many factors that hinder the wider use of these systems in the new apartment building sector. It is still expected that GSHP systems would become a more common heating system in the new apartment building sector in Finland. GSHP systems have become a topical issue due to the tightened environmental policies by both Finland and the EU. In addition, the environmental awareness in customers has increased. While it is difficult to say what the future for GSHP systems would be, interviewees believed that the use for GSHP systems would increase in the future, as this system was described as a good heating option both in the economical and technical sense for new apartment buildings.

Finland's goal is to cut out the use of coal in the year 2030. At this point, Finland's carbon neutrality is concentrated on increasing biomass use in energy generation. However, this means that there would be the increase of loggings, and loggings would decrease Finland's carbon sinks. Therefore, there is a need to find other heating options and energy sources.

The price for DH has increased in the past 20 years, and it is expected to increase. Energy companies need to invest billions of dollars for the renewable energy, which would likely increase the price for DH in the future. Heating costs are a significant cost to the real estate investors and housing cooperatives. This has made GSHP systems even more profitable to the real estate investors and housing cooperatives. In the past, construction companies have not shown much interest in the heating system of apartment buildings. Generally speaking, what is perhaps the most important area for construction companies is that the heating system works. The DH system is a reliable system, and the cost increase in the price for DH does not affect construction companies. If there is no financial benefit for the construction companies from the GSHP system, it is hard to believe that the GSHP system could become more common as a heating system for housing cooperatives. It is not likely that tenants or private apartment buyers would be willing to pay more for the GSHP systems. At this moment, they appear to be more interested apartments location and price than eco-friendliness.

International investors who invest in real estate private equities are more interested in investing in eco-friendly buildings. If they start to demand eco-friendly buildings, it is possible that GSHP systems could become attractive heating systems for the real estate private equity investors. However, the payback time of the GSHP system is still a challenging point for real estate private equity investors because they need to have their investment paid back before the real estate private equity is sold to another investor, which can be in five to seven years.

There is a need for a new business model that could increase the use of GSHP systems. Construction companies, real estate investors, ESCOs, energy companies, and DH companies have not yet found a proper business model that could cause distributed energy generation to become more attractive or could increase the use of GSHP systems in new apartment buildings. Construction companies and real estate investors are the ones who decide on the heating systems for the new apartment buildings, and so far they have not considered GSHP systems to be a viable option.

8.2 Implementing the third-party business model

For renewable distributed energy generation, the most common business model in Finland and in other countries is the third-party business model. ESCOs in Finland have used the third-party business model in the apartment building sector. Third parties can either lease the GSHP system or invest in the GSHP system themselves; they can own the GSHP system and then sell the heat to the end consumer. The investments of third parties in GSHP systems are rather low in new apartment building sector, as third parties do not consider the new apartment building sector to be a viable option because it can be difficult for them to earn enough profit from new apartment buildings (see Table 8). At this moment, older apartment buildings seem to be a more interesting investment for GSHP systems than in new apartment buildings, as older apartments have a large heat consumption. The price of DH also affects the profitability of the third party. The higher the price of DH, the more profitable the GSHP system is to the third party.

Generally speaking, there is no restriction on who could be the third party. Besides ESCO, the third party could be a construction company, an energy company, or even a DH company. As Richter (2013, 1235-1236) pointed out, third parties can be a threat for the energy companies, as the third parties may be able to offer energy that is cheaper and more environmentally friendly for the consumers. Therefore, third parties can have a competitive advantage over the Finnish DH companies if the third parties can offer cheaper heat than the DH companies for the housing cooperatives. Energy companies

and DH companies in Finland should follow how the markets for GSHP system will develop. However, it is likely that large energy companies and DH companies can make it challenging for third party businesses to be profitable.

Before third parties can enter into the market for new apartment buildings, they have to convince construction companies and real estate investors as these are the ones who choose the heating system in the apartment buildings. In other words, third parties cannot install GSHP systems in apartment buildings during the construction phase if the construction company or real estate investor does not place any orders for the system. From a construction company's perspective, third parties leasing or owning the GSHP system is an attractive point when the construction company does not have to pay for the DH's equipment and connection fee. The most important thing for the construction company is that the heating system in the apartment buildings is functional. Therefore, having a third party who operates the GSHP system can be an attractive option from the viewpoint of the construction companies.

8.3 Benefits for construction companies

The construction company can benefit from the GSHP system if the GSHP system increases the value of the apartment buildings. However, the interviewees mentioned that at this moment, private apartment buyers are not willing to pay more for the GSHP systems. Therefore, it is expected that construction companies will not receive more value from the apartment buildings that are heated with the GSHP system. However, it is not clear whether there are regional differences. Apartments prices are most expensive in the Helsinki metropolitan area than in other parts of Finland. Therefore, it is possible that private apartment buyers could not afford to pay extra for the GSHP system in the Helsinki metropolitan area, but in other parts of Finland they might be able to afford the GSHP system.

Some new housing cooperatives have decided to change their heating system from a DH system to a GSHP system. Because the construction company decides the heating system of housing cooperatives, some construction companies have made unnecessary investments in DH equipment and connection that did not serve the needs of the housing cooperative. Therefore, it is important that construction companies understand the needs of the customers so that they could avoid making unnecessary investments in the future.

Construction companies can benefit from the GSHP system if the company leases or finances the GSHP system for the housing cooperative or real estate investor. However, as Suhonen and Okkonen (2013, 787) mentioned, the ESCO business model can be

challenging in the residential sector. The investments for the GSHP system are high, and from the view of the construction companies, the revenue may be too low for them. On the other hand, construction companies could easily develop third party businesses in the apartment buildings that are contracted by construction companies because construction companies decide on the heating system in the buildings during the development stage of the property.

The following sub-sections present how the GSHP system can be an attractive point for the housing cooperatives, private residential real estate investment companies, and real estate private equity investors. This provides some insight into whether a third-party owned GSHP system would be a better option for the housing cooperatives, private residential real estate investment companies, and real estate private equity investors than their own invested and operated GSHP system.

8.3.1 Housing cooperative

The energy savings that Apollo can gain with a GSHP system amounted to under €3,000 in the first year (see Table 8). The savings become bigger every year when the amount of the bank loan decreases and as the price of DH increases. However, the savings are not much for the apartment buyers in the first year, and because the profit is not large, it is hard to expect that private apartment buyers would be interested to pay a lot for a GSHP system. If the GSHP system includes a cooling system, apartment buyers may be more willing to make the purchase. This profitability of the cooling system was not studied in this thesis.

At this moment, private apartment buyers are not ready to pay more for apartments that are heated with GSHP. Private apartment buyers have increased their environmental awareness over the years, but it is not certain how well they know about the benefits of GSHP systems.

8.3.2 Private residential real estate investment company

Heating costs are considered as significant costs to private residential real estate investment companies. The payback time for GSHP investments is not as crucial to private residential real estate investment companies than it is for real estate private equity investors. GSHP investment was not seen as a problem for private residential real estate investment companies in their view.

Private residential real estate investment companies and their tenants have become more environmentally conscious over time, but tenants are not ready to pay more rent

for eco-friendlier apartments. Such apartments can increase the corporate image of private residential real estate investment companies when GSHP systems are properly marketed to customers of private residential real estate investment companies.

Third parties are seen as an interesting option from the viewpoint of private residential real estate investment companies because these third parties are responsible for the design, construction, and GSHP system operation and maintenance. However, third parties also share the benefits of the system. Private residential real estate investment companies can invest in the GSHP system themselves, so it was seen as unnecessary to have a third party make the investment for them. Third parties do not have a business model yet that is seen to attract private residential real estate investment companies.

8.3.3 Real estate private equity

Heating costs are significant costs also for real estate private equities. However, real estate private equity investors need to have their investments paid back before the exit phase when the real estate private equity is sold or the system would need to increase the value of the real estate private equity so that it could pay itself back in the exit phase. The lifetime of an real estate private equity is approximately 10 years.

Finnish pension insurance companies and international investors are investing in real estate private equities. If real estate private equity investors demand more eco-friendlier buildings, GSHP system can be interesting choice for real estate private equities. However, GSHP system is not the only option for reducing apartment building emissions. At this moment, third parties do not have a business model that is seen as viable to real estate private equities. Real estate private equity investors can also invest in the GSHP systems themselves.

8.4 Reliability of the research

The subject of the thesis was new for the researcher and therefore it takes time to become familiarise with the subject; moreover, peer-reviewed literature was preferred as much as possible for the research, but this was not always possible. There was much available literature on GSHP systems, distributed energy generation, and different business models. However, there was lack of literature on real estate investors being attracted to invest in GSHP systems. No master's theses or scientific articles were found that investigated the customer typology of construction companies in GSHP markets. There was also a lack of literature on the businesses of real estate private equities and private residential real estate investment companies. Because there was a lack of studies available, there might be some gaps that can lower the reliability of the research done for customer typology.

The findings from the interviews represent the personal opinions of the interviewed experts and do not necessarily represent others who work in the same field. The interviews provided a broad view of the GSHP markets in Finland. Interviewees also had an excellent knowledge of the GSHP systems.

The investment calculation done in the empirical part was made by the GH consultant. The consultant is experienced and has performed the same calculations to other apartment buildings. Therefore, the calculations done for the investment costs and energy saving of a GSHP system can be seen as quite accurate. The only option to obtain the cost of a GSHP system is to ask tenders from heat pump manufacturers, GSHP contractors, and designers, and this was also done in this thesis.

However, reviewing the calculations by the GH consultant was difficult because there was no information on how these calculations were made. If there were more time, review calculations should be made, and these should be compared with the results of the calculations by the GH consultant. However, it was seen that the costs of the GSHP system were more important than the investment calculations.

8.5 Future research

Because international investors are more interested in environmentally friendly apartment buildings, there is a need to find the most cost-effective ways to reduce CO₂ emissions for apartment buildings. A GSHP system is a viable option for reducing lifecycle emissions of buildings, but the most cost-effective ways are not known yet. Future research can focus on finding the most cost-effective ways for reducing lifecycle emissions of buildings.

Another future research could be to study how a centralised GSHP system would work in a housing area and whether there are any legal aspects that restricted the use of apartment buildings in a shared GSHP system. There could also be more research on the customer typology of the construction companies in GSHP markets.

9. CONCLUSION

9.1 Research summary

This aim of the thesis was to suggest a business model for construction companies and to find out what would made GSHP systems an attractive investment for construction companies. The study presented a literature review and information about GSHP systems and the energy market as well as business models for renewable energy generation. Interviews were conducted with experts in the areas of GSHP or in real estate. The interview content provided an insight into the customer typology of the market for GSHP systems. Calculations were made to find out the costs for investing in a GSHP system and the costs for the GSHP system's operation costs, and the study also compared costs between the GSHP system and DH system. The findings answer the four research questions in this thesis:

RQ1: How is ground heat currently used in the energy generation of new apartment buildings?

It was found that only a few GSHP systems have been installed in apartment buildings during the construction phase. GSHP systems are mainly installed by housing cooperatives in apartment buildings operational phase. Housing cooperatives have noticed that GSHP system's operational costs are cheaper than district heat's price, and GSHP system's payback time is relatively short.

Third parties have managed to sell their offered services to some housing cooperatives, but they have been difficulties to sell their service to the construction companies, private residential real estate companies and real estate private equities. Third parties invested GSHP systems are still rare in new apartment building sector.

RQ2: What are the future expectations for GSHP systems?

The use of GSHP systems is expected to increase in the future, but there are many challenges that hinder a wider application of GSHP systems. The major reason why so few GSHP systems have been installed is that construction companies have not seen the business benefits for GSHP systems. If real estate investors start to demand GSHP systems to their invested housing cooperatives, GSHP system installations will increase in new apartment building sector.

Third parties need to develop their offered business model so their offered business model would be more attractive for the construction companies, private residential real

estate companies and real estate private equities. On the other hand, GSHP system's is challenging business for the ESCOs in new apartment building sector. They have difficulties to find profitable business model, which would attract construction companies, private residential real estate companies and real estate private equities. There is possible that third-party business model is not become popular if ESCOs, construction companies, private residential real estate companies and real estate private equities have difficulties to find profitable business model to install and invest GSHP systems to the new apartment buildings.

RQ3: What business models have energy companies used in Finland and in other countries when the energy comes from renewable distributed energy generation?

The third-party business model is the most common business model for the renewable distributed energy generated heat. However, in the new apartment building sector, ESCOs have not succeeded in entering this market. Construction companies and real estate investors have not considered this business model to be attractive. Moreover, real estate investors can invest in the system by themselves, and they do not want to share the energy savings from the GSHP system with third parties. Construction companies view the third-party business model as a viable model if it is cheaper than the equipment and connection fee of the DH system. However, they are not interested in the energy savings of housing cooperatives.

RQ4: How can construction companies benefit from the identified business models in their own business?

Construction companies could benefit from the GSHP system if the GSHP system bring more value to the apartment building. Construction companies could also be the heat producer for the housing cooperative. However, it was found that at this moment the GSHP system does not bring more value to the apartment building and that the third-party business model is a challenging business in the new apartment building sector.

9.2 Recommendations

The study found that there is a need for a design and building concept that construction companies can use for GSHP systems in new apartment buildings. Having such a concept prepared can lowers the risk that real estate investors have, as real estate investors would have more confidence in the investment when the GSHP system design and construction is properly done.

There are not many GSHP system designers and contractors in Finland, and so real estate investors may have difficulties finding key partners to contract GSHP systems. The GSHP systems for apartment buildings consist of different components and are more complex than the GSHP systems for small attached houses. Therefore, construction companies that have experience and knowledge in the construction of GSHP systems could be seen as a good partner in construction projects when real estate investors want to invest in ground heated apartment buildings.

The major drivers for a wider application of GSHP systems are the environmental policies set by the EU and by Finland as well as the increase of environmental awareness in customers. There are still major challenges for GSHP systems. The GSHP system is an interesting choice for lowering the lifecycle CO₂ emissions of new apartment buildings. Still, there might be some less expensive options that were not studied in this thesis. It is possible that in the future, apartment buildings need to pass underneath for certain amount of CO₂ emissions. Construction companies should study, which are economically best options to lower apartment buildings CO₂ emissions. This can bring competitive advantage for the construction company, who develop cost-effective way to reduce apartment buildings lifecycle CO₂ emissions.

It is possible to calculate CO₂ emissions with carbon footprint software such as OneClick. The GSHP system is only one of the systems that increase an apartment building's eco-friendliness. When the lifecycle emissions of apartment buildings are calculated, it is easier to compare different options to find the most cost-effective ways for reducing CO₂ emissions. When buildings consume less energy, they produce less CO₂ emissions.

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11.APPENDIX A: PRESTUDY



Esiselvitys geoenergian hyödyntämisestä

As Oy Espoon Apollo

Marinportti 3, 20360 espoo

Niko Pihlanen
9.8.2019

Esiselvitys on tehty osaksi Eetu Virtasen Diplomityötä

Selvityksessä käytetyt arvot ovat alustavia eikä niitä tule soveltaa mitoituksen lähtötietona

Kuva: YIT asunnot

Sisällysluettelo

1. Johdanto ja tulokset
2. Tietoa geoenergiasta
3. Geoenergiapotentiaali
4. Investointi ja tuotto
5. Ilmastovaikutus
6. Liitteet
 - Liite 1: Lähtötiedot ja oletukset
 - Liite 2: Kohdealueen lämmitystarveluvut
 - Liite 3: Energialaskelma
 - Liite 4: Geoenergiakentän suunnitelma
 - Liite 5: Investointilaskelma
 - Liite 6: Tuottolaskelma
 - Liite 7: Kassavirtalaskelma
 - Liite 8: Investoinnin vaikutus rahoitus- ja hoitovastikkeeseen
 - Liite 9: Investoinnin vaikutus kiinteistön arvoon
 - Liite 10: Investoinnin vaikutus vuokratuottoon
 - Liite 11: Geoenergiajärjestelmän tilantarve

Johdanto

Esiselvityksen tarkoitus on antaa kiinteistön omistajalle perustietoa geoenergiasta ja sen hyödyntämisestä. Kiinteistölle luonnostellaan energiakenttä, lasketaan energiamääriä ja hankkeen rahoitusta.

Tulokset

Kiinteistön geoenergiapotentiaali	Erinomainen	98 kWh/porattu m/vuosi
Välitön vaikutus energiakustannuksiin	Hyvä	-11 000 EUR/vuosi
Vaikutus vuokratuottoon (20 v)	Hyvä	+336 000 EUR
Vaikutus velattomaan hintaan	Kohtalainen	+113 000 EUR
Investoinnin tuotto (20 v) ¹	Erinomainen	197 000 EUR
Keskimääräinen pääoman tuotto (10 v)	Erinomainen	12,6 %

Esimerkkinä 32 neliön tila

Yhteenlaskettu hoito- ja rahoitusvastike muuttuu -2 EUR/kk.

Tilan arvo nousee noin 2 000 EUR.

Tilan osuus geoenergiajärjestelmän lainasta on noin 1 000 EUR.

Selvityksen kaikki hinnat ALV 24 %.

1) Investoinnin tuotto lainan lyhennyksen ja korkojen jälkeen

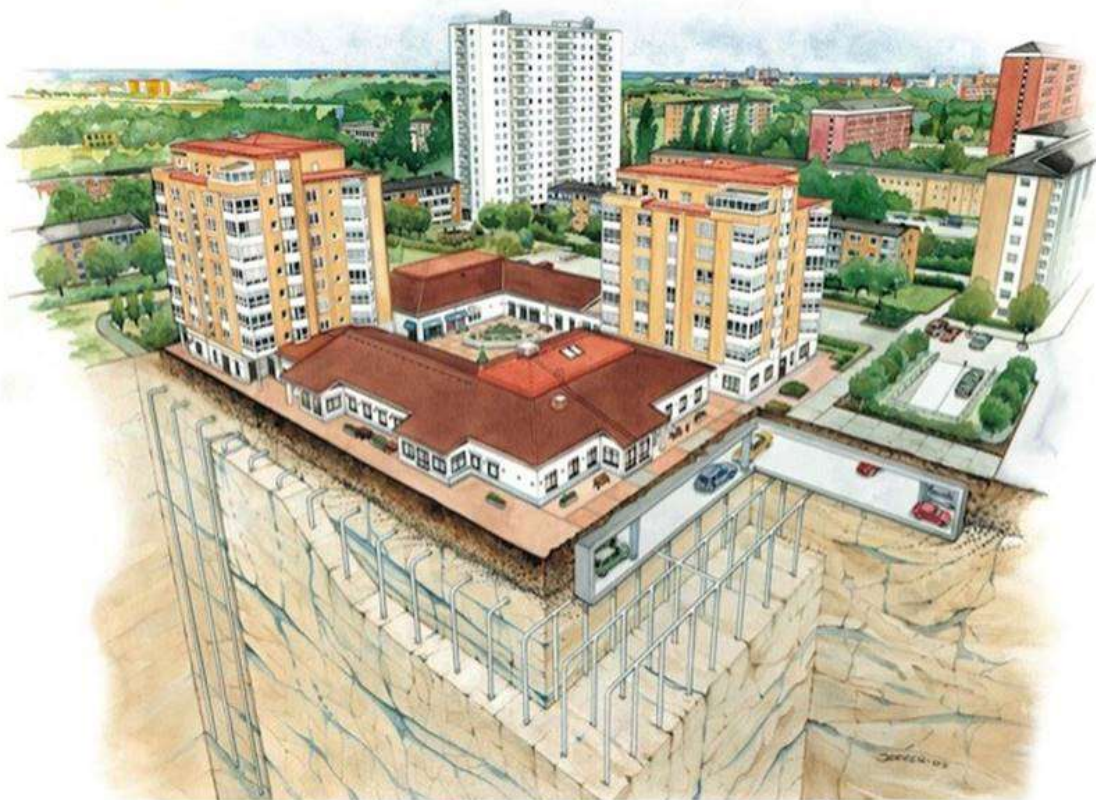
TIETOA GEOENERGIASTA

Geoenergialla tarkoitetaan kallioperään varastoitunutta auringon säteilyenergiaa ja maankuoren sisältä johtuvaa geotermistä lämpöenergiaa. Se on varastoitunut maahan, kallioon tai vesistöön. Lämpöpumpputekniikan hyödyntäminen lämmitysenergian tuotannossa on alkanut kasvaa tasaisesti 2000-luvun alusta lähtien energian hintojen nousun seurauksena.

Omakotitalojen ohella isoja kiinteistöjä kuten ostoskeskuksia, suurkiinteistöjä, kauppakeskuksia sekä teollisuuslaitoksia toteutetaan ja saneerataan geoenergialla. Lämmitys- ja jäähdytysenergian tuottaminen energiakaivokentällä on kustannustehokasta ja lämmitysjärjestelmään on yksinkertaista kytkeä lisäosia kuten lämmöntalteenotto. Hybridijärjestelmät ovat tulossa markkinoille ja niissä sovelletaan uusiutuvien energiamuotojen yhdistämistä.

Geoenergia kuuluu uusiutuviin energian lähteisiin. EU:n ilmastopolitiikan mukaan Suomen maakohtainen tavoite vuoteen 2020 mennessä on nostaa uusiutuvien energian lähteiden osuus 39 prosenttiin. Hajautetulla ja lähellä tuotetulla geoenergialla on siis kansantaloudellisesti sekä ympäristöpoliittisesti merkittävä vaikutus. Euroopan Unionin energiapolitiikan kolme päätavoitetta, missä Suomi on mukana, ovat: energiavarmuudesta huolehtiminen, kestävä kehitys, sekä kilpailukyvyn ylläpitäminen.

Rototec on toimittanut energiakaivoporauksen satoihin asunto-osaakeyhtiöihin. Energiakaivoja on porattu Rototecin toiminta-aikana yhteensä yli 35 000 tuhatta.

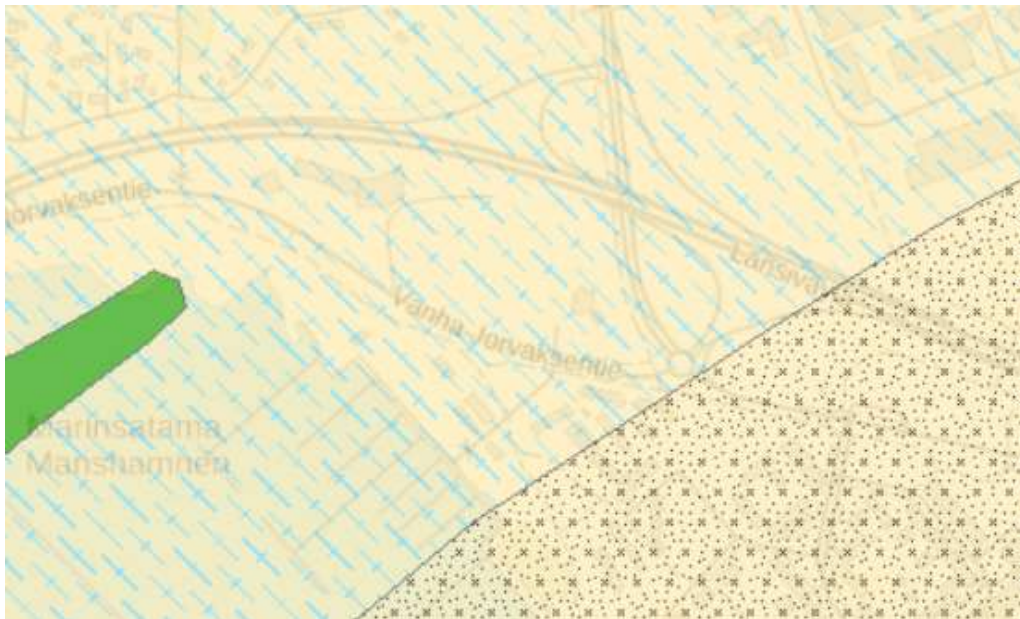


Geoenergiakentän havainnekuva

GEOENERGIAPOTENTIAALI

Kiinteistön geoenergiapotentiaalin määrittävät kallioperän lämpötila, kallion laatu ja maapeitteen paksuus.¹ Energiakaivon aktiivisyvyyden vaikuttaa lisäksi pohjaveden korkeus kaivossa.

Energiakaivon arvioitu keskilämpötila ²	7,9 °C
Kallion laatu ⁴	Kvartsi- maasälpägneissi
Maapeitteen paksuus ³	5 m (± 4 m)
Pohjaveden korkeus ³	5 m (± 3 m)
Energiakaivon arvioitu tuotto ⁵	100 kWh/m/v



Kohteen kallioperän kivilajit, DigiKp200-aineisto Geologian tutkimuskeskus (4)

Kyseisellä alueella vallitsevien kivilajien lämmönjohtavuus on erittäin hyvä/kiitettävä (2). Tämä tarkoittaa raportissa esitetyn luokituksen mukaan että lämmönjohtavuus lambda (λ) on suurempi kuin 3 [W/(m·K)].

- 1) Maan povessa piilee loputtomasti energiaa – uusi kartta kertoo Suomen kuumimmat paikat http://yle.fi/uutiset/maan_povessa_piilee_loputtomasti_energiaa__uusi_kartta_kertoo_suomen_kuumimmat_paikat/8713434, <http://gtkdata.gtk.fi/maankamara/>
- 2) Keski-Suomen geoenergiapotentiaali, http://www.keskisuomi.fi/filebank/24387-Keski-Suomen_geoenergiapotentiaali_4162018_loppuraportti.pdf
- 3) Rototecin toteuttamat energiakaivot alueella, postinumeroalue 20360
- 4) Suomen kallioperä (DigiKP200, 1:200 000 kallioperäkartta), <http://ptrarc.gtk.fi/digikp200/default.html>
- 5) Arvio perustuu alueen keskimääräisiin tietoihin kaivon keskilämpötilasta, kivilajeista ja niiden ominaisuuksista, maan peitteen paksuudesta ja pohjaveden korkeudesta. Energian tuottoon vaikuttaa myös energiakentän muoto, kaivojen keskietäisyys toisistaan ja kaivon sisäinen energian siirtyminen. Arviossa huomiota jäähdytys.

INVESTOINTI JA TUOTTO

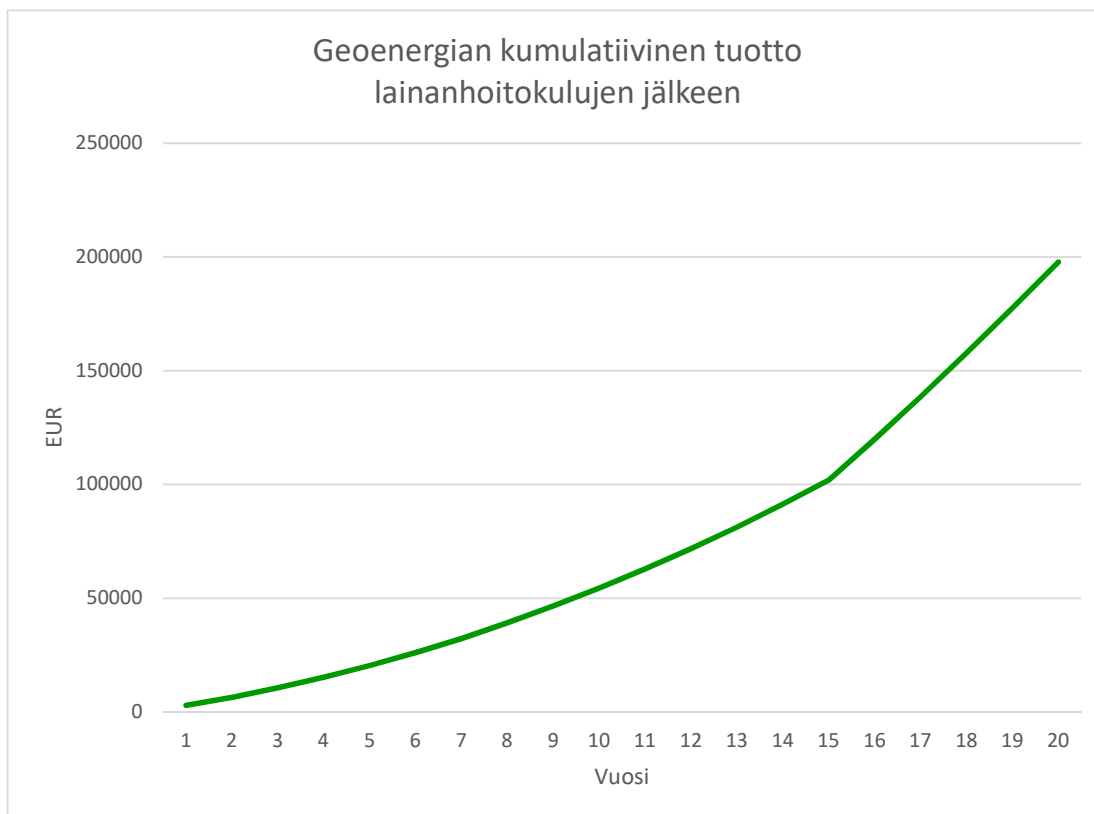
Lämmitysenergiantarve	245,08 MWh/v	(liite 3)
Jäähdytysenergiantarve	0,00 MWh/v	(liite 3)
Geoenergiajärjestelmän investointi	111 930 EUR	(liite 5)
Laina-aika	15 v	
Lainan korko	2,0 %	
Lainan lyhennys ja korot (kiinteä tasaerä)	8 678 EUR/v	

Kaukolämpö - Fortum Power and Heat Oy, Espoo	87 EUR/MWh	(liite 6)
Geoenergia	40 EUR/MWh	
Säästö lämmityskustannuksissa	47 EUR/MWh	

Jäähdytys vedenjäähdytyskoneella	0 EUR/MWh	
Jäähdytys geoenergialla	0 EUR/MWh	
Säästö jäähdytyskustannuksissa	0 EUR/MWh	

Säästö lämmityskustannuksissa (1. vuosi)	11 609 EUR/v	
Säästö jäähdytyskustannuksissa (1. vuosi)	0 EUR/v	
Lainan lyhennys ja korot (kiinteä tasaerä)	-8 678 EUR/v	
Tuotto lainakulujen jälkeen	2 931 EUR/v	

EUR	1. vuosi	5. vuosi	10. vuosi	15. vuosi	20. vuosi
Investoinnin kumulatiivinen tuotto	2 931	20 437	54 448	101 934	197 758



ILMASTOVAIKUTUS

Rakennusten lämmitykseen käytetään noin neljäsosa kaikesta Suomessa kulutetusta energiasta.¹ Noin puolet lämmityksestä tuotetaan kaukolämmöllä. Muita merkittäviä lämmöntuottotapoja ovat sähkö, lämpöpumput, puu ja polttoöljy. Fossiilisten polttoaineiden käyttö lisää hiilidioksidia- ja muita kasvihuonekaasupäästöjä.

Suomen lämmöntuotantomuotojen hiilidioksidipäästöt

Lämmöntuotantomuoto ²	Energia TWh/v	Hiilidioksidipäästö gCO ₂ /kWh	
Kaukolämpö	33	149	(2)
Sähkö	12	89	(3)
Lämpöpumput	11	36	(4)
Puu	9	0	(5)
Polttoöljy	6	261	(5)
Muut	1		

Koko maan keskiarvojen perusteella arvioitut hiilidioksidipäästöt kohteessa

Lämmöntuotantomuoto	Energia MWh/v	Hiilidioksidipäästö gCO ₂ /kWh	Hiilidioksidipäästö tCO ₂	
Polttoöljy	288	261	75	(6)
Kaukolämpö	245	149	37	
Sähkö	245	89	22	
Maalämpö	245	28	7	

Arvion perusteella maalämpö vähentää hiilidioksidipäästöjä 30 tonnia vuodessa.

Tämä vastaa samaa määrää hiilidioksia joka syntyy jos autolla ajettaisiin 5 kertaa maapallon ympäri. (7)

Huomioi että vertailu perustuu keskiarvoihin ja on vain suuntaa antava.

1) Tilastokeskus. Energian kokonaiskulutus.

http://pxhopea2.stat.fi/sahkoiset_julkaisut/energia2017/html/suom0000.htm

2) Energiavuosi 2017 - Kaukolämpö.

https://energia.fi/ajankohtaista_ja_materiaalipankki/materiaalipankki/energiavuosi_2017_-_kaukolampo.html

3) Energiavuosi 2017 - Sähkö.

https://energia.fi/ajankohtaista_ja_materiaalipankki/materiaalipankki/energiavuosi_2017_-_sahko.html

4) Arvio. Oletettu vuosihyötysuhde 2,5.

5) Yksittäisen kohteen CO₂-päästöjen laskentaohjeistus sekä käytettävät CO₂-päästökertoimet

https://www.motiva.fi/files/6817/CO2-laskenta_yksittainen_kohde.pdf

6) Oletettu hyötysuhde 85%.

7) Auton hiilidioksidipäästökseen oletettu 140 g-CO₂/km.

Liite 1: Lähtötiedot ja oletukset

LÄHTÖTIEDOT

Osoite	Marinportti 3
Postinumero	20360
Kunta	espoo
Kiinteistön huoneistoala	3 303 m ²
Kiinteistön lämmitettävä ala	3 413 m ²
Lämmitysenergian tarve	245 MWh
Käyttöveden osuus	31 %

OLETUKSET

Lämmityksen huipputehon tarve	121	kW	Käyttöveden huippu varaajalla
Jäähdytysenergian tarve	0	MWh	
Jäähdytyksen huipputehon tarve	0	kW	

Mitoituspaikkakunta	espoo
Lämmönjako	Oletus: ilmanvaihto 50/30 °C
Lämpöpumpun vuosihyötysuhde	3,6
Lämmönkeruunesteen lämpötilaero ¹	4 °C

Laina-aika	15 v
Lainan korko	2,0 %
Lyhennystapa	Kiinteä tasaerä
Lyhennyskausi	1 v

Vuokra	25,00	€/m ² /kk
Hoitovastike	3,50	€/m ² /kk
Myyntihinta	5 000	€/m ²
Remonttivaraus	0	€/m ²
Esimerkkiasunnon pinta-ala	32	m ²

Vertailtava energiamuoto	Kaukolämpö
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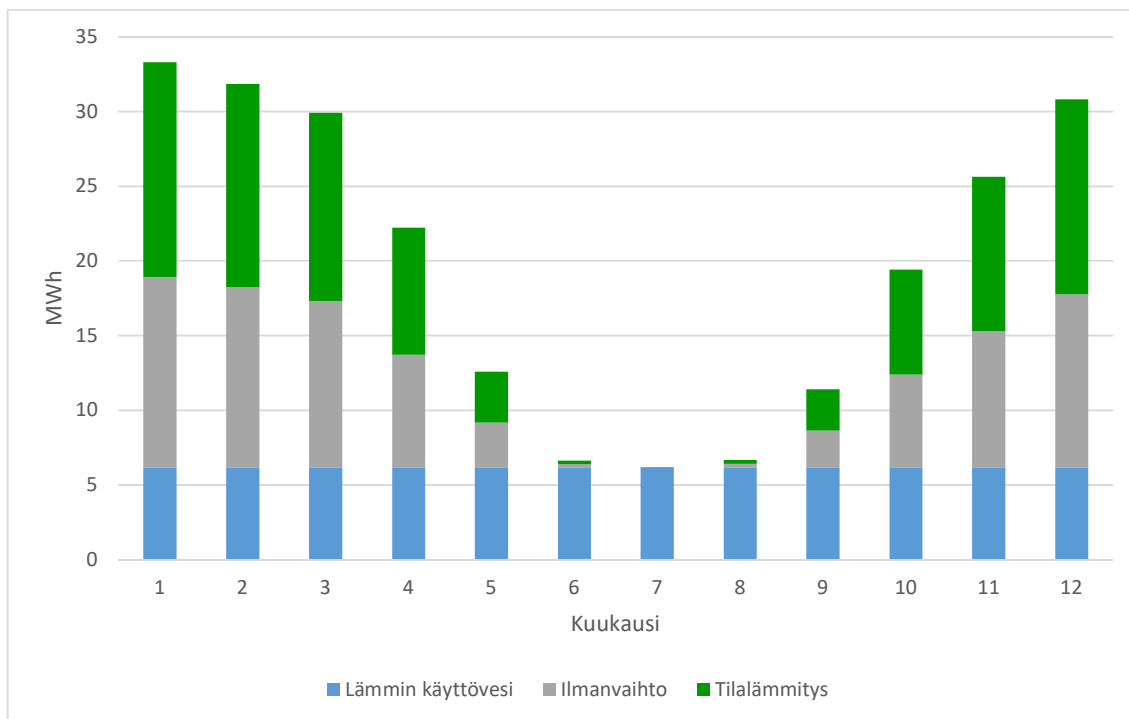
1) Lämmönkeruunesteen lämpötilamuutos maalämpöpumpun höyrystimessä mitoitusilanteessa

Liite 2: Kohdealueen lämmitystarveluvut

Lämmitystarve

Alue	Helsinki
Lämmitystarve	3 878 °Cvrk
Keskimääräinen lämmitystarve	3 878 °Cvrk
Energian normeerauskerroin (vuosi) ¹	1,00
Paikkakunta	espoo
Energian normeerauskerroin (kunta) ²	0,96
Energian normeerauskerroin yht.	0,96

Lämmitystarpeen jakautuminen



1) Uudisrakennuksissa kerroin on 1,00 eli normeerausta ei voi tehdä.

2) Paikkakuntakohtainen korjauskerroin verrattuna alueen lämmitystarpeeseen. Käytetään vain uudiskohteissa

Liite 3: Energialaskelma

Laskelma on lämpöpumppuvalmistajasta riippumaton, eikä ota kantaa laitteen ominaisuuksiin.

Laskennassa on käytetty Suomen Ympäristöministeriön ohjeistuksia lämpöpumpun mitoittamiseen.

NYKYINEN ENERGIANKULUTUS

Vuositainen energiankulutus		Lämmöntuotannon hyötysuhde	
Kaasu	0 m ³	93 %	MWh
Öljy	0 litraa	85 %	MWh
Sähkö/kaukolämpö	237 MWh	100 %	237 MWh
Pelletti	0 kg	80 %	MWh
Hake	0 irtokuutio	80 %	MWh
Energiantarve yhteensä (sisältää käyttöveden)			237 MWh
Käyttöveden osuus	31 %		
Käyttöveden osuus	74 MWh		
Tilojen lämmitys ja ilmastointi	69 %		
Normeerauskerroin	0,96		
Tilojen lämmitys ja ilmastointi	156 MWh		
Normeerattu energiantarve	230 MWh		
Mitoitus paikkakunta	espoo		
Mitoittava ulkolämpötila (DUT)	-26 °C		
Ulkolämpötilan mukainen huipputeho	73 kW		
Käyttöveden huipputeho	203 kW		
Valittu huipputehon tarve	121 kW	Käyttöveden huippu varaajalla	
Jäähdytyksen tarve ²	0 MWh		
Jäähdytyksen huipputeho ²	0 kW		

LÄMPÖPUMPUN MITOITUS¹

Maalämpöpumpun tehonpeitto	70 %
Maalämpöpumpun huipputeho	85 kW
Lämmityksen lämpötila, DUT	50 °C
Lämpöpumpun tuottama energia	233 MWh
Lämpöpumpun energiapeitto	95 %

Kohteessa voidaan käyttää vapaajäähdytystä ja siihen yhdistettyä konejäähdytystä. Vapaa jäähdytyksen osuutta ei voi lähtötietojen perusteella arvioida kovinkaan tarkasti. Yleistäen voidaan sanoa että vapaajäähdytyksellä voidaan kattaa 90-100% asuinrakennuksen jäähdytystarpeesta. Konejäähdytystä tarvitaan vain huippukuormassa. Vapaa jäähdytyksen käyttöosuuteen vaikuttaa energiakaivojen lämpötila, käytettävät lämmönvaihtimet ja jäähdytyksen jakotapa. Energiakenttä on simuloitava lämpötilatasojen määrittämiseksi.

1) Mitoitus on alustava ja perustuu vahvistamattomiin lähtötietoihin. Mitoitusta ei pidä käyttää suunnittelun perusteena.

2) Alustava arvio. Arviota tarkennettava rakennuksen lämpökuormien simuloinnilla.

ENERGIKAIVOJEN MITOITUS

Lämpöpumpun vuosihyötysuhde	3,6	
Energia kaivoista ¹	168 MWh/vuosi	
Kaivojen keskimääräinen tuotto ¹	100 kWh/m/vuosi	
Tarvittava tehollinen aktiivisyvyys	1 681 m	
Kaivoja yhteensä	5 kpl	
Arvioitu kaivon poraussyvyys	343 m	Järjestelmän kiertovesipumppu voi rajoittaa
Arvioitu poraussyvyys yhteensä²	1716 m	poraussyvyyttä.

Huomioitavaa:

Energialaskelma on suuntaa-antava, sillä kaivojen keskinäistä sijoittelua todellisuudessa ei voida ottaa huomioon. Kaivosta saatavaan energiamäärään vaikuttaa muun muassa kaivojen keskimääräinen etäisyys, kaivojen sijainti toisiinsa nähden (esim. tiivis suorakulmio tai linja) ja kallion lämpöominaisuudet.

Tarkemman mitoituksen voi tehdä esimerkiksi Earth Energy Designer -mallinnusohjelmalla (EED), johon voidaan syöttää tarkempia ominaisuuksia kallioperästä. Mikäli kohteessa energiakaivoja käytetään lämmityksen lisäksi esimerkiksi vapaajäähdytykseen tai muulla tavalla kaivojen lataukseen, on EED:n käyttö erittäin suositeltavaa. EED:ssä otetaan huomioon myös mallinnusaika.

Kallioperän ominaisuuksia voidaan arvioida muun muassa geologisista kartoista, jotka perustuvat tietoihin kivilajeista. Tarkat paikkakohtaiset kallioperän ominaisuudet saadaan termisen vastetestin (TRT) avulla. Energiakaivon poraussyvyys arvioidaan paikkakunnan keskimääräisen veden pinnan korkeuden ja maapeitteen paksuuden mukaan. Paikkakunta: espoo.

1) Lämmöntalteenotosta ja jäähdytyksestä kaivoihin latautuva energia mukaan luettuna.

2) Mitoitus on alustava ja perustuu vahvistamattomiin lähtötietoihin. Mitoitusta ei pidä käyttää suunnittelun perusteena.

Liite 4: geoenergiakentän suunnitelma

Liite 5: Investointi

INVESTOINTILASKELMA

Investointiaika	20 v	
Geoenergiajärjestelmän hankinta ¹	138 000 EUR	
Kaukolämpöjärjestelmän hankinta	-32 360 EUR	Liittymä 104 kW, alakeskukset 104 kW
Vedenjäähdytin	0 EUR	Vedenjäähdytin 0 kW
Sähköliittymän päivitys ²	6 290 EUR	3x63 A
Lisäinvestointi geoenergia	111 930 EUR	
Järjestelmäusinnat 15 v kuluttua (3)	22 000 EUR	

	Osuus	Tekninen käyttöikä (v)
Maalämpöpumppu	33 %	15
Automaatio	11 %	15
Talon sisäiset putket ja asennus	11 %	30
Energiakaivot	31 %	100
Energian keruuputket ja asennus	13 %	40
Lämmön talteenotto	0 %	25
	100 %	

RAHOITUSLASKELMA

Pankkilaina	111 930 EUR	Geoenergiajärjestelmän hankinta
Korko ⁴	2,0 % /vuosi	
Laina-aika	15 vuotta	
Lyhennys ja korko (tasaerä)	-8 678 EUR/v	
Lyhennys ja korko (tasaerä)	-0,22 EUR/m ² /kk	
Pankkilaina 15 v kuluttua	22 000 EUR	Järjestelmäusinnat 15 v kuluttua (3)
Korko ⁴	2,0 % /vuosi	
Laina-aika	15 vuotta	
Lyhennys ja korko (tasaerä)	-1 706 EUR/v	
Lyhennys ja korko (tasaerä)	-0,04 EUR/m ² /kk	

1) Investointiarvio perustuu lähtötiedoissa saatuun energiankulutukseen, mitoittavaan tehoon, hyötysuhteeseen, energiakentän luonnokseen ja yleiseen hintatasoon. Aluelämpöverkostoa ei huomioida investoinneissa. Verkoston oletetaan olevan saman hintainen lämmöntuottotavasta riippumatta.

2) Kustannus laskettu arvonlisäverollisena. Palautuskelpoiseen sähköliittymään ei elinkeinoverolain 6.1 §:n 3 kohdan mukaan lisätä arvonlisäveroa.

3) Lämpöpumpun kompressorin käyttöikä on keskimäärin 50 000 tuntia eli 15-20 vuotta asuinrakennuksessa ja muissa jatkuvassa käytössä olevissa rakennuksissa ja noin 20-30 vuotta rakennuksissa, joissa ilmanvaihtoa vähennetään öisin ja viikonloppuisin. Kompressorin lisäksi voidaan uusia ohjausautomaatiota.

4) Lokakuussa 2016 uusien nostettujen asuntolainojen keskiporko oli 1,14 %.

http://www.suomenpankki.fi/fi/tilastot/tase_ja_korko/Pages/index_29_11_2016.aspx

Liite 6: Tuottolaskelma

ENERGIAN HINNAT			
	Hinta	Ero geoenergiaan	Hinnan nousu/vuosi
Sähkö ¹	110 EUR/MWh	71 EUR/MWh	2,95 % ⁵
Öljy ²	118 EUR/MWh	78 EUR/MWh	4,90 % ⁶
Kaukolämpö ³	87 EUR/MWh	47 EUR/MWh	4,40 % ⁷
Geoenergia ⁴	40 EUR/MWh		2,95 % ⁵
Maakaasu ⁸	80 EUR/MWh	40 EUR/MWh	5,40 % ⁸

1) Sähkön siirron keskihinta ja sähköenergian 2-vuoden määräaikaisen sopimuksen verollinen tarjoushinta. L2 Pientalo, osittain varaava sähkölämmitys, pääsulake 3x25 A, sähkön käyttö 20 000 kWh/vuosi.
<http://www.energiavirasto.fi/sahkon-hintatilastot>. Spot hinta siirtoverkkoyhtiön hinnaston mukaisesti. Energiaisuus 42 EUR/MWh.

2) Tilastokeskus. Polttonesteiden kuluttajahinnat. Kevyt polttoöljy (alv 24 %).
http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__ehi/040_ehi_tau_104_fi.px. Öljykattilan hyötysuhde 90%.

3) Kaukolämmön hinnat tyyppitaloissa eri paikkakunnilla. Alle 600 MWh/v: 15 asunnon rivi-/kerrostalo, 70 kW, 150 MWh. Yli 600 MWh/v: 80 asunnon kerrostalo, 230 kW, 600 MWh. Fortum Power and Heat Oy, Espoo. <http://energia.fi/tilastot/kaukolammon-hinnat-tyyppitaloissa-eri-paikkakunnilla>. Kaukolämmön hinnat 1.1.2016 (xls). Spot hinta hinnaston mukaisesti.

4) Geoenergia 95,0% energiasta, hyötysuhde 360%. Sähköllä 5,0% energiasta. Sisältää huolto- ja ylläpitokustannuksen 1000 EUR/v.

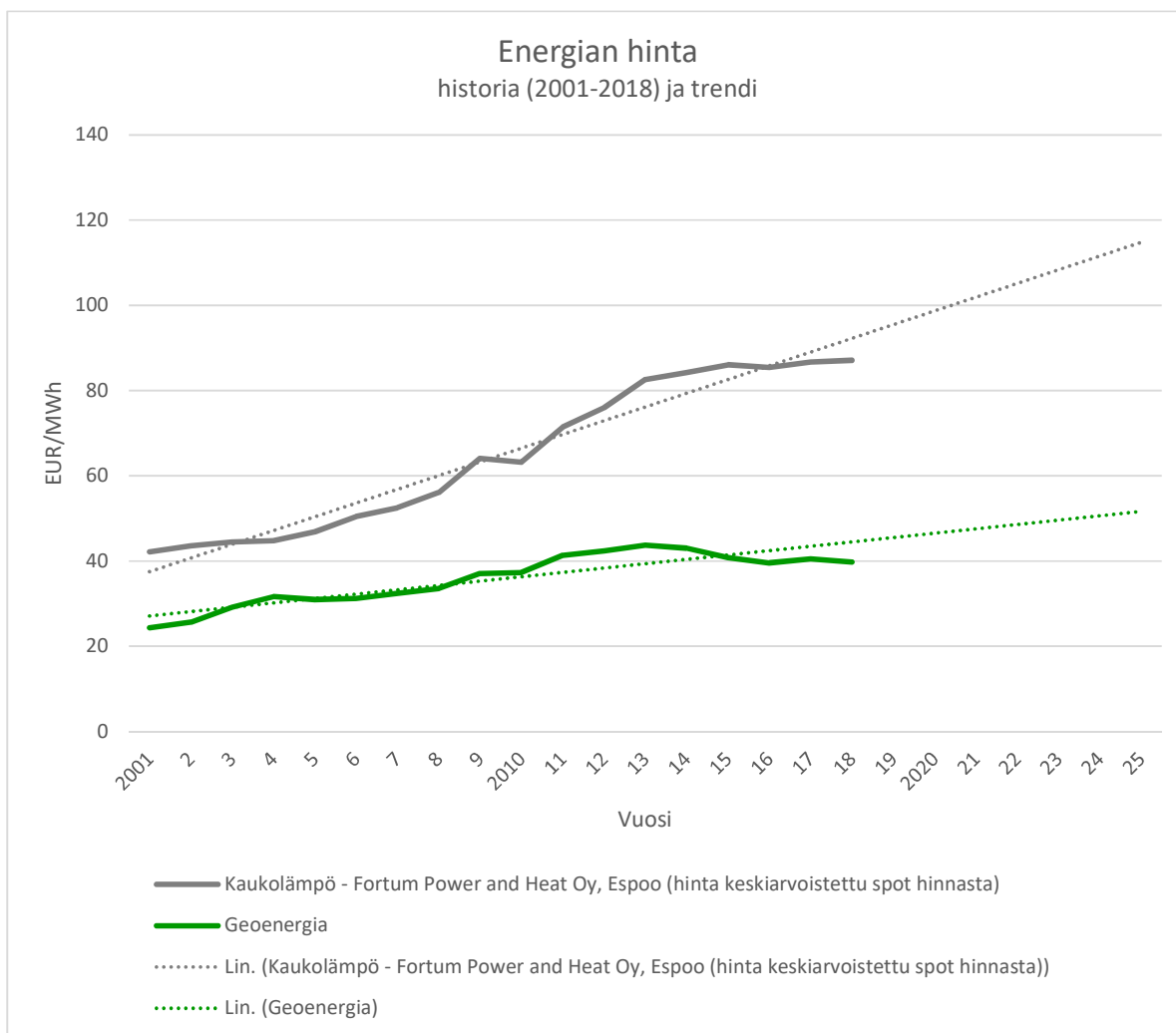
5) Sähkön hinta kuluttajatyypeittäin. Vuodet 2001-2007 T1 (Pienteollisuus, sähkön käyttö 150 000 kWh/vuosi, tehontarve 75 kW). Vuodet 2008-2017 T6 (Yritys- ja yhteisöasiakkaat 20 - 499 MWh/vuosi). Tammikuu. http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__ehi/?tablelist=true. Spot hinta siirtoverkkoyhtiön hinnaston mukaisesti. Energiaisuus 42 EUR/MWh.

6) Polttonesteiden kuluttajahinnat (sisältää alv:n). Kevyt polttoöljy EUR/MWh. Vuodet 2001-2017 tammikuu. http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__ehi/?tablelist=true. Hyötysuhde 90%.

7) Kaukolämmön hinta kuluttajatyypeittäin. Vuodet 2000-2010 Pienkerrostalo, (5000 m3, 225 MWh/a). Vuoden 2011-2015 Rivitalo/pienkerrostalo, (tehontarve 70 kW, 500 m3, 150 MWh/a).
http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__ehi/?tablelist=true

8) Maakaasun hinta kuluttajatyypeittäin, (sis. valmisteron, alv 24%), T1 (50 GWh/vuosi, huipunkäyttöaika 4000 h, Tilausteho 12,5 MW).
http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__ehi/060_ehi_tau_106_fi.px

ENERGIAN HINNAN KEHITYS



TUOTTOLASKELMA

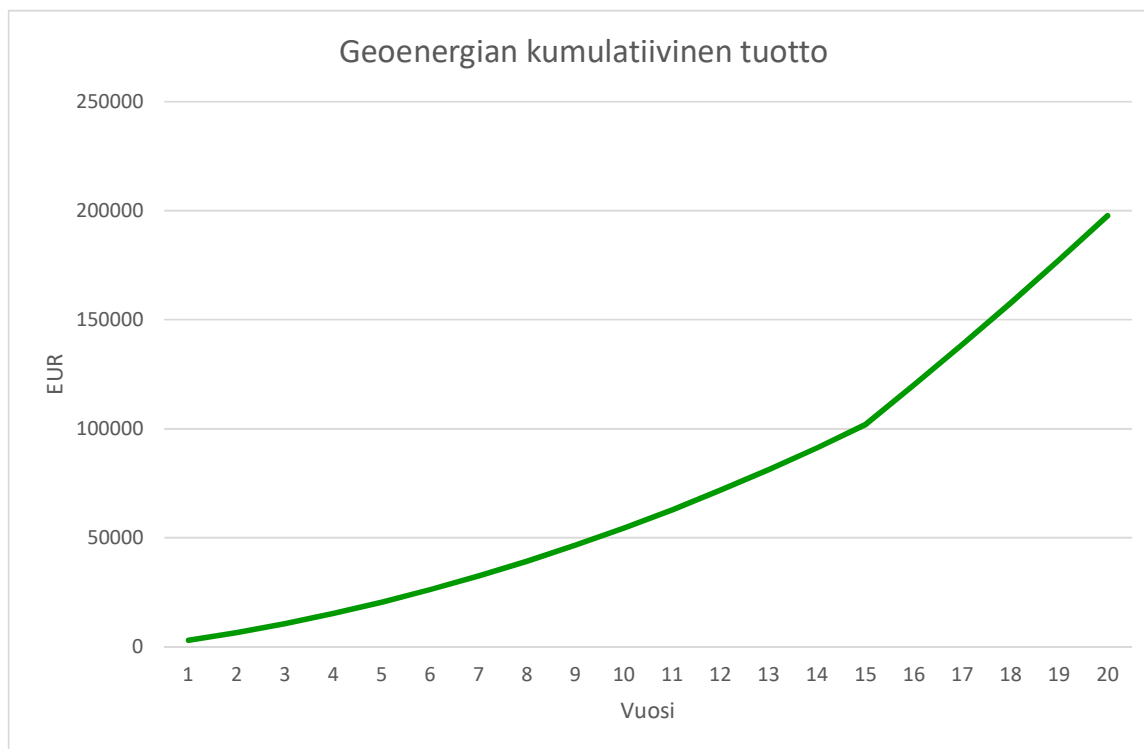
Kaukolämpö - Fortum Power and Heat Oy, Espoo	87,11 EUR/MWh
Geoenergia	39,74 EUR/MWh
Säästö lämmityskustannuksissa	47,37 EUR/MWh

Lämpöenergian kulutus	245 MWh/vuosi
Säästö lämmityskustannuksissa	11 609 EUR/vuosi

Jäähdytys vedenjäähdytyskoneella	44,19 EUR/MWh
Jäähdytys geoenergialla	8,84 EUR/MWh
Säästö jäähdytyskustannuksissa	35,35 EUR/MWh

Jäähdytysenergian kulutus	0 MWh/vuosi
Säästö jäähdytyskustannuksissa	0 EUR/vuosi

EUR / v	1. vuosi	5. vuosi	10. vuosi	15. vuosi	20. vuosi
Kaukolämpö	21 349	25 768	29 715	33 663	37 610
Konejäähdytys	0	0	0	0	0
Geoenergia	9 740	11 905	13 157	14 409	15 661
Jäähdytys geoenergialla	0	0	0	0	0
Geoenergian tuoma säästö	11 609	13 864	16 559	19 254	21 949
Lainanhoitokulut	-8 678	-8 678	-8 678	-723	-1 706
Säästö lainakulujen jälkeen	2 931	5 185	7 880	18 530	20 243



Liite 7: Kassavirtalaskelma

Tämä kassavirtalaskelma on osa "Esiselvitys geoenergian hyödyntämiseksi" -dokumenttia. Esiselvityksen tarkoitus on antaa kiinteistön omistajalle perustietoa geoenergiasta ja sen hyödyntämisestä. Kiinteistölle luonnostellaan energiakenttä, lasketaan energiamääriä ja hankkeen rahoitusta.

LÄHTÖTIEDOT										
Nimi	As Oy Espoon Apollo									
Osoite	Marinportti 3, espoo									
Arvioitu investointi	111 930 EUR									
Laina-aika	15 vuotta									
Korko	2,0 %									
Nykyinen energiakustannus	21 349 EUR/v									
Nykyinen energiamuoto	Kaukolämpö - Fortum Power and Heat Oy, Espoo									
Energian hinnan nousu	4,4 % /vuosi									
Geoenergia	9 740 EUR/v									
Energian hinnan nousu	3,0 % /vuosi									
KASSAVIRTALASKELMA										
Vuosi	1	2	3	4	5	6	7	8	9	10
Vieras pääoma	111930	105434	98812	92060	85177	78159	71005	63711	56275	48694
Korko%	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %	2,0 %
Tulo ¹	21349	23400	24189	24979	25768	26558	27347	28136	28926	29715
Energiakulu ²	9740	11153	11404	11654	11905	12155	12405	12656	12906	13157
Tuotto	11609	12247	12786	13325	13864	14403	14942	15481	16020	16559
Pääoman tuotto%	10,4 %	10,9 %	11,4 %	11,9 %	12,4 %	12,9 %	13,3 %	13,8 %	14,3 %	14,8 %
Korkokulu	2183	2056	1927	1795	1661	1524	1385	1242	1097	950
Kassavirta	9427	10191	10859	11529	12203	12878	13557	14238	14922	15609
Lainan lyhennys	6496	6622	6752	6883	7018	7154	7294	7436	7581	7729
Ylijäämä	2931	3568	4107	4646	5185	5724	6263	6802	7341	7880

1) Tulo on laskettu nykyisten energiakustannusten mukaan. Vuosittainen korotus on arvioitu lineaarisella regressiolla tilastollisista keskihinnoista (Tilastokeskus).

2) Arvio geoenergiainvestoinnin jälkeisestä energiakustannuksesta. Vuosittainen korotus on arvioitu lineaarisella regressiolla tilastollisista keskihinnoista (Tilastokeskus).

Liite 8: Investoinnin vaikutus rahoitus- ja hoitovastikkeeseen

Geoenergiainvestointi pienentää kiinteistön energiakuluja ja laskee siten hoitovastiketta.
Investointi rahoitetaan lainalla, jolloin rahoitusvastike nousee.

HOITOVASTIKE JA RAHOITUSVASTIKE

Kiinteistön huoneisto-ala 3303 m²

EUR/kk	1. vuosi	5. vuosi	10. vuosi	15. vuosi	20. vuosi
Geoenergian säästö	11 609	13 864	16 559	19 254	21 949

EUR/m ² /kk	1. vuosi	5. vuosi	10. vuosi	15. vuosi	20. vuosi
Hoitovastike (geoenergian säästö)	-0,29	-0,35	-0,42	-0,49	-0,55
Rahoitusvastike (pankkilaina)	0,22	0,22	0,22	0,22	0,04
Vastikkeen muutos yhteensä	-0,07	-0,13	-0,20	-0,27	-0,51

KOKONAISVAIKUTUS

Esimerkkiasunto 32 m²

EUR/kk	1. vuosi	5. vuosi	10. vuosi	15. vuosi	20. vuosi
Hoitovastike (geoenergian säästö)	-9	-11	-13	-16	-18
Rahoitusvastike (pankkilaina)	7	7	7	7	1
Vastikkeen muutos yhteensä	-2	-4	-6	-9	-16

Liite 9: Investoinnin vaikutus kiinteistön arvoon

Kiinteistön arvoon vaikuttavat esimerkiksi sijainti, koko, laatutaso ja hoitokulut. Geoenergiainvestointi vaikuttaa suoraan kiinteistön hoitokuluihin ja välillisesti laatutasoon. Laatutasoa nostaa kiinteistön ostajan antama arvo huoltovapaalle uusiutuvalle energialle.

Laskelmassa kiinteistön arvo määritellään myyntihetken velattomana neliöhintana. Myyntihinta (markkinahinta) lasketaan kiinteistön bruttovuokratuoton kaavasta¹.

$$Vuokratuotto(\%) = \frac{[Vuokra(\text{€/m}^2) - \text{Hoitokulut}(\text{€/m}^2)] \times 12}{[1 + \text{Varainsiirtovero}(\%)] \times \text{Markkinahinta}(\text{€/m}^2) + \text{Remonttivara}(\text{€/m}^2)}$$

MYNTIHINTA

Myyntihinta lasketaan jakamalla euromääräinen vuokratuotto (vuokra-hoitokulut) nykyisellä vuokratuottoprosentilla. Lisäksi huomioidaan varainsiirtovero ja remonttivaraus.

$$\text{Markkinahinta} \left(\frac{\text{€}}{\text{m}^2} \right) = \frac{\left[\frac{[Vuokra \left(\frac{\text{€}}{\text{m}^2 \text{kk}} \right) - \text{Hoitokulut} \left(\frac{\text{€}}{\text{m}^2 \text{kk}} \right)] * 12 \text{ kk}}{Vuokratuotto(\%)} - \text{Remonttivara} \left(\frac{\text{€}}{\text{m}^2} \right) \right]}{1 + \text{Varainsiirtovero}(\%)}$$

Esimerkki myyntihinnan laskemisesta 50 neliön kaksiossa

	€/kk	€/m ² /kk
Vuokra	500	10
Hoitovastike	150	3

Remonttivaraus 200 €/m² (esim. ensi vuodelle suunniteltu julkisivuremontti)
Ostajan haluama vuokratuotto 4 %

$$\text{Markkinahinta} \left(\frac{\text{€}}{\text{m}^2} \right) = \frac{\left[\frac{[10,00 \frac{\text{€}}{\text{m}^2 \text{kk}} - 3,00 \frac{\text{€}}{\text{m}^2 \text{kk}}] * 12 \text{ kk}}{4 \%} - 200 \frac{\text{€}}{\text{m}^2} \right]}{1,02} = 1862 \left(\frac{\text{€}}{\text{m}^2} \right)$$

VELATON HINTA

Velaton hinta lasketaan vähentämällä myyntihinnasta geoenergiainvestoinnin lainan määrä.

$$\text{Velaton hinta} \left(\frac{\text{€}}{\text{m}^2} \right) = \text{Markkinahinta} \left(\frac{\text{€}}{\text{m}^2} \right) - \text{Geoenergiainvestoinnin laina} \left(\frac{\text{€}}{\text{m}^2} \right)$$

KIINTEISTÖN ARVO KESKIMÄÄRÄISEN VUOKRATUOTON PERUSTEELLA

Keskimääräinen vuokratuotto Suomen suurimmissa kunnissa vaihtelee välillä 2,0 % - 5,5 % riippuen asunnon koosta ja sijainnista¹.

Geoenergiainvestointi vähentää kiinteistön hoitovastiketta ja siten lisää vuokratuottoa.

Laskelmassa vuokratuotto on kiinnitetty 2,0% tai 5,5% ja investoinnin hyöty on laskettu kiinteistön markkinahintaan ja velattomaan hintaan.

Kiinteistön pinta-ala	3 303 m ²
Geoenergian säästö	967 €/kk
Säästö hoitokuluissa / m ²	0,29 €/m ² /kk

		Vuokratuotto 2%		Vuokratuotto 5,5%	
		Nykytila	Geoenerg.	Nykytila	Geoenerg.
Arvioitu vuokratuotto ²					
Vuokra	€/m ² /kk	7,70	7,70	13,30	13,30
Hoitovastike	€/m ² /kk	3,46	3,17	2,60	2,31
Vuokratuotto	€/m ² /v	51	54	128	132
1 + Varainsiirtovero 2%		1,02	1,02	1,02	1,02
Markkinahinta	€/m ²	2000	2172	1800	1863
Remonttivara	€/m ²	500	500	500	500
Yhteensä		2540	2715	2336	2400
Vuokratuotto (%)		2,00 %	2,00 %	5,50 %	5,50 %

		Vuokratuotto 2%	Vuokratuotto 5,5%
		€/m ²	€/m ²
Kiinteistön myyntihinnan nousu			
Myyntihinta		2000	1800
Myyntihinta geoenergia investoinnin jälkeen		2172	1863
Myyntihinnan nousu		172	63
Myyntihinnan nousu %		8,6 %	3,5 %

		Vuokratuotto 2%	Vuokratuotto 5,5%
		€/m ²	€/m ²
Kiinteistön velattoman hinnan nousu			
Myyntihinta		2000	1800
Geoenergia investoinnin laina		34	34
Velaton hinta geoenergia investoinnin jälkeen		2138	1829
Velattoman hinnan nousu		138	29
Velattoman hinnan nousu %		6,9 %	1,6 %

Koko kiinteistön velattoman hinnan nousu (EUR)	456 258	95 138
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1) Asuntosijoittamisen tuotto (%). <http://www.vuokranantajat.fi/attachements/2013-07-03T09-05-3023412.pdf>

2) Vuokratuotot laskettu asuntosijoittajan vuokratuottolaskurilla. Tulokset ovat keskimääräisiä. Tuotto vaihtelee vuokran, hoitokulujen, markkinahinnan ja tulevien remonttien mukaan. <http://vuokratuotto.fi/>

KIINTEISTÖN ARVO LÄHTÖTIE TOJEN PERUSTEELLA

Kiinteistön pinta-ala	3 303 m ²	(arvio)
Geoenergian säästö	967 €/kk	
Säästö hoitokuluissa / m ²	0,29 €/m ² /kk	
Vuokra	25,00 €/m ² /kk	(arvio)
Hoitovastike	3,50 €/m ² /kk	(arvio)
Myyntihinta	5000 €/m ²	(arvio)
Remonttivaraus	0 €/m ²	(arvio)
Vuokratuotto (%)	5,06 %	

Arvioitu vuokratuotto		Nykytila	Geoenerg.
Vuokra	€/m ² /kk	25,00	25,00
Hoitovastike	€/m ² /kk	3,50	3,21
Vuokratuotto	€/m ² /v	258	262
1 + Varainsiirtovero 2%		1,02	1,02
Markkinahinta	€/m ²	5000	5068
Remonttivarau	€/m ²	0	0
Yhteensä		5100	5169
Vuokratuotto (%)		5,06 %	5,06 %

Kiinteistön myyntihinnan nousu	€/m ²
Myyntihinta	5000
Myyntihinta geoenergia investoinnin jälkeen	5068
Myyntihinnan nousu	68
Myyntihinnan nousu %	1,4 %

Kiinteistön velattoman hinnan nousu	€/m ²
Velaton hinta	5000

Myyntihinta geoenergia investoinnin jälkeen	5068
Geoenergia investoinnin laina	-34
Velaton hinta geoenergia investoinnin jälkeen	5034

Velattoman hinnan nousu	34
Velattoman hinnan nousu %	0,7 %

Koko kiinteistön velattoman hinnan nousu	113 056 EUR
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Esimerkiksi 32 neliön tila

Geoenergiainvestointi maksaa 1084 euroa.
Myyntihinta nousee 2180 euroa.
Velaton hinta nousee 1095 euroa.

1) Velaton hinta = myyntihinta geoenergiainvestoinnin jälkeen - geoenergiainvestoinnin laina

Liite 10: Investoinnin vaikutus vuokratuottoon

VUOKRATUOTTO LÄHTÖTIE TOJEN PERUSTEELLA

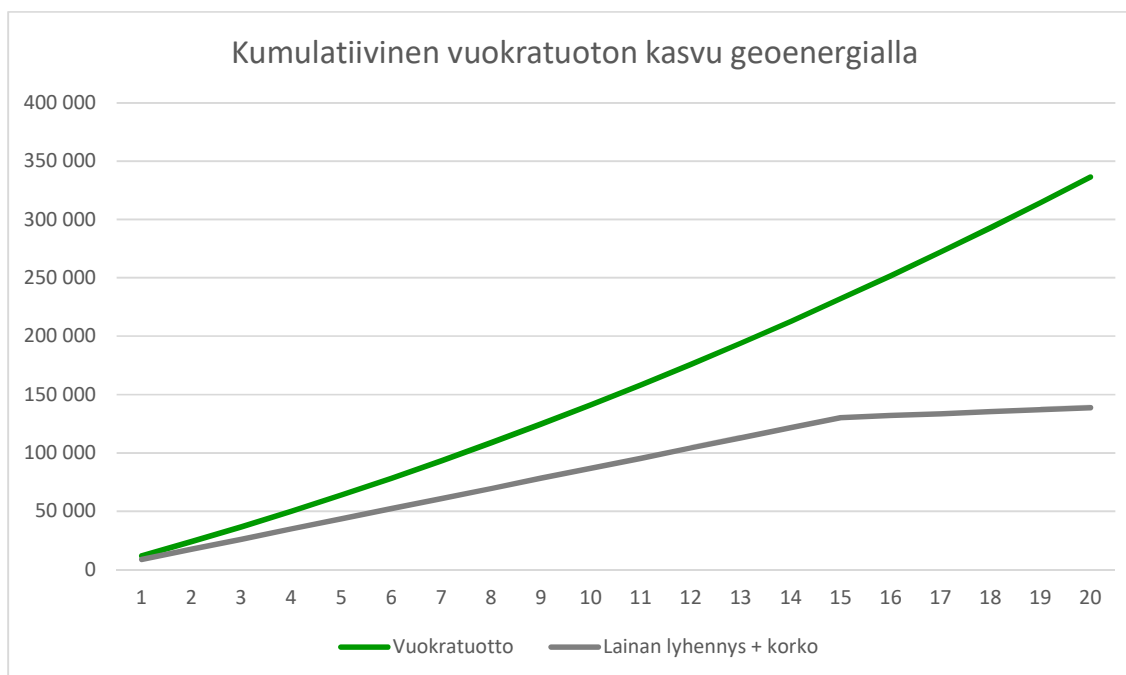
Kiinteistön pinta-ala 3 303 m²

EUR/kk	1. vuosi	5. vuosi	10. vuosi	15. vuosi	20. vuosi
Energiakustannukset - Kaukolämpö	1 779	2 147	2 476	2 805	3 134
Energiakustannukset - Geoenergia	812	1 013	1 096	1 201	1 305

EUR/m ² /kk	1. vuosi	5. vuosi	10. vuosi	15. vuosi	20. vuosi
Energiakustannukset - Kaukolämpö	0,54	0,65	0,75	0,85	0,95
- muutos 1. vuoteen	0,00	0,11	0,21	0,31	0,41
Energiakustannukset - Geoenergia	0,25	0,31	0,33	0,36	0,40
- muutos Kaukolämpö 1. vuoteen	-0,29	-0,23	-0,21	-0,18	-0,14

Vuokratuotto	1. vuosi	5. vuosi	10. vuosi	15. vuosi	20. vuosi	
Vuokra	25,00	26,02	27,07	28,74	30,20	€/m ² /kk
Hoitovastike - Kaukolämpö	3,50	3,61	3,69	3,81	3,91	€/m ² /kk
Hoitovastike - Geoenergia	3,21	3,26	3,29	3,32	3,36	€/m ² /kk
Geoenergian säästö	3,5	4,2	4,9	5,8	6,6	€/m ² /v
Geoenergian säästö	11 609	13 864	16 020	19 254	21 949	€/v

Vuokratuotto kumulatiivinen	1. vuosi	5. vuosi	10. vuosi	15. vuosi	20. vuosi	
Geoenergia vs. Kaukolämpö	11 609	63 830	141 232	232 110	336 464	€
Lainan lyhennys + korot	8 678	43 392	86 785	130 177	138 706	€



Liite 11: Geoenergiajärjestelmän arvioitu tilantarve

TILANTARVE

Geoenergiajärjestelmä voidaan sijoittaa kiinteistön lämmönjakohuoneeseen tai muuhun tilaan johon voidaan tuoda sähkö- ja vesiliittymä. Tilan korkeus ja oviaukon leveys kannattaa ottaa huomioon maalämpöpumppua ja muita asennettavia osia valitessa.

Järjestelmän tilantarpeeseen vaikuttavat suunnittelussa päätettävät järjestelmän osat:

- Maalämpöpumppu
- Käyttövesi- ja lämmitysvaraajat
- Paisunta-astiat
- Varalämmitysjärjestelmä (sähkö, öljy, kaasu, kaukolämpö...)
- Jakotukit (käyttövesi, lämmitys, jäähdytys)
- Maapiirin putkisto
- Sähköalakeskus

Keskimääräinen tilantarve 85 kW järjestelmälle on 10 - 18 neliötä.

12. APPENDIX B: FIRST INTERVIEW ROUND

Interviewees

Joel Kronqvist, Nibe
Niko Pihlanen, Rototec

12.1 Theme areas

1. GSHP system in the Marinranta housing area
2. The costs and profitability of GSHP systems.

13. APPENDIX C: SECOND INTERVIEW ROUND

Interviewees are not listed in the same order as interview was made

Jari Kanervo, Sato
Juha Haapakoski, Icecapital
Juha Kostiainen, YIT Finland Ltd
Juhani Puhakka, Toas
Matti Simppala, Enersys,
Niko Pihlani, Rototec
Pasi Kujansuu, Kojamo
Tomi Mäkipelto, LeaseGreen

13.1 Interview questions

1. What is the present state of the GSHP market in the sector of new apartment building construction?
2. What are the challenges of GSHP systems and what factors restrict a wider use of the GSHP systems in new apartment building construction?
3. What are the factors that could increase the use of GSHP systems in new apartment building construction?
4. What are the key business opportunities that GSHP system could bring to other parties?
5. Why there are not many parties that either lease the GSHP system to housing cooperatives or own the GSHP systems themselves and then sell the heat to housing cooperatives?
6. How GSHP investments from third parties could become more attractive to construction companies?
7. How interviewees view the future of GSHP systems in the sector of apartment buildings?
8. What could be the role of construction companies in the energy generation of apartment buildings?