Finland’s push for energy independence through geothermal heat pumps

The impact of the changing geopolitical climate and shifting energy demands

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Abstract

The changing geopolitical climate in Finland following the recent invasion of Ukraine and Finland's application to NATO has implications on Finland's energy independence and energy sovereignty due to historical dependence on Russian gas and oil. Geothermal energy can be used as a potential renewable source of energy to contribute to Finland's energy transition. The main question is "*How does the changing geopolitical climate and current public perception of geothermal energy influence its demand and growth as a renewable energy source in Finland?"* This research question is answered by conducting elite interviews with experts or stakeholders in geothermal energy in Finland, to give several perspectives on the impact of the changing geopolitical climate. The thesis concludes that the need for energy independence is accelerated by the geopolitical situation where the main challenge for Finland to overcome is the material challenge in the lack of heat pump production, increasing steel prices, lack of human resources and equipment necessary for planning and drilling new geothermal wells.

Keywords: *geothermal energy, ground-source heat pumps, Finnish energy landscape, geopolitical climate, temporality, spatiality and materiality of energy*

1. Introduction

1.1 Background

Global energy demands are shifting from carbon sources to renewable sources as different countries harness renewable energy sources fit for their circumstances. In 2020, renewable energy sources made up 23% of the energy used for heating and cooling in the European Union, which increased from 12% back in 2004 (Eurostat, 2022). The overall share of renewables also increased to 22% in 2020 from 10% in 2004, as the growth of the industrial sector and the use of heat pumps for the electrification of heating accelerated the growth in the use of renewable energy sources specifically in heating and cooling (Eurostat, 2022). Regarding the renewable energy used for heating and cooling in the EU, Sweden has the highest use of 66% followed by Estonia and Finland with 58% which mostly consists of the use of heat pumps and biomass. Finland has been relatively active in pursuing the use of geothermal energy for heating, as in 2021 the world's deepest geothermal borehole was drilled in Espoo in southern Finland with the purpose of producing district heating with the system beginning in mid-2021 (Richter, 2021). Water is pumped into the geothermal borehole, where the natural geothermal energy heats it to 120 degrees Celsius after which the water is pumped into an already existing district heating network in Espoo, supplying around 10% of Espoo's heating requirements (Richter, 2021). Geothermal energy can be used very efficiently to produce heating without emissions. In the process of producing 40 megawatts of energy for heating demands, the pumps used to pump the water in and out of the geothermal borehole consumes 4 megawatts, resulting in an efficiency of 90% which can be combined with the use of wind energy for zero-emissions (Richter, 2021).

Following the targets set by the EU's Green deal to cut carbon emissions and become climate neutral by 2035, Finland among the other EU countries is also increasingly pressured into shifting from the use of fossil fuels to renewable energy sources. Another external issue pushing Finland to shift its energy demands is the recent invasion of Ukraine by Russia due to Finland's historical energy dependence on Russia combined with historical animosity between the countries. In 2016 the primary energy imports of Finland consisted 67.7% of trades with Russia (Jääskeläinen et al., 2018). Due to the high dependence on energy from Russia primarily in the form of oil, public debate followed in Finland regarding whether the dependence on Russia for energy and Finland's low self-sufficiency in energy was an energy security threat or just a

mutually beneficial trade relation (Jääskeläinen et al., 2018). This historical lack of energy independence in Finland combined with the ongoing sanctions on Russia may push Finland to achieve energy sovereignty and push the country's energy independence by generating more energy domestically.

For Finland to further develop their energy independence, the public perception is important for successful growth in the use of renewable sources. For example, if the social acceptance of geothermal energy based on its public perception is good, it could persuade energy consumers to start investing in heat pumps for heating instead of oil which is historically the most common heating source in Finland. The research of Pellizzone et al. concluded that "*Successful implementation of geothermal exploitation strongly needs public participation to manage the energy innovation process on a socially sustainable path. Apparent contradictions between different stakeholders views and needs strongly ask for the construction of a public debate able to involve all stakeholders from the very early stage of the innovation process.*" (Pellizzone et al., 2015, p.10). Another aspect influencing public perception of geothermal energy is the lack of knowledge. Vargas Payera (2018) mentions that the lack of knowledge of the possible local benefits and lack of knowledge of geothermal potential can affect the general attitude that people have towards it. She also hinted at future research on energy expansion could include levels of social acceptance and public engagement along with the integration of local knowledge in the direct use of geothermal power.

1.2 Research problem

The aim of this study is to analyse the current public perceptions of geothermal energy in all of Finland based on elite interviews with stakeholders of geothermal energy and to gain a new understanding of what kind of impact the invasion of Ukraine has had on Finland's energy landscape as well as the challenges Finland may face as a result. These stakeholders include energy companies and geothermal or renewable energy representatives in the energy industry. The objective is to answer the research questions by interviewing individuals in the energy industry who have greater knowledge of the use and public perception of geothermal energy in Finland. The main topics of discussion include the general public perception of geothermal energy in Finland, followed by how that public perception affects the demand and growth in the use of geothermal heat pumps for home heating. The knowledge gap and societal relevance of

the research comes from having a discussion with interviewees on the impact of the changing geopolitical climate on Finland's energy landscape and more specifically the use of geothermal energy. This topic is very recent, and thus little research has been done on it. Therefore the interviews can bring to light new perspectives on this timely issue that is having a large impact on Finland's energy landscape.

The next chapter introduces the theoretical background of this research which outlines the relevant theories and concepts which are used to form a conceptual model that helps to answer the research questions. First the spatiality, temporality and materiality of energy are introduced, followed by an explanation of geothermal energy and how its used to produce heat and electricity. After this general understanding of geothermal energy, the energy transition and the role which geothermal energy plays in Finland is discussed which describes the use and public perception of geothermal energy in Finland. The literature review then concludes with the conceptual model which is based on the discussed literature, followed by the sub-questions of the research which were formed based on the literature review in order to help answer the main research question.

2. Literature review

2.1 Spatiality, temporality and materiality of energy

To understand the context behind energy production and the role that it plays in society, it is important to fundamentally break down the spatiality, temporality and materiality of energy. What are the spatial implications of energy production? How does time influence the production of energy? What material implications does energy consumption and production have?

Spatiality of geothermal energy

The most basic definition of energy is 'the capacity to do work', however Huber and McCarthy (2017) argue that not enough attention is paid to the 'spatialities' of energy production as the conceptualisation of energy often ignores the space required for the production of that energy.

To understand the relationship between energy and society, it is crucial to take into account the spatial implications of energy production in the geographies of energy transitions. The is a distinction between the space required to produce energy, and the fact that energy can produce spaces. The spaces produced by energy relate to space as a product of the 'work' gained from energy (Huber and McCarthy, 2017). Literature on energy and space often focuses on energy as a tool for political power or the politics that surround the distribution of energy. This conceptualisation of energy in space is heavily political as it views energy as a strategic object 'in space' that can be controlled and thus creating regimes of power (Huber and McCarthy, 2017). This view on energy in space ignores the physical space required to actually produce that energy. For example, the space required to produce coal is drastically different to producing energy through wind turbines. Population growth means that space is also becoming increasingly contested in addition to changing energy demands. As the global energy transition takes place with the shift from fossil fuels to renewable energy sources, the importance of different land-use requirements behind energy production becomes crucial to take into account (Huber and McCarthy, 2017).

Bridge and Gailing (2020) take a geographical political economy perspective on energy transition which highlights the energy transition as a space-making process. The research outlines three contributions that the geographical political economy perspective brings, starting with uneven and combined development. This refers to how new and old energy systems can be combined in creating 'new energy spaces'. To further explain, 'uneven' development acknowledges that there are spatial differences in infrastructuring and that the territorializations of energy politics is different between countries or regions. Acknowledging spatial differences in the energy transition is just as important as the combination of old and new. Combined development refers to how old energy production technologies are carried over or combined with new energy production. Uneven and combined development, therefore, emphasises the recombination of energy technologies rather than replacement in creating new energy spaces. Another contribution of this perspective on the energy transition is the regional dynamics of accumulation. This refers to how regions have 'geographically differentiated pathways and institutions' meaning that regions have different forms of social and economic agency when creating new energy spaces (Bridge and Gailing, 2020). The final contribution is the spatial and scalar aspects of governance. Bridge and Gailing also explain how part of the geographical political economy perspective is "*to analyse how the sites, scales and spatialities of energy systems are key contemporary site of struggle, through which broader questions of political*

economic governance (and the social relations of capitalism) are being worked out." (Bridge and Gailing, 2020, p.1042). This contribution highlights how the spatiality of energy is related to the political economy in energy geographies because the governance of space and the spatial variance in energy systems are inherently linked. This also shows that when planning for the energy transition, it's important to consider who governs the space that is used for energy production. The spatiality of energy can also be affected by time, hence in the next section the temporality of energy is introduced, which discusses how time plays a role in the production of energy.

Temporality of energy

The United Nations Framework Convention on Climate Change and the Paris Agreement resulted in the target of keeping the global average temperature increase below 2°C and giving the effort to keep it below 1.5°C. In addition to this, European Union set a long-term strategy of becoming climate neutral by 2050. This long-term strategy proposes that emissions need to be reduced by 45% by 2030 and net zero by 2050. How do countries reach this goal by the set timeframes? When planning for the energy transition, 'transition' also implies a change over time meaning that the aspect of time is crucial to the energy transition. The temporality of energy, therefore, refers to the role that time plays in the production of energy.

Marquardt and Delina (2021) discuss the centrality of time in energy and climate studies by providing four dimensions that are linked to the temporality in energy and climate research. The first dimension, *temporality and nature* refers to the natural limits of the Earth's carrying capacity. They give the example of how crossing certain natural tipping points might not have immediate consequences, but over time those consequences become much more severe. This means that to combat the consequences of climate change, it's important to take action as early as possible because the severity of the consequences could get worse. *Temporality and knowledge* is linked to how there is an increase in global social movements against climate change because people are becoming increasingly more knowledgeable about the issues that climate change can bring. Marquardt and Delina (2021) mention how the idea of 'time is running out" to stop climate change is a major theme of climate change movements. This shows that knowledge about the lack of time to solve the problem gives people a reason to be more climate-friendly. *Temporality and technologies* refers to how energy technologies are often tied to timescales due to the need for changes and the fact that energy technologies often have a lifespan for their use. As new technologies are implemented into the energy mix, it's important to

consider the lifespan of those technologies and plan around them, making sure that energy demands even though the use of older technologies expires. *Temporality and society* is also linked to the previously mentioned idea of 'time is running out' and how it brings out more climate activists in the need for immediate action. It is the societal and political change through climate mitigation efforts (Marquardt and Delina, 2021), where the change implies a change over time. These four dimension of temporality in energy highlight how the timescales of reaching carbon neutrality, the temporality of energy technologies and how urgency for change is linked to socio-political action and movements.

The conceptualisation of temporality of energy and the need for an energy transition stems from the imperative factor of speed in the transition. The previously mentioned goals set by the European Union of achieving carbon neutrality by 2050 implies that change needs to happen before a certain time. Delina and Sovacool (2018) emphasize this aspect of temporality in the energy transition. The speed at which the energy transition takes place is crucial as countries want to meet the demands of changing policies that enforce the need to reduce emissions and the demands for renewable energy technologies. Appel, Anand and Gupta (2020) connect temporality with infrastructure, by explaining how infrastructure mediates time as much as it mediates space. They go on to explain that infrastructures configure time by enabling certain kinds of social time and making only some temporalities possible. This concept of temporality and infrastructure can be applied to the infrastructure that comes with new energy technologies and their implementation. Time plays a massive role in this process of new infrastructure, as time is needed to both produce and build that infrastructure, as well as the time required in the management and production of energy. The next section introduces the materiality of energy, explaining the complexities behind the materials in energy systems.

Materiality of energy

Materiality of energy typically refers to the physical material resources required to produce that energy. The complexity of energy systems in how the energy is produced, distributed, consumed or transported all contribute to the materiality of energy. The materiality behind energy, therefore, includes the physical material sources used to produce energy, the materials used to construct the necessary infrastructure for its production, transportation and consumption through appliances of energy use as well as the physical landscapes influenced by energy extraction and generation (Moss, Becker and Gailing, 2016). The complexity behind energy

systems and the multitude of processes that come with them means that when reconfiguring energy systems from fossil fuels to renewable sources, the reorganization of physical structures and the flows between is inevitable. The materiality required for all the processes for energy systems to work has to be taken into account for the energy transition as adapting new technologies entails the reorganization of energy systems (Moss, Becker and Gailing, 2016).

Balmaceda et al. (2019) ask four crucial questions about energy materiality, which helps in creating a bigger picture of the concept. The first question, "*where is energy materiality located?*" looks at the physical characteristics of energy sources as, including the infrastructure that comes with energy systems. "*How is energy materiality used and by whom?*" relates to the consumption of energy, and materiality as a constraint on actors' behaviour. "*What are the relational characteristics of energy materiality?*" is an important question when identifying causal linkages of energy materiality. This question focuses on how objects and their physical characteristics have a technological and spatial relationship. The fourth question "*What analytical role does energy materiality play in different approaches?"* takes a multidisciplinary approach on the materiality of energy to understand how energy materiality in research can be an independent variable as a causal factor, a dependent variable, or an intervening variable that appears as a constraint (Balmaceda et al., 2019). The discussion of materiality as a constraint on actor's behaviour can also be found in the work of Cederlöf (2019) who argues that the materialities of energy sources and energy infrastructures can both catalyse and condition human action. Cederlöf (2019) also gives the example of the materiality of electricity as 'its flows, cables, meters and pylons' which relates the many aspects of materiality previously discussed.

Balmaceda et al. (2019) also discuss politicizing energy materiality by giving an example of the "Not In My BackYard" (NIMBY) effect. A large number of publications on the NIMBY effect are related to energy infrastructure of which the most common are wind turbines (Cederlöf, 2019). Using the example of wind turbines, the physical material aspect of the wind turbines causes the NIMBY effect, which emphasizes the importance of consideration for the materiality of energy in, planning. Further literature also discusses the increased debate around the visual impact can have on the social acceptance of renewable energy sources as "*it is increasingly recognized that social acceptance may be a constraining factor in achieving this target [of increasing the share of renewable energy]. This is particularly apparent in the case of wind energy, which has become a subject of contested debates in several countries largely due to its visual impact on landscapes.*" (Wüstenhagen et al.2007, p.2683). In the next section, geothermal as a source of

energy is introduced, explaining how the renewable source of energy is used in the production of heat and electricity, and the different applications and technologies that harness geothermal energy.

2.2 Geothermal energy

“Geothermal” specifically refers to the Earth’s thermal energy that is stored under the surface and by using this logic, geothermal energy is the energy that humans can access and use (Manzella, Allansdottir and Pellizzone, 2019). The geothermal energy that comes from under the surface of the Earth is created through planetary and geological processes. The heat from the Earth’s core moves towards the surface and the geological process of the decay of radioactive isotopes in the Earth's crust adds to the heat that can eventually be used as energy through the use of geothermal technologies. The term *geothermal gradient* refers to the variation of temperature with depth, which essentially means the temperature rises the deeper from the surface we go (Manzella, Allansdottir and Pellizzone, 2019). This geothermal gradient typically ranges from 15 °C to > 50 °C per kilometre and averages around 25 °C , which means that the temperature difference between the Earth’s layers creates an upward heat flow (Solomon and Calvert, 2017). This is a core reason why geothermal energy is easily accessible to humans to utilise for heating or generating electricity. The difference in temperature and depth also means that different geothermal technologies can be utilized at different depths for different purposes. Shallow geothermal technologies and deep geothermal technologies utilize geothermal energy at different depths meaning that they produce different levels of heating depending on the depth.

Technologies that use geothermal energy for heating purposes often use water as the carrier of heat. By simply using the geothermal heat under the surface of the Earth to heat water, it can then be pumped above the surface and then typically used for space heating or cooling, bathing, agriculture or different industrial processes (Manzella, Allansdottir and Pellizzone, 2019). Figure 1 shows a typical layout of a geothermal technology used for heating that involves a geothermal plant with a heat exchanger. At the plant, deep wells are used to extract fluid to the surface which is then distributed to houses for heating, while some fluids are reinjected back into the ground to avoid unnatural interference with the aquifers underground. The investment that has to be made for geothermal systems is usually quite intensive, with a majority of the

initial cost coming from drilling the production and injection wells and installing the pumps used for extraction and injection. While the initial investment might be high, the renewable aspect of the energy source and the flexibility depending on the energy demand means that the overall operating expenses are lower than conventional systems (Manzella, Allansdottir and Pellizzone, 2019).

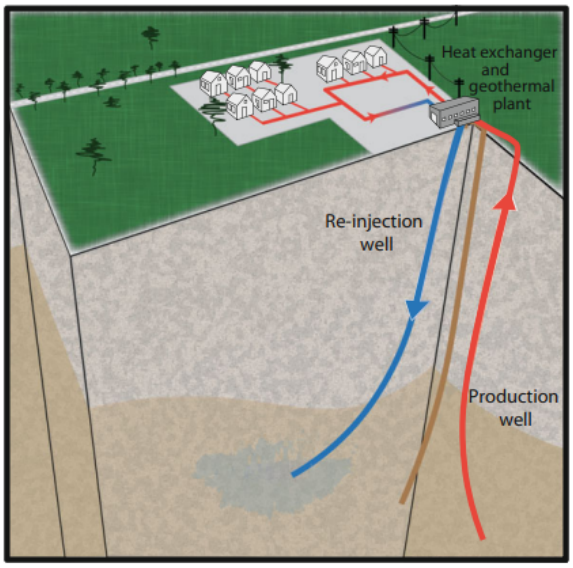

Figure (1): Double-Triplet system used for heating purposes. (Manzella, Allansdottir and Pellizzone, 2019)

Geothermal applications are becoming more and more flexible as the technologies adapt their limitations. The form of heating and cooling in which fluids are used at a required temperature for essentially “free” heating and cooling. The limitation of this is that it has to adjust to the natural temperature of the groundwater available. Geothermal applications are becoming more flexible as they can cool or heat fluids more efficiently, including *geothermal or ground source heat pumps* (GSHP). GSHP systems are a shallow geothermal technology which is used for heating and cooling by exploiting groundwater temperatures at the depths of around 10-200m meters. The heat pump system is able to move heat from a space to cool spaces and also able to release heat at higher temperatures to heat spaces. The GSHP system is much more efficient than air-air heat pumps such as air conditioners in the cold season because the ground has a higher temperature than the air. While GSHP systems don’t use electricity for heating or cooling as the energy is simply the temperature of fluids, the process of moving those fluids efficiently and easily requires electricity. This means that an important aspect to take into consideration

when using GSHP systems is the electricity required to operate the heat pumps. The drilling that is required for these geothermal technologies has environmental implications which can be minimized as long as the process is done sustainably.

"*The sustainable development of geothermal energy implies that it is produced and used in a way that is compatible with the well-being of future generations and the environment"* (Manzella, Allansdottir and Pellizzone, 2019, p.15). Understanding the environmental implications of the use of geothermal energy can help in minimizing the risks by adapting to them. The environmental impact that geothermal energy technologies have on the environment is proportional to the scale of the exploitation and depth of the geothermal systems (Manzella, Allansdottir and Pellizzone, 2019). This means that shallow geothermal systems and deep geothermal systems can have drastically different environmental impacts. For shallow geothermal systems, there is less risk as they can avoid environmental impacts simply by adapting to elementary precautions. The general public has a hard time evaluating the pros and cons of geothermal energy systems because of the lack of information on the technologies and comparisons with other energy sources (Manzella, Allansdottir and Pellizzone, 2019).

The lack of knowledge is a core reason for why there has been increased debate around the sustainability of geothermal plants, which should be supported by social studies and public engagement in the geothermal sector. One of the biggest environmental risks of geothermal systems is thermal pollution when the rate of extraction is too high or the boreholes are misplaced. Outside of the operation of geothermal systems and the potential environmental risks that come with it, the most well-known effect on the environment comes from drilling the boreholes and installing the necessary infrastructure for the geothermal system to function. While the impact caused by the construction of geothermal systems is only temporary, there could be potential damage to local flora and fauna due to changes in surface morphology, as well as noise pollution for which the best solution is to avoid drilling close to urban areas and as quickly as possible (Manzella, Allansdottir and Pellizzone, 2019). Adapting to the environmental risks is the best solution to sustainably implement geothermal energy systems without compromising the future generations. In the following section, the role of geothermal energy is discussed in the context of Finland.

2.3 Energy transition and Geothermal energy in Finland

The energy transition in Finland is a very timely issue due to the historical high dependence on energy from Russia in the form of imports of oil and gas, where 67.7% of Finland's primary energy imports in 2016 were trades with Russia (Jääskeläinen et al., 2018). The geopolitical situation in rapidly changing in Finland due to the invasion of Ukraine as Finland applied to join NATO since they began to see their neighbouring country as a larger threat. This resulted in Russia completely cutting its trades with Finland. The sudden lack of imports from Russia and the pressure from EU's Green deal to become climate neutral by 2035 is pushing Finland to become more energy independent by producing more of its energy locally in means that are environmentally friendly. For Finland to achieve this energy transition, the Finnish government has also set a ban on coal-fired power and heating generation which is set to take effect on 1 May 2029 (Valtioneuvosto, 2019). Enforcing low-carbon and renewable energy systems will push for the further use of the already growing use of geothermal energy through ground-source heat pumps in Finland.

In 2019 the annual heat pump purchases made by individual people was worth 600 million euros, making it Finland's biggest investment in renewable energy (Hirvonen, 2021). Around 75% of single-family home builders in Finland choose a heat pump, where 50% are ground source heat pumps extracting heat from geothermal wells, thus harnessing geothermal energy which is renewable and very environmentally friendly. In 2019 heat is being extracted from 150000 geothermal wells (Hirvonen, 2021). The changing geopolitical situation is rapidly increasing oil and electricity prices, and as half a million people in Finland are using electric heating in addition to 50% of the Finnish heating market being comprised of district heating (Hirvonen, 2021) which runs on oil, many homeowners are starting to consider alternative heating methods, thus increasing the demand and growth of ground source heat pumps.

The next section presents the conceptual model which has been developed on the basis of the literature review to explain the pathways between the concepts

2.4 Conceptual model

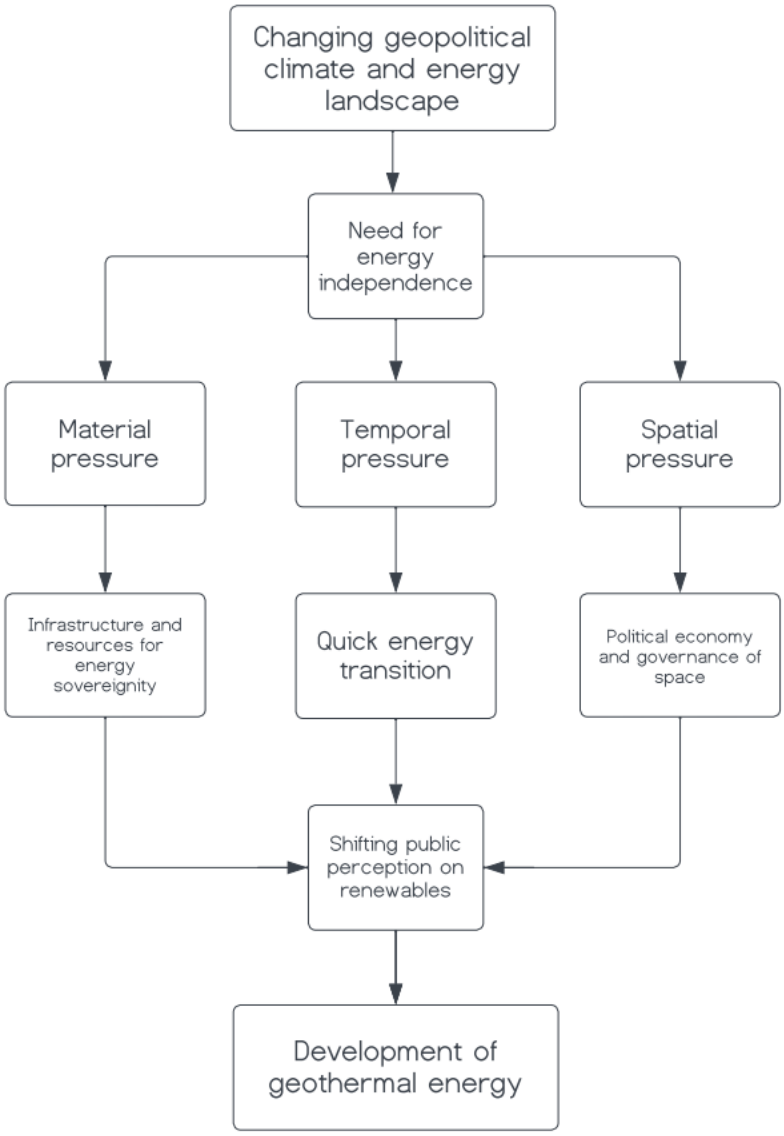

Figure (2): Conceptual model

Figure 2 represents how the changing geopolitical climate and energy landscape leads to the development of geothermal energy through three different coexisting pathways. As the geopolitical situation changes and there is an increased need for energy independence, material pressure builds up in the form of necessary changes or addition of relevant infrastructure and resources required to produce more geothermal energy. The temporal pressures that build up are more related to the timeframe in which energy goals need to be achieved, essentially how quickly changes to energy systems and energy use need to be made. The spatial pressures

which build up are related to spatial planning, where the governance of the space used for producing geothermal energy becomes increasingly important. As these three forms of pressures builds up and the relevant stakeholders, including the public begin to understand what needs to change in order to achieve further energy independence, the perception on renewables shifts, potentially resulting in the further development of geothermal energy as it can be seen as part of the solution to achieve total energy independence.

The conceptual model tries to explain the links between the concepts by showing some of the causal relationships between them. The literature and conceptual model are used to guide the research sub-questions by identifying certain elements that need to be analysed and discussed using the proper methodology.

The main research question of this study is "*How does the changing geopolitical climate and current public perception of geothermal energy influence its demand and growth as a renewable energy source in Finland?"*

The help answer the main research question, the following sub-questions are proposed:

A. *How does the current public perception of geothermal energy influence its development in the energy sector?*
B. *What role does geothermal energy play in the current energy landscape in Finland?*
C. *How has the invasion of Ukraine and Finland's application to NATO influenced Finnish energy independence?*

The next chapter explains the data collection and data analysis strategy and the reasoning behind the use of this methodology for answering the research questions. This also includes ethical considerations of conducting semi-structured interviews and a reflection on the aftermath of the data collection process.

3. Methodology

3.1 Data collection strategy

To answer the sub-questions outlined in section 2.4, semi-structured interviews are conducted with stakeholders and experts in the field of geothermal energy in Finland (see Table 1 for a list of respondents). In order to find participants for the semi-structured interviews on geothermal energy in Finland, it's important to identify stakeholders who have the knowledge or expertise to answer the questions found in the interview guide in appendix 1. The data collection strategy involved sending an email request to several stakeholders in the field of geothermal energy in Finland, explaining the topic of my thesis and requesting their time for an interview to gain their insight into answering the research questions. These stakeholders included; renewable energy groups, heat-pump associations, geothermal energy companies, academics researching geothermal in Finland as well as individuals from the ministries responsible for energy and spatial planning. The email request asking for the interview also included the option to answer the questions in a written format instead of an interview. The goal of the data collection was to get at least 10 interviews for sufficient data that is used for analysis and discussion. The purpose of the data collection strategy was to interview stakeholders of geothermal energy in Finland. This method of choosing certain interviewees based on what they have done or who they are is called elite interviews. The term ‘elite’ refers to an individual who has a powerful position that gives them unique knowledge from a privileged perspective (Natow, 2019). The elites that are relevant to this research are the previously mentioned stakeholders, as they can provide this unique knowledge that is valuable to the research. The concept of triangulation is important in research that involves elite interviews (Natow, 2019) as interviewing multiple elites to gain several perspectives on the same subject can help in creating a bigger picture of the researched topic.

Respondent #	Respondent background	Type and date of response (Interview or written response)
1	Fortum - Energy provider company in Finland	Interview - 21.6.2022

2	City of Helsinki - Geotechnical Division	Interview - 14.6.2022
3	Rototec - Geothermal energy pioneering company in Europe	Interview - 2.6.2022
4	SULPU (Suomen lämpöpumppuyhdistys - Finnish Heat Pump Association)	Interview 1.6.2022
5	Bosch - Heat pump manufacturer	Interview 13.6.2022
6	University of Turku researcher on sustainability transitions and renewable energy	Interview 7.6.2022
7	TEM (Työ- ja elinkeinoministeriö) - Ministry of Economic Affairs and Employment of Finland	Interview - 20.6.2022
8	Motiva - State-owned sustainable development company	Interview - 30.5.2022
9	Suomen Lähienergialiitto - Finnish Clean Energy Association	Written response - 13.6.2022
10	University of Helsinki researcher on the use of geothermal energy in Finland	Written response - 26.6.2022

Table 1: Descriptive table of respondents

3.2 Data analysis strategy

The audio recordings of the interviews are transcribed using the software “Descript” which automatically transcribes audio files into text. After this automatic transcription, the transcripts have to be checked once more for any mistakes to make sure that the transcript is correct. The software also allows the user to easily remove filler words from the transcript that makes the overall process of transcribing easier. Interviews that were conducted in Finnish were translated using “DeepL Translator” and were checked once more manually to avoid any mistakes in

translation. After the interviews are transcribed, they are coded and analysed using “Atlas.ti”. The purpose of coding the transcripts is to be able to highlight key parts of the text that refer to important points of discussion for the analysis of the interviews. By coding each of the interviews the data analysis process becomes much easier especially when providing quotes from multiple interviews. Once the interviews are transcribed and coded the most important quotes that are relevant to answering the research questions are presented and discussed in relation to the literature review and conceptual model. The interview guide found in Appendix 1 included questions that are similar to the subquestions outlined in section 2.4 which helps in the coding and analysis when comparing the interviews between each other for the discussion chapter.

The main codes that are used in Atlas.ti to highlight key parts of the interviews are as follows; “energy landscape”, “energy transition”, “public perception”, “role of geothermal”, “energy independence” and challenges relating to energy “material”, “spatial” and “temporal”. These codes help identify the key points of discussion that are used to answer the research questions.

3.3 Ethical considerations

Conducting ethical research is essential for protecting the rights, welfare and dignity of those taking part in the research (Lillie and Ayling, 2020). When sending out emails to potential interviewees, the email included the consent form found in appendix 2 which informs them of the use of the interview for research purposes. Before each interview began, verbal consent was asked if it was to record the interview. After receiving this consent and the recording started, the interviewees were asked for verbal consent concerning the use of the interview for research purposes, followed by the full interview.

3.4 Reflection on data collection

The data collection process of trying to obtain atleast 10 interviews, including written responses was initially quite a slow process as most of the emails sent requesting for interviews received no responses. Many of the respondents also suggested several other individuals that I could potentially contact, which snowballed the rate at which I could organize interviews with respondents. This greatly helped the outcome of trying to obtain at least 10 responses that would be sufficient for further discussion. Another interesting factor of the data collection

process was that when I initially reached out to possible interviewees who were all from Finland, I had mentioned that I would prefer to do the interviews in English as I was more comfortable with talking about the topics in English, however I did offer the option of giving responses in Finnish as well which resulted in a couple of the responses being in Finnish. Conducting the interviews in Finnish language was initially a challenge for me as I found it hard to elaborate on certain discussion points, but this was an interesting challenge of the data collection process.

The next chapter presents the results of the semi-structured interviews. This consists of showing the most important results of the interview that can then be used to help answer the research questions. To help present the most important results from the semi-structured interviews and written responses given by respondents, the questions used in the interview guide (appendix 1) are used as the basis for the sections in this chapter. The following section focuses on respondents' views on geothermal energy landscape in Finland. After this I present their views on public perception to be followed by their visions on the challenges for energy independence brought forth by the invasion of Ukraine. Finally, the chapter ends with the respondents' views on temporal, spatial and material challenges of heat pump driven energy transition in Finland.

4. Results

4.1 Geothermal energy landscape of Finland

Respondents were asked about the current geothermal energy landscape in Finland and the extent to which geothermal energy is used in the country. Many of the respondents talked about how the use of geothermal heat through heat pumps has rapidly grown in Finnish energy use. Respondent 10 (26.6.2022), a researcher on the use of geothermal energy in Finland gave some statistics about the use of heat pumps in Finland's energy needs.

> "In total, heat pumps currently produce about 2% of Finland's energy needs. I cannot say exactly what role geothermal heat plays in this. Heat pump energy (ambient energy) accounted for about 9% of residential energy consumption in 2020."

Several respondents mentioned of the future targets set by the city of Helsinki for the use of geothermal energy for heating. Respondent 5 (13.6.2022) who is a heat pump manufacturer mentioned:

> "area of Helsinki it's like a 1.6% of properties are heated by geothermal and they want it to be in 20% in 2030. So that's huge boost of our industry and geothermal very much."

Many of the respondents talked about the growth of geothermal as a main source of heat for buildings since the early 2000s, mentioning how it has become the most used heat source for detached houses. Respondent 6 (7.6.2022) who researches sustainable energy transitions and renewable energy explained how heat pumps have become part of Finlands energy landscape:

> "So the big change in attitudes with regards to heat pumps has happened during the last 15 or so years, I think in 2010 or around there, ground source heat pumps became the most popular way of producing heat for detached house. So more than 50% of house builders at that time started to opt forground source heat. And so then it first started, the popularity of ground source heat in detached houses. So people building homes for themselves but also quite suddenly then larger buildings came in and nowadays when well for instance if a large office or industrial facilities being built. Quite often, well at least ground source heat is among the options you choose the heating option for your building. Of course in more urban areas it's district heating that still attends to dominate, although it's facing some problems also due to high energy prices. So the way ground source heat is seen in Finland, it's very positive. Nowadays it's well known. There's nothing that sort of, the kind of uncertainties that tend to label new forms of energy. They don't exist anymore for ground source heat in Finland."

In addition to this understanding of the use of geothermal energy in Finland, respondents were asked about the role of geothermal energy in Finnish energy demands both in the present and the future.

Respondent 4 (1.6.2022) who is part of the Finnish Heat Pump Association highlighted the importance of heat pumps and the role which they will play in the future:

> “First of all, this role of heat pumps will be bigger and bigger in every market. And because we must get rid of fossil fuels. And in long term, we have to get rid of burning, all kind of burning, also bio mass. It is renewable energy source, but in huge, it is less and less renewable cause all kind of restrictions are coming. So, we have to electrify the heating system. That means that practically we have to use heat pumps for that and all those energy which we have surrounding houses to get all waste energy in use. So this boom for heat pumps is huge in our country. It is in whole Europe. And if you look this EU targets today, we have to triple or, or three or four times bigger this market in eight years.That is a target”

Several respondents mentioned the competition between the growing use of shallow geothermal energy and heat pumps and the traditional district heating methods that are widely used in Finland. When asked about why the role of ground source heat pumps is the way it is in Finland, respondent 6 (7.6.2022) explained:

> “Of course there are these underlying factors that it's, you know perceived as easy to use, it's reliable and that wasn't the case something like 15 years ago, but yeah I'd say the most important thing at the moment is that it's affordable, the energy produced by ground source heat, it's affordable and specifically in larger buildings that are located outside district heating networks. I'd say almost everyone. If they're building a new building or renovating an energy system. I think that's the you know, go-to choice for that kind of buildings. As for buildings in areas where district heating is available, I think there still are building owners or builders who choose district heating, but depends a lot on the price level of district heat in that particular area. Cause well, in Finland, the district heating networks, they are operated by local energy companies and they might have a big differences in what fuels they use to produce that energy. So for instance, there's been a lot of debate on and a lot of articles in the press, how expensive the district heating is in Helsinki region. Because they've sort of have trouble with the big, large amount of coal in their energy mix in their district heating. Whereas here in Turku region, I think it's nowadays 100% biofuels and large heat pumps also. So I think in Turku region, the price of district heating is more expensive than the Finnish average. But I know that large buildings still here tend to opt for district heating at times. So there might be different reasons than just the price at this particular point in time.”

After gaining an understanding of geothermal energy in Finland, the respondents were asked about the public perception of geothermal energy in Finland which is discussed in the following section.

4.2 Public perception of geothermal energy in Finland

Respondents were asked about the current public perception of geothermal energy in Finland by asking “why” the perception is the way it is, and what can influence this perception. All respondents confirmed that the public perception of geothermal energy in Finland is good. One of the key reasons for this good public perception is because of how geothermal heat has become a very well known heat source due to many good examples of its use concisely mentioned by respondent 9 (13.6.2022) who is part of the Finnish Clean Energy Association:

> “Heat pumps have a good image and are very well known, because they are very common. Also the financial aspects (cheaper than fossil fuels) and climate change aspects increase their popularity.”

The main reasons for “why” this public perception is good relates largely to affordability and environmental factors as explained by respondent 6 (7.6.2022):

> “Finnish energy industry does this very large polls on energy attitudes of Finns and what I remember there, it's quite often it's the affordability. And also that whatever energy source used, it's reliable. Then also of course the environmental factors they atleast, if I remember correctly, you need to look the results up yourself. But I think these environmental factors, they play a big role, but well, sometimes there seems to be a bit of discrepancy there between what people state in polls. And then when they are, for instance, making a choice on what type of energy they will, you know, purchase from an energy company. They often tend to choose the most inexpensive one. So perhaps the more expensive options even if they were not produced with the more environmentally friendly methods might not get selected. So I think it's first and foremost, the affordability then.”

The affordability of heat pumps comes from their potential efficiency in heating for a long term period with low costs. The drawback of shallow geothermal heating solutions however is the initial investment costs as discussed by respondent 8 (30.5.2022) who is part of a sustainable development company:

> “The image of shallow geothermal heat is good. The general perception of geothermal heat is good. It is considered to be quite ecological and economical to use and mainly its investment costs is what then perhaps a little limit in a way, or I do not know whether even the investment costs of the growth now so that there is currently the order books may be full of companies and drilling equipment that is found in Finland is quite active use, but so far, however, air-source heat pumps eat in a certain way the share of geothermal heat because of the lower investment costs. With lower efficiency and higher consumption peaks but lower investment costs. So geothermal heat is very abudant, and of course it is a site-specific question of what is the most economical form of heating for the life cycle. It depends on many factors.”

Subsidies given by the government to change from traditional oil burners to heat pumps also reinforces the affordability aspect of the public perception of geothermal as explained by respondent 5 (13.6.2022):

> “The one reason is that government is giving a subsidies. If you are changing now your oil burner to heat pump, you can get tax relieves and this kind of subsidies that's the main driver to go that direction. And the other reason of course is our, Eastern neighbour Russia and what they are doing and oil price is rapidly growing.”

Respondents were also asked about the potential influence that this public perception can have on the development of geothermal energy technologies. All of the respondents thought that the good public perception of geothermal boosts its development as an energy source as explained by respondent 4 (1.6.2022):

> “It is absolutely boosting. We are are someway quite lucky because we have not so much technological challenges here. It is quite ready technology. Technology is available. It is reliable and it is just how to increase the market. How to make the market and then how to arrange enough companies which are offering this, this technology. So of course it's a

> communication thing. Also, how you communicate that with your clients, politicians, society, and that there is a big role for heat pump associations."

The good public perception of geothermal energy in Finland reinforces the role which it will play in the future of heating in Finland as mentioned by respondent 9 (13.6.2022):

> "Heat pumps and geothermal energy are considered as the heat of future, so their popularity and use will continue to increase."

In the next section, the results relating to the impact of the invasion of Ukraine are presented through multiple perspectives.

4.3. Invasion of Ukraine and energy independence

After gaining an understanding of the energy landscape in Finland, participants were asked how the changing geopolitical climate due to the invasion of Ukraine and Finland applying to join NATO has influenced the energy landscape and energy independence. All respondents mentioned how energy independence has increased due to the changing geopolitical climate. Respondent 3 (2.6.2022) who is part of a geothermal energy pioneering company explained this increase in energy independence:

> "I will say it has. Definitely increased or I don't know it, I think it make it quicker because everybody's now talking more about that we should be energy independent and we should, you know, sit on our own energy and everybody knows. I don't think that we will turn back, if Putin goes away and there will be another leader, I think this is irreversible. I don't think that we have a pretty long memory. I don't see a scenario where 2024. We would you know, start to build a bigger north stream gas pipe or anything. I think that's in the past, and now we are looking into the future"

Many of the respondents mentioned that Russia has stopped importing oil and gas to Finland, which accelerated Finland's energy independence. Respondent 5 (13.6.2022) mentioned this change in energy imports from Russia:

> "Very strictly because now Russia cut out the gas supply in Finland and there is no Russian gas anymore used in Finland. And I think that Finland has been getting benefit of Russian oil getting little bit cheaper than other countries, but now it changed. Now, we are 100% out of that. And yes, that will and it's already in people's mind that nobody wants to fill the car in their Teboil chain owned by Russians, it seems everywhere that nobody wants that anymore because the way they are behaving"

An important part of Finland becoming more energy independent because of the Ukrainian crisis as mentioned by one of the respondents, is that the changing geopolitical climate is not the sole reason for why Finland aims to become more energy independent as they are already aiming to do so, however the crisis is accelerating the rate at which Finland transitions to become more energy independent. Respondent 1 (21.6.2022) who works for one of Finland's largest energy

providers, explained how Finland is becoming more energy independent also emphasizing the fact that the geopolitical situation is accelerating Finland's energy independence rather than creating it:

> "If you ask me or other millennials, many of the things that we are now accelerating within Finland to become more energy independent or less reliant on Russian fossil fuels, or fossil fuels in general. I think millennials have been demanding that kind of development on an accelerated level for years, if not a decade. But now this war has basically brought everyone on the same page with the required speed. It's not that millennials knew that invasion would be coming, but kind of the same trend applies. If you buy a lot of fossil fuel imports, you are sending money out of the country and relying on then some external suppliers. So over time obviously, that's not an attractive proposal, if you ask me it wasn't before the invasion, it's less so after it. So certainly all the investment decisions and strategic plans should now be heavily in line with what's happened this year. But for us, for example, we are lucky to greatly already have been on the path to reduce the dependence because we have our decarbonization plans and commitments to be carbon neutral by the end of the decade. So many of the investments that we have been wanting to do, they have already been on the pipeline."

Respondent 2 (14.6.2022) who works for the City of Helsinki, explained how Finland would be in a similar situation regardless of the Ukrainian crisis:

> "I don't know if I have anything to add it, but it's a situation that we must have. Some new solutions. And without this Ukrainian crisis, we would still be in almost the same situation. But this is some something that makes us make these decisions much quicker."

When asked about how the changing geopolitical climate has influence Finland's energy transition, respondent 7 (20.6.2022) who is part of the Ministry of Economic Affairs and Employment in FInland also talked about how the situation speeds up the energy transition process and how new solutions need to be made for industries that rely on gas:

> "It probably speeds up the fact that we have renewable energy targets and energy efficiency targets in the EU, we are there at the top, now we have really reached our own targets and clearly already ahead of schedule and so as it is just related to the fact that all the time we have been thinking about alternative ways to produce energy and move away from fossil fuels faster and faster, but of course this speeds up the process, because if we have thought that it can be done gradually as we go along, we will replace the fossil fuels with renewable ones, but now of course this speeds it up, which means that we need to find solutions more quickly, for example for those areas where natural gas has been used in bakeries and other places where it has been used, and we need to find new solutions. One of the things we talk about a lot is the electrification of industry, so using electricity as an alternative in these areas"

Respondent 8 (30.5.2022) also explained regardless of the changing geopolitical situation, Finland has different solutions to address the energy transition such as the frequently mentioned "Olkiluoto 3" nuclear power plant also aids Finland's energy independence:

> "Yes, it speeds it up, let's put it this way, that here there has been going on this energy breakthrough, despite the geopolitical situation, it just accelerates it. Finland has been in an exceptionally good situation, precisely because we have such large investments in wind power coming and then Olkiluoto 3 and it is now getting up to full speed, probably in the autumn, so it does make it much easier in terms of electricity this issue that the most challenging of all is gas, its

> replacement, but there also came a rented floating terminal. A large terminal vessel that is practically capable or by the end of the year will be able to replace Russian natural gas completely. And yes there will be a solution to that but they say that the cold early winter may be that it may bring its own challenges. Very quickly we will be able to replace the Russian gas with much more expensive gas and that will put pressure on prices."

Respondents also explained the implications that this changing geopolitical climate can have on the development of geothermal energy technologies through the temporal, spatial and material challenges that Finland faces as a result of the changing geopolitical climate. These challenges are presented in the next section.

4.4 Temporal, spatial and material challenges

The final part of the interview consisted of asking the respondents about the different types of challenges that the energy industry in Finland faces due to the changing geopolitical climate and the need for further energy independence.

When asked about challenges the energy industry in Finland needs to overcome because of the need for energy independence, Respondent 5 (13.6.2022) explained how energy use cannot grow anymore and that for the energy industry to grow, solutions need to be made that don't involve using more energy:

> "We generally I think that we in land of Finland, we have to accept that energy use of energy cannot anymore grow . So we have to find better solutions that the energy use is not growing anymore because it's getting more and more expensive. It's getting more and more difficult to produce. It's getting more and more of a political thing. So of course there is always this kind of enforcement and solutions that for example you don't have to drive so fast. You can set down your electricity when you are leaving home, you don't leave the lights on and don't use any energy so much. I think that is what we are now have to face and have to find the solutions. That everybody have to think that, okay, we have to find the growth somewhere else than use more energy."

The respondents were specifically asked about temporal, spatial and material challenges relating to the use of geothermal energy and energy independence. When the respondents were asked about the temporal challenges that Finland faces, many of the respondents mentioned the carbon neutrality goals of 2035, as well as the coal ban law in Finland that takes place in 2029 as mentioned by Respondent 1 (21.6.2022):

> "Well, the carbon neutral target 2035 is of course one. Then we have a coal ban in law by 2029."

Respondent 4 (1.6.2022) also mentioned the carbon neutrality target setting the temporal challenge for Finland to achieve energy use targets:

> “Of course we have this carbon neutrality neutrality target 2035. And we want to be the first country in the world, atleast in Europe, carbon natural. This is a good target, but today our situation is not so, good. We are not so independent of Russia not so independent of also fossil fuels. We are changing it quite fast.”

Another temporal aspect that many of the respondents discussed was how the changing geopolitical situation is accelerating Finland's energy independence due to the lack of gas and oil imports from Russia as mentioned by respondent 5 (13.6.2022):

> “Temporarily because the Russian cut out the gas. We have 11,000 properties without energy source now. We are getting something with that Eastern Estonia pipeline, but that's not enough. And there is coming this LNG boat storage tank, in Estonia. And we are getting something out of that. But that's fast what we have to do, 11,000 properties are on end of gas pipe. So, that's first thing that we have to decide and do something.”

When discussing the spatial challenges that Finland faces, many respondents discussed the spatial limitations of geothermal energy, especially in urban areas where drilling geothermal wells close to each other can be problematic as explained by respondent 6 (7.6.2022):

> “And of course there's also in densely built areas. There's only so many energy wells where you recover the energy that you can drill in one particular area so that they won't sort of extract heat from each other. So that's sort of a spatial limitation and that creates some challenges of especially using a lot of ground source heat pumps in densely populated areas. Well, our cities, they're not like cities in central Europe or in Asia. So we usually have a lot of space, but this underground building and plans for building something underground, they are sort of something that affects use of ground source heat in urban areas.”

The city of Helsinki has come up with solutions to overcome these spatial challenges that come from drilling geothermal wells close to each other as mentioned by respondent 3 (2.6.2022):

> “Helsinki has already granted all the public areas to be used as a geo geothermal.… Helsinki has already decided, and they already give permits so that you can really, you know, drill with an angle in the public areas. So when you look at in Helsinki you can't see anything, but all the nearby houses have, drilled 500 meters in. And you'll get tax money more from it becaus, otherwise you don't need the space. You will have a carbon neutral building. So, this is a really, you know, win-win situation to do that. And also previously it was impossible to drill, for example, near the subways. But now we can drill, for example, there's 50 meters that you can drill you know, with an angle. … so there is really no hinders to get Helsinki, you know, into the geothermal 100%”

Another spatial challenge relates to spatial planning and zoning rights that are necessary for the further development and use of geothermal heat pumps as mentioned by respondent 4 (1.6.2022):

> “One speciality is all kind of permissions, permission bureaucracy. It is really challenging. It is very slow. It is lack of resources there. Maybe we have to change some laws and, and regulation for, for all kind of this new system and renewable energy system. And that is really, really challenging situation that, although we have a business, we have the sales, but we have no permission to drill.”

And also mentioned by respondent 1 (21.6.2022):

> “For example, with our strategic plan, the biggest bottlenecks are with electricity supply and available land and right zoning.“

Helsinki has made progress regarding the zoning and drilling laws that has allowed for the increase in the use of geothermal heat pumps in urban areas as mentioned by respondent 2 (14.6.2022):

> “So one of the solutions is that we do deeper bore holes. But then there is also today, there is a possibility to use the street areas, the park areas, green areas, it used to be not possible, but today it is. And that is the work I've been doing now the last one and a half year. And doing also at the moment, how to make it possible.”

The material challenges relating to the use of geothermal energy was one of the most widely perceived challenges by the respondents which has been influenced by the war in Ukraine as mentioned by respondent 7 (20.6.2022):

> “Of course, it also applies to everything other than geothermal and shallow geothermal heat, but all the raw materials and machinery, accessories, equipment that are imported from abroad to Finland, so they can be associated with price increases and then availability becomes difficult. That is one of the messages we have heard constantly from the field, and it has been the impact of this war.”

The use of steel in geothermal energy technologies is also causing a material problem as the crisis is causing steel prices to increase as explained by respondent 3 (2.6.2022):

> “It of course get more expensive because we use a lot of steel. So the purchases for the steel has gone up three times, in a year, the purchase price. So if the crisis continue, we might see that it takes, we could lack, steel pipes for some time, but, we really need it. So we'll get it with money.”

The growth in the demand for geothermal heat causes several material challenges including the equipment and the workforce necessary for its growth as mentioned by respondent 8 (30.5.2022):

> “It can be certain kinds of challenges in terms of geothermal heat, for example, that if the demand for geothermal heat will grow so much that even in Finland, for example, at some point the existing drilling equipment capacities will be reached so the impossible can not be done, but also the workforce.”

One major material challenge is the lack of people with sufficient training and knowledge in drilling and planning new geothermal wells which is essential for the growth in the use of heat pumps which was discussed by respondent 4 (1.6.2022) as a lack of human resources:

> “Of course this human resources like drilling guys, installing guys, planning guys, space guys, entrepreneurs. We have, there could be more, but it's very difficult to educate them by public systems. So it is some kind of market economy, which

> makes, if you have a lot of demand, there comes entrepreneurs and they will be some way acquiring this knowledge to how to install and so on."

This lack of human resources was also mentioned by respondent 2 (14.6.2022):

> "of course we have a lack for laborers. Of course those from Ukraine, they are doing another job that they used to do in, Finland and we used to have lot of Russians. And today it's also a lack of human resources."

Respondent 6 (7.6.2022) also discussed this bottleneck of human resources to further grow the use of heat pumps:

> "The sort of the bottleneck, at least how, how it appears to me with well, any heat pump install, installing any heat pump is the availability of skilled personnel to do the actual, you know design and and install work. but even that's, you know, that's, manageable. And then the sort of delay that you have from ordering heat pump system you know, to the day you really get it."

The material challenge in the lack of heat pump production leading to long waiting times is therefore also a temporal challenge as there are long waiting times to get components needed to drill geothermal wells as mentioned by respondent 3 (2.6.2022):

> "Well, it, I can say at this moment, it's just scaling up. It's just, it's hard work. It's rough drilling work and one bottleneck is the component, the lack of components. Cause if I now order five units, a truck and a drill compressor and a drill it takes one year to get them."

As well as respondent 4 (1.6.2022):

> " We already have queues waiting for heat pumps. We have delivery times of half a year to one year. "

Respondent 5 (13.6.2022) explained this long waiting times to be the result of a supply chain crisis:

> "now in this point, in this moment, we are middle of crisis of supply chain. Because of war because of lack out of components because of semiconductors these small chips are finito all over the world and raw materials like metal or whatever is now, it's not easy to find. Supply chain is broken. This global supply chain It's not what, what it used to be. So demand of market. Every market is growing rapidly and then there is no, no you may heard that if you are now ordering a new car, then it's over a year time. But it's the same to heat pumps yeah half year deliver times"

The next chapter begins to answer the research questions by going back to the conceptual model and literature review while relating them to the results found from the empirical research. To help answer the main research question, three sub-questions were proposed at the end of the literature review which were the result of the background research and the conceptual model seen in figure 2. The data in the results section support this conceptual model in showing

the causal relationships and effects between the changing geopolitical climate and energy landscape and its influence on the eventual development of geothermal energy. Therefore the next section discusses how the results relate to the literature review and conceptual model referring back to those sections and whether any new information has become apparent.

5. Discussion

5.1 Role of geothermal energy in the Finnish energy landscape

Many of the respondents gave statistics on the use of heat pumps in Finland's energy needs and explained how heat pumps have become an important part of Finland's energy landscape as ground source heat pumps are becoming the most popular way of heating for detached houses and more and more house builders are choosing to opt for ground source heat as the primary heating source which is similar to the growing investment in heat pumps in Finland (Hirvonen, 2021).

The general consensus was that the role of heat pumps will only get bigger as there must be changes what kinds of energy sources can be used, primarily that the use of fossil fuels must be reduced and renewables need to be more utilised. This also relates to the EU energy targets which apply temporal pressure as seen in the conceptual model, and thus further push the need to develop the use of geothermal energy.

The shifting role which geothermal energy and heat pumps have in the Finnish energy landscape is largely related to its main competition in district heating, which still is the main heating source, especially in urban areas due to spatial pressure which was also discussed by Hirvonen (2021) . Changing energy prices causing district heating to be more expensive and the growing use and positive association with ground source heat pumps is directly influencing the growing role of geothermal energy and heat pumps in the future of Finland's energy landscape, thus further accelerating the development of geothermal energy in Finland. The growing use and positive perception of ground-source heat pumps has a large role in this, which is discussed in the next section.

Answering the sub-question "*What role does geothermal energy play in the current energy landscape in Finland?"*, geothermal energy is a rapidly growing part of Finland's energy landscape, as ground source heat pumps as a main source of heating are increasingly being used over the historically dominating district heating systems that use fossil fuels. Geothermal energy usage by ground source heat pumps being a renewable energy source, with long term affordability benefits along with increasing energy prices means that the role which geothermal energy will have in the future of Finland's energy landscape will increase in the energy transition as the usage of fossil fuels decreases to meet EU energy targets.

5.2 Public perception and development in the energy sector

The results here were similar to the literature review, mainly how the growth in the use of heat pumps has been due to the affordability of heat pumps in being able to heat over a long period of time with relatively very low cost, and further supported by environmental factors due to its positive environmental image and renewability. These factors result in the positive public perception of ground source heat pumps, causing more people to choose this type of heating source, and then consequently setting a good example for other people to also adopt this energy source. The shifting public perception on renewables also leads to the development of geothermal energy, which was also shown by the conceptual model in figure 2.

Answering the sub-question *"How does the current public perception of geothermal energy influence its development in the energy sector?"*, the public perception of geothermal energy in Finland is very positive and growing more positive as the use of ground source heat pumps is rapidly growing especially in properties outside densely built urban areas. The long-term affordability and environmental benefits that ground source heat pumps have, give the technology a very good public image, and as more households are choosing to use heat pumps as their primary heating source, its setting a good example for other households who hear about the positive experiences and long term affordability that they can provide. This is causing the public perception of these heat pump technologies to strengthen over time, which consequently cause also increases the overall use and development of geothermal energy in the energy sector.

5.3 Invasion of Ukraine and challenges for energy independence

The conceptual model tries to show how the changing geopolitical climate created a need for energy independence which then creates material, temporal and spatial pressures eventually leading to the development of geothermal energy. The invasion of Ukraine refers to the changing geopolitical climate in Finland due to the history and geographical context behind Russia and Finland. Historically Finland has imported large amounts of oil and gas from Russia, which has recently ceased as a result of Finland applying to join NATO due to the security threat of sharing a large border with Russia and the willingness of Russia to invade neighbouring countries. This sudden lack of energy imports created a further need for Finland to achieve energy independence as shown in the conceptual model. This changing geopolitical situation did not “create” the need for energy independence, but it rather accelerates it as EU energy targets have already created the need for countries to become more energy independent. The results in section 4.4 present this acceleration in energy independence due to becoming less reliant on Russian fossil fuels.

The temporal, spatial and material challenges that Finland faces due to the changing geopolitical climate and acceleration of energy independence, relate to the same three types of pressures presented in the conceptual model. The temporal challenges presented in the results mostly relate to the energy transition and the time pressure that comes from the sudden lack of energy imports from Russia. This change has an effect on the energy transition of Finland, and how quickly it needs to be achieved, which is also largely related to the EU climate and energy use targets, as well as the carbon neutrality targets set by Finland. By setting goals with specific deadlines, temporal pressure is inherently applied as timescales of reaching carbon neutrality is linked to socio-political movements and action (Marquardt and Delina, 2021). The meaning of the energy transition already implies the temporal pace at which that transition takes place, and therefore the speed at which the energy transition takes place is a crucial factor in meeting energy use and emission targets (Delina and Sovacool, 2018).

The spatial pressures as presented in the conceptual model are related to the political economy and the governance of space. This aspect of governance of space was apparent from the results as the spatial limitations of geothermal energy in urban areas is a challenge for Finland to overcome if they want to further develop and increase the use of geothermal energy. The

main problem with the use of ground source heat pumps in urban areas is the spatial limitations of drilling geothermal wells close to each other, however, both technical solutions and regulatory solutions made by spatial planners are making rapid progress, especially in Helsinki to allow for further use of ground source heat pumps in the densely built urban areas. As the shift from fossil fuels to renewable energy types such as geothermal heat takes place, it also means that the land-use requirements behind this energy production change and is therefore important to take into account and plan accordingly (Huber and McCarthy, 2017).

The material pressures in the conceptual model and the material challenges presented in the results were similar as they are related to both infrastructure and resources necessary for the production of geothermal heat pumps. The results stated that the material challenges are perceived to be one of the biggest limiting factors in the further use and development of geothermal energy in Finland, which has also been an impact of the invasion of Ukraine. The increased price of steel which is used in ground source heat pumps to deliver geothermal heat has been a result of the invasion, as Ukraine is one of Europe's largest steel exporters, thus it is making geothermal energy more expensive to implement. As the growth and demand for ground-source heat pumps is rapidly growing in Finland, it is becoming increasingly difficult to meet those demands in terms of both physical and human resources necessary to install ground-source heat pumps. One of the most discussed points in the interviews was the lack of human resources, such as the people capable of drilling, installing and planning the use of ground-source heat pumps in Finland. In addition to this, there is a lack of heat pump production in all of Europe leading to long waiting times to get heat pumps, or the components needed to drill geothermal wells, making it difficult to meet the increased demand for geothermal energy in Finland. Materiality of energy is a crucial part of changing energy systems to adopt more renewable energy sources while abandoning fossil fuels (Moss, Becker and Gailing, 2016) as adapting new technologies is a part of the reorganization of energy systems.

Answering the sub-question “*How has the invasion of Ukraine and Finland’s application to NATO influenced Finnish energy independence?”*, the changing geopolitical situation in Finland as a result of the invasion of Ukraine and Finland’s application to join NATO has accelerated the rate at which Finland wants and needs to achieve energy independence. The geopolitical pressure has not created the need for Finland to achieve energy independence, as it only accelerates Finland’s energy transition. This acceleration and changing geopolitical situation has also caused temporal, spatial and material pressures and challenges for Finland to

overcome. The main challenges for Finland to achieve energy independence are that of a quicker need to change the energy sources Finland uses due to a sudden lack of imports of gas and oil from Russia which Finland has historically depended upon. For the energy transition to take place and for renewables such as geothermal heat pumps to become more widely used, spatial planners and lawmakers need to work together to change zoning rights for an increased usage of ground-source heat pumps in urban areas. Along with the increased demand of ground source heat pumps, the biggest challenge as a result of the invasion of Ukraine is the material problem of increased steel prices in Europe as Ukraine is one of its largest exporters and the lack of human resources and equipment in planning and drilling new geothermal wells to achieve energy independence.

The following chapter concludes the research by answering the main research question of the thesis based on the results and discussion chapters. The societal and academic implications of the research is then discussed, followed by the strengths and weaknesses of the research and how they influence the validity of the results. Finally, some future research recommendations are made that could be used to draw different conclusions relating to the same subject.

6. Conclusion

6.1 Answering the main research question

This thesis investigated the research question *”How does the changing geopolitical climate and current public perception of geothermal energy influence its demand and growth as a renewable energy source in Finland?”* using qualitative methods by conducting elite interviews with individuals who have knowledge, or are part of the energy industry in Finland. The interviews focused on the use of geothermal energy in Finland, and how the invasion of Ukraine followed by Finland’s application to join NATO has influenced Finland’s energy landscape and the use of geothermal energy. To answer the main research question, the changing geopolitical climate, or more specifically the invasion of Ukraine has increased the demand and growth of geothermal energy through the use of ground source heat pumps. As a result of Finland applying to join NATO, Russia the trade of oil and gas with Finland has been cut off, increasing the need for energy independence requiring Finland to produce more of its energy locally. In addition to the sudden lack of imports of energy, the EU’s climate neutral targets of 2035 and Finland’s coal ban on 2029 is further pushing Finland to use more renewable energy sources, of which ground source heat pumps are the largest growing source of energy for heating. While the demand and growth of ground source heat pumps is rapidly growing as Finland is trying to reduce the use of fossil fuels, challenges arise of temporal, spatial and material pressures as they are a part of the inevitable energy transition to meet energy use and emission targets set by the European Union. The need for energy independence that is influencing the growth in the use of ground source heat pumps was not created by the changing geopolitical situation, as it is only being accelerated by it. The main challenges that Finland faces limiting the growth of geothermal energy in Finland are material challenges in the lack of heat pump production, increasing prices of steel, lack of human resources and equipment required for planning and drilling new geothermal wells. Next, the societal and academic implications of this conclusion are introduced.

6.2 Societal and academic implications

The societal and academic implications of the conclusion of this paper are centered around creating debate and discussion around the impact which the invasion of Ukraine has had on the energy landscape. By understanding the implications of the changing geopolitical situation in Finland and the challenges that the energy industry faces as a result, the energy industry can better adapt to the situation by having this greater understanding which can help the society improve on itself. Therefore the societal implications of this study come from helping society better understand why and how the energy landscape is changing, and perhaps what can be done better going forward with the energy transition.

The academic implications of this study revolve around the further use of the unique perspectives on the implication of the changing geopolitical in Finland which were provided by this thesis. The results of this research can help further academic research on a similar topic, as for example this research helped create a basis for other academic research to compare the implications of the invasion of Ukraine on countries other than Finland. The results of the interviews can be used in academic research in combination with quantitative research which is further discussed in the future research recommendations as the academic implications of this study are strongly linked to further academic research.

6.3 Strengths and weaknesses in relation to the validity of the results

The diversity of the respondents for the empirical research is a strength of this paper that strengthens the validity of the results, as the more perspectives used in this type of qualitative research, the bigger the overall picture the results can portray. The limitations of this research stem from the lack of focus on the impact of the changing geopolitical situation on Finland’s energy landscape. The validity of the results could be better if the research and interviews would have focused more on new issues that have been the result of the changing geopolitical situation, and what the interviewees think should have been done to solve them. Future research recommendations which are discussed in the following section could also help fix some of the limitations of this study.

6.4 Future research recommendations

Future research on this subject that would be interesting could be a follow-up quantitative study on the change in energy attitudes of citizens as a result of the invasion of Ukraine as well as quantitative research on energy consumption before and after the invasion investigating whether the impact on energy consumption as a result of the invasion. These should be based on previous research that has been done before the invasion, and then conducted in the same manner after the invasion for a proper comparison.

Further qualitative research could also be conducted on whether the changing geopolitical has influenced the energy habits and attitudes of normal citizens. Rather than conducting elite interviews, it would be interesting to see how the opinions of everyone have been influenced regarding the need for energy independence. The next and final chapter reflects on the entire research process, answering what could have been done differently and what also went well.

7. Reflection

This final chapter of the thesis reflects on the research process by pointing out what went well and what didn't, what could have been done differently in hindsight and whether the outcomes appear convincing. The process of finding interviewees went well during the research process, as many of the respondents to the email asking for an interview respondent with contacts of other potential interviewees which snowballed the number of individuals I could approach. Conducting the interviews also went very well as they lasted longer than I had initially anticipated since many of the interviewees had very elaborate answers to the questions asked which made for a nice discussion. The length of the interviews and the translation process of the interviews that were conducted in Finnish was very time-consuming which is an aspect that perhaps didn't go so well during the research process. This time-consuming process in addition to my slow pace of writing resulted in needing additional time to finish the entire thesis.

This thesis attempted to answer a very broad research question, hence looking at the entire thesis and the research process in hindsight, I could have focused the research more on the impact of the invasion of Ukraine on the energy industry as it is very relevant today, and perhaps left out parts that were on the public perception of geothermal energy. The outcomes of the thesis do appear convincing to me when looking at the outcomes as a small piece of the whole discussion on the changing geopolitical situation and its effects on geothermal energy in Finland. However, drawing any factual conclusions from the outcomes is difficult which might make the answers to the research questions less convincing.

References

Appel, H., Anand, N. and Gupta, A. (2020). Introduction: Temporality, Politics, and the Promise of Infrastructure. *The Promise of Infrastructure*, pp.1–38.

Balmaceda, M., Högselius, P., Johnson, C., Pleines, H., Rogers, D. and Tynkkynen, V.-P. (2019). Energy materiality: A conceptual review of multi-disciplinary approaches. *Energy Research & Social Science*, 56, p.101220.

Bridge, G. and Gailing, L. (2020). New energy spaces: Towards a geographical political economy of energy transition. *Environment and Planning A: Economy and Space*, 52(6), pp.1037–1050.

Cederlöf, G. (2019). Out of steam: Energy, materiality, and political ecology. *Progress in Human Geography*, p.030913251988462.

Delina, L.L. and Sovacool, B.K. (2018). Of temporality and plurality: an epistemic and governance agenda for accelerating just transitions for energy access and sustainable development. *Current Opinion in Environmental Sustainability*, 34, pp.1–6.

Eurostat. (2022). *Renewables steadily increasing in heating and cooling*. [online] Available at: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/edn-20220211-1.

Hirvonen, J. (2021). Today's one million heat pumps are already in essential role in smart energy transition towards carbon neutral Finland.

Huber, M.T. and McCarthy, J. (2017). Beyond the subterranean energy regime? Fuel, land use and the production of space. *Transactions of the Institute of British Geographers*, 42(4), pp.655–668.

Jääskeläinen, J., Höysniemi, S., Syri, S. and Tynkkynen, V.-P. (2018). Finland's Dependence on Russian Energy—Mutually Beneficial Trade Relations or an Energy Security Threat? *Sustainability*, 10(10), p.3445.

Lillie, K. and Ayling, P. (2020). Revisiting the un/ethical: the complex ethics of elite studies research. *Qualitative Research*.

Manzella, A., Allansdottir, A. and Pellizzone, A. eds., (2019). *Geothermal Energy and Society*. *Lecture Notes in Energy*. Cham: Springer International Publishing. doi:10.1007/978-3-319-78286-7.

Marquardt, J. and Delina, L.L. (2021). Making time, making politics: Problematizing temporality in energy and climate studies. *Energy Research & Social Science*, 76, p.102073.

Moss, T., Becker, S. and Gailing, L. (2016). Energy Transitions and Materiality: Between Dispositives, Assemblages and Metabolisms. *Conceptualizing Germany's Energy Transition*, pp.43–68.

Natow, R.S. (2019). The Use of Triangulation in Qualitative Studies Employing Elite Interviews. *Qualitative Research*, 20(2), pp.160–173.

Pellizzone, A., Allansdottir, A., De Franco, R., Muttoni, G. and Manzella, A. (2015). Exploring public engagement with geothermal energy in southern Italy: A case study. *Energy Policy*, 85, pp.1–11. doi:10.1016/j.enpol.2015.05.002.

Richter, A. (2021). *World's deepest geothermal well - geothermal heating ambitions in Finland | ThinkGeoEnergy - Geothermal Energy News*. [online] Think Geoenergy. Available at: https://www.thinkgeoenergy.com/worlds-deepest-geothermal-well-geothermal-heating-ambitions-in-finland/.

Solomon, B.D. and Kire Calvert (2017). *Handbook on the geographies of energy*. Cheltenham: Edward Elgar Publishing.

Valtioneuvosto. (2019). *The act banning the use of coal for energy generation in 2029 to enter into force in early April*. [online] Available at: https://valtioneuvosto.fi/en/-//1410877/kivihiilen-energiakayton-vuonna-2029-kieltava-laki-voima an-huhtikuun-alussa [Accessed 9 Jan. 2023].

Vargas Payera, S. (2018). Understanding social acceptance of geothermal energy: Case study for Araucanía region, Chile. *Geothermics*, 72, pp.138–144.

Wüstenhagen, R., Wolsink, M. and Bürer, M.J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, 35(5), pp.2683–2691.

Appendices

Appendix 1: Interview Guide

Semi-structured interview guide

Opening Questions
How are you involved in the (geothermal) energy industry in Finland?

- What aspect do you have the most experience or expertise with regarding geothermal energy or the overall energy landscape in Finland?

Miten olet mukana (geotermisessä) energiateollisuudessa Suomessa?
Millä osa-alueella sinulla on eniten kokemusta tai asiantuntemusta geotermisestä energiasta tai Suomen yleisestä energiakentästä?

Main Questions
How would you describe the current geothermal energy landscape in Finland?

- How is geothermal energy used in Finland currently?
- Why is it used to that extent?

Miten kuvailisit Suomen tilanteen maalämmön käytössä?
Miten kuvailisit Suomen nykyistä geotermistä energiamaisemaa?
Kuinka paljon sitä käytetään ja miksi?

What role does geothermal energy play in Finnish energy demands?

- Why?
- What about the future energy demands? Is there a vision for how it will be utilised in the future?

Mikä on maalämmön rooli Suomen energiantarpeessa?
Miksi?
Entä tulevaisuuden energiantarve? Onko olemassa visio siitä, miten maalämpöä hyödynnetään tulevaisuudessa?

How would you describe the current public perception of geothermal energy in Finland?

- Why is the perception the way it is?
- What influences the public perception of geothermal energy and why?

Miten kuvailisit geotermisen energian tämänhetkistä yleistä käsitystä Suomessa?
Miksi käsitys on tällainen?

Mikä vaikutta maalämmön yleiseen käsitykseen ja miksi?

How does this current perception influence the development of geothermal energy technologies in Finland?

- Does it hinder or boost its development and why?

Miten tämä nykyinen käsitys vaikuttaa geotermisen energiateknologian kehittämiseen Suomessa?
Estääkö vai edistääkö se sen kehitystä ja miksi?

How has the invasion of Ukraine and Finland applying to join NATO influenced Finland's energy landscape? (Historically Finland has been dependent on Russian oil)

- How has it influenced energy sovereignty and energy independence?
- What are the implications for the future of the Finnish energy landscape and Finlands' energy transition?
- Implications for the growth and development of geothermal energy technologies (including heat pumps)?
- Does it influence the public perception of renewable energy technologies?

Miten Ukrainan invaasio Suomen hakeutuminen NATO:oon vaikuttaa Suomen energiateollisuuteen?
Miten se on vaikuttanut Suomen energiaomavaraisuuteen?
Mitä vaikutuksiä tällä on Suomen energiamurrokseen? (energiasuuntaikseen)?
Vaikutukset geotermisen energiateknologian kasvuun ja kehitykseen?
Miten se vaikuttaa uusiutuvien energiatechnologioitten yleiseen näkemykseen?

What challenges does the (geothermal) energy industry in Finland need to overcome because of the changing energy climate and the need for further energy independence? (this does not need to be strictly about geothermal)

- What are the temporal challenges? Is there a time limit on the energy transition?
- What are the spatial challenges or implications? Spatial planning
- What are the material challenges? In terms of infrastructure or resources?

Mitä haasteita Suomen (geotermisen) energiateollisuuden on voitettava muuttuvan energiailmaston ja energiaomavaraisuuden lisäämisen vuoksi?
Mitkä ovat ajalliset haasteet? Onko energiamurrokselle asetettu aikaraja?
Mitkä ovat alueelliset haasteet tai vaikutukset? Aluesuunnittelu?
Mitkä ovat materiaaliset haasteet? Infrastruktuurin tai resurssien osalta?

Closing Questions
Is there anything you would like to add or ask me?

Appendix 2: Consent form

DECLARATION OF INFORMED CONSENT

Research project name: Anton Korpela's master thesis work

This master thesis research investigates the promise and pitfalls of geothermal energy (including heat pumps) in Finland as a renewable energy source from the perspectives of stakeholders in the energy industry. The purpose of the study is to fill the knowledge gap on spatial planning dimensions of energy transition using heat pumps and geothermal for district heating purposes. Using qualitative data, the research aims at a better understanding of the visions and perceptions of energy stakeholders in Finland, including national and local authorities, business representatives and civil society. Methodologically, it involves in-depth semi-structured interviews with key respondents and analysis of policy documents.

You have been invited to participate in this research as an interviewee.

Please provide your consent that

1. You have been informed about the purpose of the research;
2. You have spontaneously and in complete freedom accepted to be interviewed;
3. You consent the use of anonymized interview data for the research aims of the project, including its publication.

I declare that I am aware that:

- The research includes the collection of individual responses, opinions, evaluations
- each participant is free to ask for clarifications on the data collection procedure and about every other aspect of the project;
- each participant is free to leave the session in every moment;
- the eventual refusal to participate or the renunciation during the session will not involve any negative consequence for the participant;
- personal data collected for research purpose will not be transmitted to third parties;
- the collected personal data will be elaborated anonymously
- the research is conducted in the light of the University of Groningen's research ethics policy (see https://www.rug.nl/about-ug/policy-and-strategy/research-ethics/?lang=en)

Date_____

Signature_____

In case you believe you have been mistreated during this interview or for further information you may wish to have regarding the research process, please contact the thesis supervisor, Dr. Ethemcan Turhan (e.turhan@rug.nl), Assistant Professor of Environmental Planning.