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MAKING HEAT NETWORKS HOT

Understanding the barriers to connecting to heat networks as perceived by homeowners and how to overcome them

A case study of Groningen, The Netherlands

Master thesis Environmental and Infrastructure Planning

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Preface

Dear reader,

Before you lies my master thesis for the master's program Environmental and Infrastructure Planning of the Faculty of Spatial Sciences in Groningen. Throughout the, sometimes challenging, process of writing this thesis, I have been supported greatly by my thesis supervisor prof. dr. Christian Zuidema and fellow student Laura Fransen who helped me maintain focus and motivation during our many study sessions together. In addition, I would like to thank the experts that have taken the time to be interviewed for this thesis and all homeowners in Groningen that have taken the time to fill in my survey. Thank you.

Tess ten Have

Groningen, July 10, 2022

Abstract

In 2019, still 95% of Dutch households were heated using natural gas. Using a different and/or more efficient way of heating residences is, therefore, seen as one of the most promising strategies to reduce CO_2 emissions in the Netherlands. A popular alternative for domestic gas-fired heating systems is a heat network. A heat network is an underground network of pipelines that transport heat to buildings and residences by means of hot water. Heat networks require active support from citizens since homeowners must willingly adjust the energy system of their homes. It is, therefore, important to understand the barriers that homeowners may perceive to adopting heat networks. In this thesis, the barriers to connecting to heat networks as perceived by homeowners and the instruments that may support homeowners to overcome these barriers are explored. To gain a better understanding of these perceived barriers, the influence of one's personal values is included in the study. There are four types of values (hedonic, egoistic, altruistic, and biospheric) that influence how people process information and, consequently, form their evaluation of an energy technology. An understanding of the values that underpin one's evaluation of a technology is beneficial in order to develop effective instruments to overcome the barriers. For this purpose, the study has made use of a combination of a survey and expert interviews.

The results show that all barriers included in the survey to some extent form a barrier for homeowners to connect to the heat network. The most common barriers for homeowners are the investment costs, the expected monthly tariffs for heat, the monopoly position of the heat supplier, the reliability of the network, a lack of (objective) information, and the expected changes that are needed inside the home. Most barriers are negatively associated with the preparedness of homeowners to connect to the heat network and removing the barriers will increase the preparedness to connect to the heat network. In order to overcome the barriers, it is important to increase trust in the municipality and the process of implementing the heat network. In addition, the following instruments were identified that may help homeowners to overcome the barriers:

- **Distributed ownership** over the heat network by the municipality and energy cooperatives to keep costs low and increase the direct influence of homeowners
- **A central heat authority & energy coaches** that provide objective information and help homeowners to find the most appropriate heating alternative for their homes
- **A good offer** including a fair price, clear expectations, and a guaranteed level of control
- **Ambassadors & personal counseling** to increase trust in the technology and lower the barrier regarding the renovations inside the home

Lastly, it was confirmed that personal values do, to some extent, influence which barriers homeowners find important. To be able to support different types of homeowners in overcoming the barriers to connecting to the heat network, the provided information and the offer should contain aspects that appeal to all values.

Key words: "*heat network*", "*district heating*", "*energy transition*", "*barriers*", "*social integration*", "*instruments*", "*EPV-Q*", "*homeowners*"

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List of Abbreviations

ACM = Authoriteit Consument en Markt (Consumer and Market Authority)
COP21 = 21st Conference of the Parties (also known as Paris Climate Conference)
EPV-Q = Environmental Portrait Value Questionnaire
HOAs = Homeowner Associations
MLR = Multiple Linear Regression
NMDA = Niet Meer Dan Anders principe (No More Than Usual principle)
TPA = Third Party Access

1. Introduction

To limit global warming, 196 parties signed the Paris Climate Agreement at the COP21 in Paris in 2015. The Climate Agreement is a legally binding accord to limit the increase in temperature compared to 1990 to 1.5 degrees Celsius (UNFCCC, 2022). The Netherlands, as part of the Climate Agreement, set targets to reduce CO2 emissions by 49% by 2030 and 95% by 2050. However, the Netherlands is still largely reliant on fossil fuels. In 2021, 44% of the total Dutch energy consumption came from burning natural gas (EBN, 2021). Since still 95% of Dutch households were heated using natural gas in 2019 (figure 1), a different and/or more efficient way of generating heat is one of the most promising strategies to reduce CO2 emissions (CBS, 2021b; Heldeweg *et al.*, 2017). Therefore, the Netherlands has entered what is known as the "gas transition" to reduce CO2 emissions in the residential sector. Gas-free alternatives for heating homes are heat pumps, solar boilers, biomass boilers, or pellet stoves. Other options are the use of all-electric alternatives, sustainable gas, or heat networks (Gasmonitor, 2020).

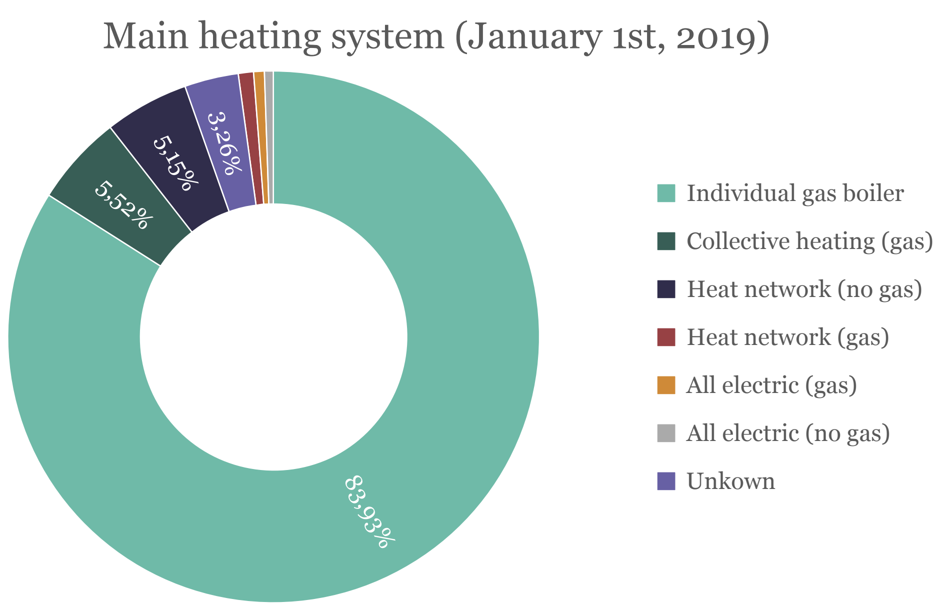


Figure 1: Main heating system of residences in the Netherlands on January 1, 2019 (source: CBS, 2021a)

A heat network, also referred to as district heating, is an underground network of pipelines that transport heat to buildings and residences by means of hot water. The water is heated at a central source and then transported for the purpose of heating and sanitary water (WarmteStad, 2021a). The heat source can be a biomass plant, geothermal heat, or residual heat from industry. Nowadays, heat networks are occasionally heated by burning natural gas. Still, even when fossil fuels are used, the heat network uses energy more efficiently, significantly reducing CO2 emissions in the residential sector (Reynebeau, 2019). In addition, it reduces local air pollution, and, in the future, energy costs are expected to be considerably lower than for systems using fossil fuels which may help to reduce energy poverty (Reynebeau, 2019; Bush & Bale, 2013). The development of district heating networks is seen by many Dutch municipalities as the most desirable alternative for gas. This is, amongst others, due to the relatively low social and capital costs, the (often) sufficient access to residual heat, and because alternatives that require electrification of heating will increase the need for renewable energy (Beauchampet & Walsh, 2021). Yet, since heat networks have only recently gained attention as a valuable instrument to reduce CO2 emissions, there are also several challenges to the implementation of these heat networks, of which the most important one is the social integration of the technology (De Koning *et al.*, 2020).

General support for alternative energy technologies has often been more related to passive acceptance or tolerance, such as with wind farm developments, than active support (Upham & Jones, 2012). Heat networks, however, require active support since citizens must willingly adjust the energy system of their homes. As mentioned by the Dutch politician Diederik Samson in his presentation on the Climate Agreement in 2018: "*Getting neighborhoods off gas is for 10 percent about technology and finances and for 90 percent about people*." Though the statement should not be interpreted literally in terms of percentages, it reflects the importance of the human aspect in achieving the transition. Therefore, in order to achieve the gas transition, it is vital to understand the factors that may hinder citizens' preparedness to connect to heat networks.

1.1. Societal relevance

Currently, around 6% of residences in the Netherlands are heated via a heat network (figure 1). Most development projects for heat networks are focussed on (social) housing corporations. According to Beauchampet & Walch, this is because 1) collective heating infrastructure is already in place here, and 2) large apartment buildings fit the scope needed to present a business case for profitable implementation of a heat network. Elzenga *et al.* (2017) from the Dutch Socio-cultural Planning Office, mention that ground-level, owner-occupied houses are a more difficult market for heat networks because the distances between the houses are greater and contact with homeowners' associations is more difficult than with housing corporations. The focus of heat network providers is, therefore, mainly on mid- to high-rise buildings with collective heating infrastructure owned by housing corporations (Elzenga *et al.*, 2017).

The research by Elzenga *et al.* from 2017 did not yet reveal any examples of successful district heating projects for existing, ground-level houses in the Netherlands. Yet, before 2050, individual households will need to switch to gas-free alternatives for heating systems as well, for whom the social and capital costs of the needed renovations form a bigger barrier (Beauchampet & Walsh, 2021). According to Jansma *et al.* (2020), homeowners have a more negative attitude toward switching to gas-free alternatives and have a stronger desire to participate in the process as compared to tenants. As mentioned, sufficient support from homeowners in the gas transition is crucial as the heating system reaches behind the front door. A street or neighborhood can only be disconnected from the gas network if every household has willingly adopted a new energy source (Beauchampet & Walsh, 2021). Additionally, while there are individual gas-free alternatives available, such as all-electric, many municipalities do not view this as a large-scale solution because they are deemed unsuitable for houses with poor insulation and the technology is relatively immature and expensive (Beauchampet & Walsh, 2021). Individual solutions can be used as complementary to a collective system, but a large part will still need to adopt, for example, a heat network (Beauchampet & Walsh, 2021). By focusing explicitly on homeowners in understanding the barriers that influence the preparedness to connect to the heat network and by identifying what instruments may support homeowners to overcome the barriers, lessons can be identified for municipalities to scale up the use of heat networks in achieving the gas transition.

1.2. Scientific relevance

Most of the present literature surrounding the social integration of heat networks uses case studies from Scandinavia, where the operation of heat networks is more advanced than in most other European countries (Bouw, 2017). Gorroño-Albizu & De Godoy (2021) analyzed consumers' perceived barriers to heat networks' natural monopolies in Denmark and Sweden, Ahvenniemi & Klobut (2014) identified consumer preferences for district heating in Finland, and Mahapatra & Gustavsson (2010) investigated Swedish' homeowners decision-making process to adopting district heating systems. These and similar studies have succeeded in setting out several potential barriers that consumers may perceive to connecting to heat networks. Yet, Mahapatra & Gustavsson (2008), make the important observation that the factors influencing the adoption of heat networks vary from country to country and may change from time to time. The results may, therefore, not be able to present universal findings for countries with developing heat networks, such as the Netherlands, where the research into perceived barriers to heat networks is limited.

In addition, limited research has been done into how the different perceptions of barriers to adopting heat networks are formed. Research by Steg and colleagues (Perlaviciute & Steg, 2014; Steg *et al.*, 2015; Steg *et al.*, 2014) revealed that how people perceive characteristics of energy alternatives (contextual factors) is influenced by one's personal values (psychological factors). While this theory has been tested for the adoption of nuclear energy and energy-efficient appliances (De Groot *et al.*, 2013; Perlaviciute & Steg, 2014), such assumptions have not yet been tested explicitly for heat networks. Steg & Lindenberg (2007) suggest that future research should consider these personal values to be able to understand which (policy) instruments might be most effective to increase the adoption of energy technologies.

As such, this research contributes to the existing literature in two ways. First, it adds to the limited empirical evidence on citizens' perceived barriers to connecting to heat networks in the Netherlands. And second, to the researcher's knowledge, this study makes a first attempt at exploring the influence of one's personal values to identify the most effective instruments to increase the adoption of heat networks, as proposed by Steg & Lindenberg (2007).

1.3. Research objectives

To add to the limited empirical evidence on citizens' perceived barriers to connecting to heat networks in the Netherlands and to support municipalities in connecting more owner-occupied residences to the heat network, the objective of this research is to acquire an understanding of the barriers that influence the preparedness of homeowners to connect to a heat network. In addition, this research will identify what instruments may support homeowners to overcome these barriers. In order to do so, these objectives are explored for the specific case of homeowners in the city of Groningen, the Netherlands.

1.4. Research questions

Based on the research objective, the following research questions have been formulated:

Central research question: "*Which barriers influence the preparedness of homeowners to connect to a heat network and what instruments may support homeowners to overcome the barriers?*"

Secondary research questions:
- "*What barriers do homeowners in Groningen perceive to connecting to a heat network?"*
- *"To what extent do one's personal values influence the perceived barriers?"*
- *"To what extent do the perceived barriers influence the preparedness to connect to a heat network?"*
- *"What instruments may support homeowners to overcome the barriers in order to increase the preparedness to connect to connect to the heat network?"*
- *"How do one's personal values influence what instruments one is susceptible to?"*

1.5. Reading guide

This first chapter forms the introduction to the topic and objectives of this study. In the second chapter, the theoretical background of this study is explained in-depth, and chapter three sets out the used methods for conducting the research. In chapter four, the results of the research are set out and placed into the wider academic discussion on the social integration of heat networks. The conclusions of this study and the recommendations for further research can be found in chapter five. A reflection on the research methods and the references and appendices are added after the conclusion.

2. Theoretical Framework

In this chapter, the theoretical background of this research is explained in depth. As introduced in chapter one, this theoretical framework is based upon the two key components that, according to Perlaviciute & Steg (2014), define how a person evaluates alternative energy systems: contextual factors and psychological factors. The contextual factors, in this research, refer to the characteristics of heat networks that may form a barrier for homeowners to connect to the heat network, such as the costs. The psychological factors, in this research, refer to the personal values that influence how people perceive the contextual factors. Firstly, an overview of the possible barriers is given after which various potential instruments to overcome the barriers are set out. Then, the influence of one's personal values on the barriers and instruments is explored. This literature review forms the basis for the used research methods.

2.1. Barriers

In this section, the main potential barriers for prospective customers of heat networks have been identified. In practice, a broader variety of potential barriers can be found. As mentioned, the factors that positively or negatively influence the choice of heating system differ per country and can vary from time to time (Mahapatra & Gustavsson, 2008). However, for the sake of clarity, this review sets out a confined set of the most common potential barriers found in research and satisfaction studies from the Netherlands, the UK, and Scandinavia. These potential barriers have been categorized under barriers related to costs, trust, control, and comfort.

2.1.1. Costs

Costs are among the key concerns of heat consumers and are mentioned in various ways in research and satisfaction studies (De Koning *et al.*, 2020; Hoogervorst, 2017; Bouw, 2017). Firstly, the investment costs associated with the connection to the heat network and the needed gas-free renovations may form significant obstacles (De Koning *et al.*, 2020; Beauchampet & Walsh, 2021). For making the grid connection, heat suppliers are allowed, based on requirements of the Dutch Consumer and Market Authority (ACM), to charge a maximum amount of €4,959.14 for the first 25 meters. If a house is removed further than 25 meters from the grid, heat providers are allowed to charge a maximum of €224.49 for each additional meter (ACM, n.d.). The exact costs for the connection, therefore, differ per supplier and per (type of) residence. The heat interface set, which is used to provide the indoor installation with hot water, can often not be purchased but must be rented from the heat supplier. For the rent of a heat interface set, a heat supplier is allowed to charge a maximum amount of €131.16, which is based on the average price for a gas boiler (ACM, n.d.). In addition, depending on the delivery temperature of a heat network, heat demand may need to be reduced to be able to heat residences sufficiently, for which increased insulation is often necessary (Mulder & Hulshof, 2021). Making the connection to the grid is, therefore, usually combined with renovations to improve the insulation of the residence. According to the climate agency HIER, the total costs for making a connection to the heat network for an existing private residence can be up to 10,000 to 20,000 euros (RTLnieuws, 2018). Although the owner of the residence must pay for these costs, there are various subsidies and other financing options available, which are explained in more detail in chapter 2.3.1.

In the long run, making the connection and renovations may pay off by reducing energy costs and improving the quality of indoor living. However, citizens have a relatively short-term perspective on investments (Throne-Holst *et al.*, 2008). This can be explained using the Energy Efficiency Paradox (EEP). According to the EEP, when confronted with the trade-off between initial investments and the costs of operating the technology, customers tend to underestimate or brush off the future financial benefits of implementing energy-efficient technologies (Jaffe & Stavins, 1994). Such an underestimation of future benefits results in customers' reluctance to adopt new technologies. According to Throne-Holst *et al.* (2008), their respondents mentioned being willing to invest in their energy system if it saves them money within three to five years. However, the gas-free renovations have a long return-on-investment period of possibly 20 years, depending on the gas prices (Beauchampet & Walsh, 2021). Research by TNO revealed that citizens, especially people of age, are afraid they will not be able to recoup their investments (De Koning *et al.*, 2020). Next to the fear of losing potential investments, people are locked in by their individual heating systems due to sunk costs (Upham & Jones, 2012). For their current heating systems, citizens have already made investments in, for example, domestic boilers and gas stoves and ovens (Upham & Jones, 2012; Hoogervorst, 2017). As such, the investment costs and sunk investments in homeowners' current heating systems are included in this research as potential barriers.

Furthermore, to protect customers from paying more for heat from heat networks as compared to gas, the Heat Act introduced the "Niet Meer Dan Anders" principle (NMDA). NMDA heat providers cannot charge consumers more for heat from a heat network than for heat from a gas-fired heating system (Hoogervorst, 2017). The tariffs that heat suppliers can charge their customers are, therefore, constrained by a cap that is based on the consumption of an average household with a gas connection (WarmteStad, n.d.). However, this cap has resulted in an undesirable effect: rising gas prices (which may arise from a variety of external factors unrelated to heat delivery) may lead to heat suppliers also charging higher tariffs for heat from heat networks as the cap on the tariffs will be higher as well (WarmteStad, n.d.; Hoogervorst, 2017). While the tariffs are fixed for a year, the differences between the yearly tariffs can be large. The maximum tariffs that heat suppliers were allowed to charge per GigaJoule as set by the ACM doubled from 2021 to 2022 (ACM, n.d.). The monthly tariffs that homeowners are expecting to pay for heat from a heat network compared to the tariffs for their current heating system has, therefore, been included as a potential barrier in this research.

2.1.2. Trust

Heat networks in the Netherlands have a negative image (Beauchampet & Walsh, 2021; Hoogervorst, 2017). The main reasons for this are the monopolistic market structure and reliability concerns. Because heat networks are calculated to be profitable after approximately 20 years, the current Heat Act stipulates that one party is given the responsibility for supplying heat for a minimum of 20 and a maximum of 30 years (ACM, n.d.). The monopolistic market structure is a barrier to many citizens, since it may lead to a lack of transparency (Hoogervorst, 2017; Bouw, 2017). For example, many find the pricing for heat networks unclear, because it is not possible to break down the heating costs (Hoogervorst, 2017; Bouw, 2017). Some see the way the tariffs are set as unfair because price formation does not occur through a market mechanism or because the cap on the tariffs is not based on people's specific situations (Haffner *et al.*, 2016). According to Bouw (2017), the Heat Act has not been able to increase the trust in the fairness of the prices since it is not possible for citizens to compare the costs to heating alternatives. In addition, suppliers currently unilaterally determine which heat interface set customers must rent, while according to installers there is no reason to have a monopoly role here because the functioning of the heat interface set does not influence the functioning of the heat network as a whole (Haffner *et al.*, 2016). Customers do not trust suppliers to choose the most efficient heat interface set or are afraid that unnecessarily expensive sets are chosen (Haffner *et al.*, 2016; Hoogervorst, 2017). And, since citizens are tied to one provider it is impossible to switch to alternatives if they are not satisfied with the service, which may be misused by the providers (Bouw, 2017; De Koning *et al.*, 2020). As such, the monopoly position of the supplier was considered a potential barrier in this research.

The lack of trust can also be related to the functional reliability of the network. Upham & Jones (2012) mentioned that UK citizens had concerns surrounding the technical aspects of the network, such as the frequency of leakages or the temperature of the water at the furthest distances from the source. For heat networks based on residual heat, concerns may arise about how improved industrial efficiency or the termination of industrial activities could influence the heat supply (Upham & Jones, 2012; Beauchampet & Walsh, 2021). While these concerns are unfounded in many cases, they can still form a barrier to making a connection to the heat network. Therefore, in this research, functional reliability was also taken up as a potential barrier.

2.1.3. Control

Another barrier to connecting to a heat network may be the little control that citizens have in comparison to other heating alternatives. Firstly, to be able to make a connection to a heat network, individual households are dependent on collective action. A new heat network or an extension of an existing heat network will not be constructed if only a hand full of homeowners in a neighborhood is interested in making a connection (Beauchampet & Walsh, 2021). For suppliers of heat to be able to undertake an investment in a fully new, large heat network (in Amsterdam), a minimum of roughly 1,500 to 2,000 housing units or other major customers is required (De Graaf & Das, 2021). In the case of existing networks, an acceptable risk for a heat supplier to extend the grid may already be presented at a minimum of around 500 units (De Graaf & Das, 2021). Besides, those living in collective housing structures are dependent on collective decisions, e.g., from Homeowners' Associations (HOAs) (Throne-Holst *et al.*, 2008; Kort *et al.*, 2020). This dependency on collective action may especially form a barrier in neighborhoods with low social cohesion (Beauchampet & Walsh, 2021). The dependency on collective action has been regarded as a potential barrier within this study.

When deciding to connect to a heat network, citizens cannot choose their provider since heat network companies, as mentioned, have local monopolies. This results in a lack of consumer choice (Hoogervorst, 2017; Bouw, 2017). In addition, being tied to one provider means customers cannot benefit from discount offers as is the case with energy suppliers, or enjoy loyal customer advantages (Haffner *et al.*, 2016; Bouw, 2017). Also, the limited control over the heat source can form a barrier (Kort *et al.*, 2020). As a consumer of a heat network, you are dependent on the heat source offered by the provider. However, people perceive different types of heat sources differently. Residents may find it important that a heat source is renewable or do not want to be dependent on imported gas (Kort *et al.*, 2020). As a result, consumers have little influence on their energy supply.

Lastly, a lack of control over the indoor temperature was also mentioned as a barrier (Kort *et al.*, 2020). Although the temperature of heat from a heat network can be controlled using a thermostat in the same way as the temperature with a gas-fired system, it appears that consumers may expect to have little control over their indoor temperature as the water is delivered at a certain temperature (Kort *et al.*, 2020). In this research, the lack of control over the heat source and the expected control over the indoor temperature are, thus, included as potential barriers.

2.1.4. Comfort

While, once connected, comfort is usually perceived as high due to the low maintenance and improved indoor climate, the concerns regarding the expected comfort are often a barrier to connecting to the heat network. Firstly, citizens are concerned about the construction of the grid connection and heat interface set. Several publications mentioned how citizens are worried about the "mess" or "hassle" that comes with the needed construction work and renovations (De Koning *et al.*, 2020; Beauchampet & Walsh, 2021). The frequently asked questions on the heat providers' website reflect this as well: "*Can I still park my car in the street during the construction work?*" or "*Can my trash container be emptied during the construction work?*" (WarmteStad, n.d.). In addition, people may feel uncomfortable when other residents in the neighborhood are inconvenienced by the construction work (Kort *et al.*, 2020). It was, therefore, decided to take up the hassle of construction as a potential barrier in this research.

Secondly, the organization of the transition from gas to a heat network may raise concerns among potential customers (Kort *et al.*, 2020). Due to a lack of time or understanding of heat networks, homeowners may be unable or stressed about making the necessary arrangements to make the change themselves, such as signing a contract, arranging the necessary renovations, and purchasing a new stove and pans (Kort *et al.*, 2020). Thus, these concerns about the organization were included as a potential barrier in this research.

Lastly, research by TNO revealed that consumers may perceive electric cooking to be dissatisfactory. Respondents in their study expressed a love of cooking with gas and often associated electric cooking with ceramic plates or with less control over their heat (De Koning *et al.*, 2020). The perceived discomfort of electric cooking was, therefore, added to the potential barriers.

Table 1: Typology of the possible barriers for homeowners

Barriers	**Costs**	High investment costs
		Sunk costs of current system
		Expected heat tariffs
	Trust	Monopoly position of the supplier
		Concerns regarding functional reliability
	Control	Dependency on collective action
		Lack of control over heat source
		Little control over indoor temperature
	Comfort	Hassle of construction
		Concerns about organization
		Electric cooking

2.2. Preparedness to connect to heat networks

The previous section has set out the possible barriers to the implementation and use of a heat network as can be perceived by homeowners. Barriers can hinder particular behaviors (Kollmuss & Agyeman, 2002). According to Pruess (1991), there is a distinction between one's "abstract willingness to act" and "concrete willingness to act". The abstract willingness to act, which is based on principles such as pro-environmentalism, is often greater than a person's concrete willingness to act or actual behavior (Pruess, 1991; Kollmuss & Agyeman, 2002). Various barriers are often responsible for the difference between the two (Kollmuss & Agyeman, 2002). When translating this to the case of heat networks, it may be that while, in essence, citizens are willing to change their energy system, barriers like high costs or limited trust can decrease the actual preparedness to connect to a heat network. As such, it can be expected that homeowners that perceive barriers to a high extent are less prepared to make a connection to a heat network (figure 2).

H1: Homeowners who perceive barriers to a high extent are less prepared to make a connection to a heat network compared to homeowners who perceive barriers to a low extent.

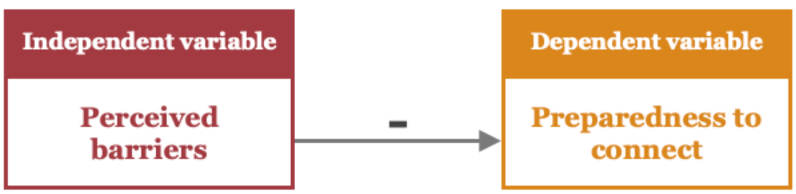


Figure 2: Conceptual overview of the relationship between the perceived barriers and preparedness to connect to a heat network

Previous research has shown that, especially during the considering stage, the socio-demographic factors age, income, and education also may be critical influencers in the adoption of new energy technologies (Ebrahimigharehbaghi *et al.*, 2019; Broers *et al.*, 2019). Mahapatra & Gustavsson (2008) demonstrated that as respondents' ages increase, the percentage of those expecting to adopt renewable energy technologies is lower. This may have to with the fact that environmental issues are generally seen as more important by younger generations than by older generations. This is also reflected by data from the Dutch Central Bureau for Statistics (CBS), which shows that young people are relatively often (very) positive about the gas transition. 65.7% of people in the age category 18 to 25 and 66.1% of people in the age category 25 to 35 indicate that they are (very) positive towards the transition, while for the age categories 35 to 45, 45 to 55, 55 to 65, 65 to 75, and 75+ this is 55.7%, 49.6%, 52.2%, 41.9%, and 40.6% respectively (CBS, 2021c). However, it could also be explained by the fact that older homeowners may be concerned that they will not be able to recoup their investment (Gaspari *et al.*, 2021; De Koning *et al.*, 2020).

Findings by Sardianou & Genoudi (2013) show that as income increases, so does the likelihood of adopting renewable energy technologies. This positive correlation may be explained by the fact that homeowners with a higher income are more capable of investing in new energy technologies. Having the right resources is crucial in the preparedness to make the connection because, in addition to being willing, one must also be able to make the connection (Steg *et al.*, 2015). Besides income, capital is therefore also important. However, because it is difficult to get an insight into homeowners' available capital, income will be seen as the indicator for resources in this study. Lastly, previous research has suggested that education may be considered a factor, as those with higher education levels may be more capable of obtaining the necessary information and skills to adopt new technologies (Schleich, 2019).

We may expect that age, education, and income influence a respondent's preparedness to connect to a heat network and these factors should, therefore, be controlled for when exploring the relationship between perceived barriers and the preparedness to connect. Yet, as explained by Yang *et al.* (2022), given the frequent interconnectedness between education and income, the effect of these two factors on the outcome may not be mutually exclusive. To avoid problems with covariance between the two factors, it was chosen to only include income in this study. By adding age and income as control variables when testing the relationship (figure 3), it can be said with more certainty whether the effect is due to the independent variable(s).

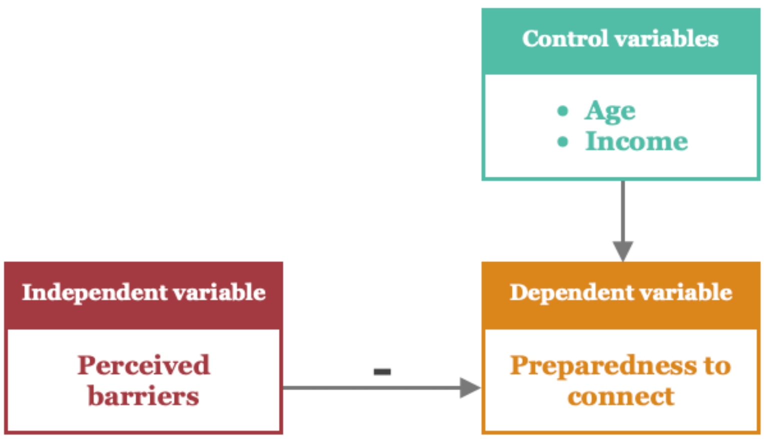


Figure 3: Conceptual overview of the relationship between the perceived barriers and preparedness to connect to a heat network including control variables

2.3. Potential instruments to overcome the barriers

By identifying what instruments may support homeowners to overcome the perceived barriers, lessons can be identified for municipalities to scale up the use of heat networks in achieving the gas transition. Based on previous research and experiences from cities with developed heat networks, several potential instruments have been identified that can support homeowners to overcome the perceived barriers.

2.3.1. Financial support

Financial support plays an important role in overcoming the barrier formed by the investment costs associated with the connection to the heat network and gas-free renovations. For this reason, subsidies have already been made available to homeowners that want to make a grid connection. Dutch homeowners can receive a subsidy of €3,325 for connecting to a heat network through the Investment Subsidy for Sustainable Energy and Energy Conservation (RVO, 2022). In addition, homeowners and HOAs can apply for a subsidy for insulation measures. The amount of this subsidy depends on the type of house and type of measures but can result in up to 20% of the total costs for the insulation measures (RVO, 2022). No national subsidy scheme is yet available for cooking on induction and the associated kitchenware. Some municipalities do offer schemes, such as in Amsterdam and The Hague where homeowners can receive up to €500 in subsidies for the purchase and installation of an induction cooktop (Amsterdam, n.a.; Den Haag, 2022). Such subsidies could help residents to overcome the barrier of switching to electric cooking.

Next to subsidies, homeowners and HOAs can apply for an "energy-saving loan" from the national heat fund. This loan must be used to improve the sustainability of the residence and must be repaid within 20 years (Consumentenbond, 2022). To lower the barrier to making investments, this loan can be linked to the home rather than the homeowner. In this way, the residual debt for the renovations can be sold with the house in the event of a sale.

Financial support may also help to overcome the barrier related to the loss of investments in homeowners' current heating system. For homeowners that have made recent investments in their heating systems, e.g., for a new domestic boiler, the best option may be to compensate homeowners for the losses or to redeem the new boiler (Sernhed & Pyrko, 2008).

Lastly, over the past year, gas prices have increased notably, which has resulted in rising energy costs for consumers of almost every type of energy system (WarmteStad, n.d.). Due to the NMDA-cap, the heat tariffs for heat networks have also been allowed to increase. Due to these rising prices, the state provides compensation through a tax credit on the energy tax of about €400 per household (ACM, n.d.). In addition, municipalities offer opportunities for additional support (ACM, n.d.). Besides these ad hoc measures to tackle the consequences of high gas prices, the Ministry of Economic Affairs is currently drafting a new Heat Act in which the NMDA-cap on heat tariffs is no longer included (ACM, n.d.). Once the cap has been lifted, the heat tariffs must be calculated based on the costs incurred by the heat suppliers (ACM, n.d.). Next to overcoming the cost-related barrier to the NMDA-cap, removing the cap may also increase trust as it may improve transparency in costs.

2.3.2. Socialization of grid costs

Heat networks have a disadvantage compared to gas and electricity networks, as gas and electricity networks are socialized which means that the annual grid costs per energy type are divided among all connections to gas and electricity networks (Blom, 2017). Since this is not the case for heat networks, investment risks for constructing heat networks are currently high, leading to high capital costs that are often passed on in the heat tariffs (Hoogervorst, 2017). When the investment costs are taken over by the government through socialization, the risk for investors decreases, and heat tariffs can potentially be reduced (Hoogervorst, 2017). In addition, it may improve the business case for smaller heat networks where the investment risks are higher than for large networks (Blom, 2017). Finally, it also ensures a more equitable allocation of costs among users. Because the expenses of developing heat networks are different for each project, the costs for the grid connection as well as the tariffs for heat transport currently vary for consumers in different neighborhoods and buildings (Blom, 2017). With socialization, individual consumers pay based on the average grid costs of the larger group of users, rather than on the costs of the specific heat network to which they are connected (Blom, 2017). The socialization of the grid costs may, therefore, help to overcome cost-related barriers, but may also increase trust as it may lead to a more equitable allocation of costs.

2.3.3. Changing ownership

A part of the potential barriers can be attributed to the monopolistic market structure of heat networks. A change in ownership of the network may help to overcome such barriers. Firstly, Third Party Access (TPA) may be a logical instrument. TPA means that the owner of the heat network must give access to the grid to other producers and suppliers of heat (Haffner *et al.*, 2016). In general, the benefits of allowing third parties to access the grid are: reduced dependence on a specific producer and lower tariffs for consumers through competition between suppliers (Bouw, 2017; Haffner *et al.*, 2016). TPA also gives homeowners more consumer choice, by being able to choose their preferred heat provider. However, competition through the implementation of TPA for heat networks may have minimal effects on the tariffs for consumers, while it may have a large negative impact on the grids' cost efficiency (Söderholm & Warell, 2011). This can firstly be attributed to the dependency between production and distribution of heat since pipeline losses are greater with heat networks as compared to gas or electricity networks. Secondly, TPA asks for extensive regulation and monitoring, which will increase operating costs (Haffner *et al.*, 2016). As such, TPA will most likely not result in successful competition (Haffner *et al.*, 2016).

Besides the downside of the cost efficiency, residents often have little faith in large commercial parties (Kort *et al.*, 2020). To increase trust, local governments could become owners of local networks or supervise the management of networks by private parties (Hoogervorst, 2017). Another option to change the monopolistic market structure is to introduce community ownership (neighborhood heat networks). By becoming a co-owner of the heat network, as part of a heat cooperative, homeowners have more influence over the design of the network and there is no need to consider shareholders. According to Kort *et al.* (2020), cooperative ownership not only increases the (public) acceptance of heat networks but can also increase residents' involvement in the topic of sustainability.

These measures to change the ownership of the heat network may not only help to overcome trust-related barriers, as they may reduce the dependency on a single party and increase the transparency in costs, but collective ownership can also help to increase homeowners' control over their energy supply.

2.3.4. Warranties and insurance

Warranties and insurance can be offered to lower the barrier regarding the trust in the functional reliability of a heat network (Mahapatra & Gustavsson, 2008). Heat network operators can offer warranties to increase consumers' trust in two ways: product warranty and performance warranty (Bianchi *et al.*, 2020). A product warranty means that the producer is responsible for defects in the grid construction or heat delivery set for a certain period. System performance warranties can be given by entering into Service Level Agreements whereby the producer pays for additional costs if the system performance does not meet pre-agreed requirements (Bianchi *et al.*, 2020). For solar panels, more types of warranties are offered which could potentially be applicable to heat networks as well, such as installation warranties and system warranties (Consumentenbond, 2021). Regarding the insurance, special insurance can be introduced for customers of heat networks as is also the case for solar panels (Consumentenbond, 2021).

2.3.5. Information provision

According to Kort *et al.* (2020), prejudices about heat networks may often be the result of a lack of complete knowledge. Providing transparent and personal information through marketing campaigns, information sessions, or house visits may support homeowners to overcome barriers.

Firstly, as is explained in section 2.2.1., part of the reason that the investment costs may form a barrier could be because potential adopters tend to underestimate the future benefits of the implementation (Jaffe & Stavins, 1994). Providing information on the accurate financial returns on investments can help homeowners to make the trade-off between initial investment costs and future financial benefits. According to Mårtensson & Frederiksen (2006), the (additional) market value of a residence can be a guiding factor in the decision-making process of potential adopters of energy-efficient technologies. Therefore, offering tools for homeowners to calculate the potential increase in the market value of their residence may help in making the beforementioned trade-off. In addition, homeowners can be supported in creating a profitability analysis to get an overview of energy costs before and after conversion (Sernhed & Pyrko, 2008).

Secondly, information can be provided to potential adopters about no-regret measures they can take to prepare for a possible connection to the heat network in the future. For example, homeowners can be given information about investments they can make in advance, such as improved insulation or an induction cooktop, or those they should avoid, such as new domestic boilers (Duurzaambouwloket, 2019). This information can best be tailored to the situation of the potential consumer by visiting them in person.

Lastly, heat network operators may invest in marketing and communication to be able to better market the strengths of the network (Mahapatra & Gustavsson, 2008). Comfort-related barriers may arise from concerns related to the hassle of construction and electric cooking. However, once connected, comfort is generally seen as one of the strong points of heat networks (Ahvenniemi & Klobut, 2014). By investing in marketing that is focused on the strengths of the technology, the current prejudices may be overcome, including the prejudice regarding the lack of control over the indoor temperature.

For all of the above, personally visiting homeowners and informing them about what a heat network means for their situation helps them to make an informed decision (Kort *et al.*, 2020). And, having a personal point of contact in the neighborhood may help to increase trust in the provider (Kort *et al.*, 2020).

2.3.6. Homeowner engagement

Several previous studies have mentioned the importance of engaging homeowners early and appropriately in the development of a heat network (Kort *et al.*, 2020; De Koning *et al.*, 2020). Engaging homeowners throughout the development of the heat network can help to overcome various barriers. For example, greater engagement of citizens may lower the barrier regarding the hassle of construction. During construction work, residents can be relieved by combining projects to upgrade the neighborhood so that the street is only closed off once and all residents of the neighborhood will gain from the construction work (WarmteStad, n.d.). In the planning process of such integral neighborhood approaches, participation is of great importance to secure support for energy projects. Also, citizens may bring local knowledge (Beauchampet & Walsh, 2021).

As mentioned before, there are prejudices regarding the comfort of heat networks. While improved marketing may already help, familiarization with heat networks may also positively influence the attitude toward heat networks (Huijts *et al.*, 2012). Next to providing information, this barrier may, therefore, be overcome by getting homeowners acquainted with the network. An example of how this can be done is through a "show house" where district heating is displayed (Sernhed & Pyrko, 2008). The show house can also be extended to a service where homeowners are provided with the option to stay at a fully renovated residence with a grid connection and electric cooking for a few days. Next to the comfort barrier, this familiarization may also help to overcome the lack of trust one may have in the functional reliability of the network.

Lastly, in neighborhoods where social cohesion is low, the dependency of homeowners on the collective action of the neighborhood to be able to make a connection to the heat network may especially form a barrier (Beauchampet & Walch, 2021). To overcome this barrier and stimulate collective action, local officials can support citizens with trust-building and the development of action plans (Hoppe *et al.*, 2015). This can be done by organizing neighborhood festivals, where local homeowners can get to know their neighbors and share ideas and concerns regarding the possibility of making a connection to the heat network.

2.3.7. Unburdening homeowners

Lastly, to alleviate homeowners from their concerns about organizing the transition from gas to the heat network, homeowners must be unburdened as much as possible. To unburden homeowners, standard packages of measures can be offered (Kort *et al.*, 2020). In addition to installation measures, the standard package can also offer a new cooktop and pan set (Kort *et al.*, 2020). This package may save homeowners time in selecting the necessary arrangements and can possibly be offered with a discount because the elements in the package can be purchased on a larger scale (Kort *et al.*, 2020). Furthermore, as the necessary measures must often be customized to the residence, choosing the right measures and a reliable company to make the adjustments is not always as easy (De Koning *et al.*, 2020). By offering homeowners free advice or support when making the arrangements, the organizational concerns can be removed (De Koning *et al.*, 2020).

Table 2: Typology of potential instruments to overcome the barriers

Potential instruments	**Barriers they may help to overcome**
Financial support	Cost-related barriers
Socialization of grid costs	Cost-related barriers Trust-related barriers
Changing ownership	Trust-related barriers Control-related barriers
Warranties and insurance	Trust-related barriers
Information provision	Cost-related barriers Trust-related barriers Control-related barriers Comfort-related barriers
Homeowner engagement	Trust-related barriers Control-related barriers Comfort-related barriers
Unburdening homeowners	Comfort-related barriers Cost-related barriers

To conclude, it can be expected that as instruments to overcome the barriers are provided, the preparedness of homeowners to connect to the heat network will increase (figure 4). This overview of potential instruments (table 2), together with the results of the interviews, will help to identify the most effective instruments to increase the preparedness of homeowners in Groningen to connect to the heat network.

H2: As instruments to overcome the barriers are provided, the preparedness of homeowners to connect to the heat network will increase.

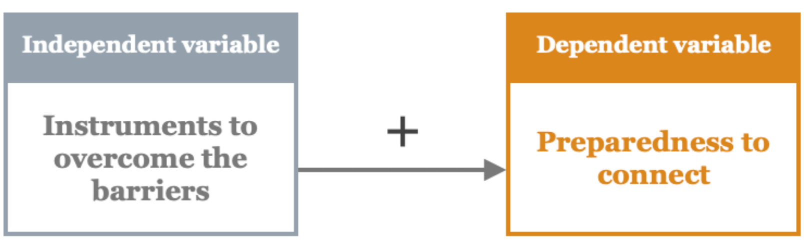


Figure 4: Conceptual overview of the relationship between the instruments to overcome the barriers and the preparedness to connect to the heat network

2.4. Personal values

Next to the contextual factors, which are the potential barriers and instruments to overcome the barriers, previous research has pointed out the importance of personal values in adopting new energy technologies in general (De Groot & Steg, 2008; Steg *et al.*, 2015). Personal values influence how information is processed and how attitudes are formed (Vlek & Steg, 2007). These values may, therefore, influence which or to what extent one perceives barriers to connecting to heat networks, but also which instruments to overcome the barriers one is susceptible to.

2.4.1. The influence of personal values

According to Steg *et al.* (2015), one's evaluation of the positive and negative aspects of, e.g., energy technologies is based on four types of values: hedonic, egoistic, altruistic, and biospheric. Individuals with dominant hedonic values are mainly concerned with pleasure and comfort, which results in e.g., avoiding effort or uncertainty (Steg *et al.*, 2015; Lindenberg & Steg, 2007). Individuals with dominant egoistic values are focused on preserving and increasing their resources, such as money and time (Steg *et al.*, 2015). Individuals with dominant altruistic values are concerned with the well-being of others, and those with dominant biospheric values are concerned with nature and the environment (Steg *et al.*, 2015).

Personal values influence how important certain consequences are to people (Steg *et al.*, 2015). Those with dominant hedonic and egoistic values, also defined as self-enhancement values, emphasize individual gain either through pleasure or resources (Schwartz, 1992). For example, we may expect that people with dominant hedonic values may find the need for cooking on induction a significant barrier, as it is often expected to negatively influence one's comfort. People with dominant egoistic values, who base their evaluations of technologies mainly on the costs and benefits, will likely find the investment costs or sunk investments to be a significant barrier. Altruistic and biospheric values can be defined as self-transcendence values, which emphasize a concern for the welfare of the collective (Schwartz, 1992). For example, people with dominant altruistic values may find the hassle of construction to be a significant barrier, as the construction work will affect all residents of the neighborhood, and people with dominant biospheric values may find their lack of control over the heat source to be a significant barrier as the source of a heat network may not always be renewable. Besides the influence of values on the perceived barriers, values may also guide one's general evaluation of heat networks as a potentially useful or attractive option.

Interestingly, the dominant values may also influence how individuals evaluate other aspects of energy technologies that should be less relevant to them based on their values (De Groot *et al.*, 2013). For example, people with egoistic values have shown to be associated with a positive assessment of nuclear energy, as the technology is regarded as affordable and provides a secure energy supply (Steg *et al.*, 2015). Surprisingly, these people were also more inclined to associate nuclear energy with positive environmental impacts, even though concern for the environment does not necessarily align with their dominant egoistic values (Steg *et al.*, 2015). In other words, people are prone to exceedingly optimistic or negative evaluations of energy technologies that are compatible with their dominant values (Steg *et al.*, 2015).

Seemingly, people's values influence how people process information and respond to it (Steg *et al.*, 2014). By focusing particularly on the information that aligns with their dominant values, people form their evaluation of an energy technology (Steg *et al.*, 2014). However, information, in turn, may also influence which values are dominant. Environmental knowledge is linked to increased concern about environmental issues and, as a result, more altruistic and biospheric values (Steg *et al.*, 2015). People with dominant hedonic and egoistic values often are less aware of the environmental impact of their energy behavior and, consequently, they are also less likely to be willing to change their energy system or behavior (Steg *et al.*, 2015). In previous research, knowledge has shown to be positively correlated with the adoption of energy-efficient technologies (Burlinson *et al.*, 2018; Achterberg *et al.*, 2010). Providing information may, therefore, be a useful instrument to increase one's preparedness to adopt a technology. However, there are also studies that showed more environmental knowledge does not increase the likelihood of people adopting such technologies (Kollmuss & Agyeman, 2002). This may have to do with the fact that the impact of one's personal values on knowledge is more dominant than the other way around (Kollmuss & Agyeman, 2002; Steg *et al.*, 2015).

According to Steg *et al.* (2015), increased knowledge may have limited effects if the information does not align with one's dominant values. This was also noted by Kort *et al.* (2020), who concluded that residents who oppose heat networks are often well informed and that if ignorance is assumed when communicating with these residents, communication or information strategies can be counterproductive (Kort *et al.*, 2020). Values, in this case, do not only influence the perceived barriers but may also influence the strength and/or direction of the relationship between the instruments and the preparedness to connect to the heat network (figure 5). Other such examples could be that people with dominant biospheric values may need less financial support to increase their preparedness to connect, as these people are usually prepared to pay a higher price for energy-efficient technologies, and measures to give people more control over their heat supply can have an adverse effect on people with dominant hedonic values, as more control may also come with more effort. Lastly, values may also affect how specific instruments are viewed by a person in general, because they may or may not align with the individuals' perception of a reasonable or equitable manner of implementing heat networks.

To be able to develop effective instruments to overcome the barriers, an understanding of the values that underpin one's evaluation of a technology is, therefore, beneficial (Steg *et al.*, 2015) and will be included in this research.

H3: Personal values influence the perceived barriers.
H4: Personal values influence the relationship between the instruments to overcome the barriers and the preparedness to connect to the heat network.

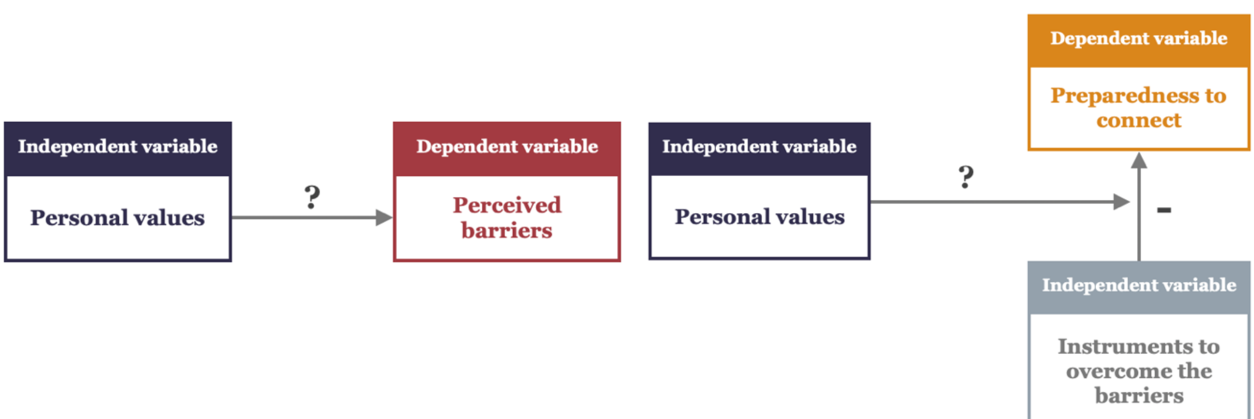


Figure 5: Conceptual overview of the influence of personal values

2.5. Conceptual framework

The conceptual model below (figure 6) gives an overview of the concepts that are expected to be related to each other. Based on the literature review, it can be expected that homeowners that perceive barriers to a higher extent are less prepared to make a connection to a heat network (H1). Since income and age have shown to be correlated with the preparedness to connect to a heat network, these factors will be accounted for when exploring the relationship between perceived barriers and the preparedness to connect. Secondly, it can be expected that as instruments to overcome the barriers are provided, the preparedness of homeowners to connect to the heat network will increase (H2). In addition, the perceived barriers can be expected to be influenced by one's personal values (H3). Lastly, one's personal values can also be expected to influence the relationship between the instruments to overcome the barriers and the preparedness to connect (H4).

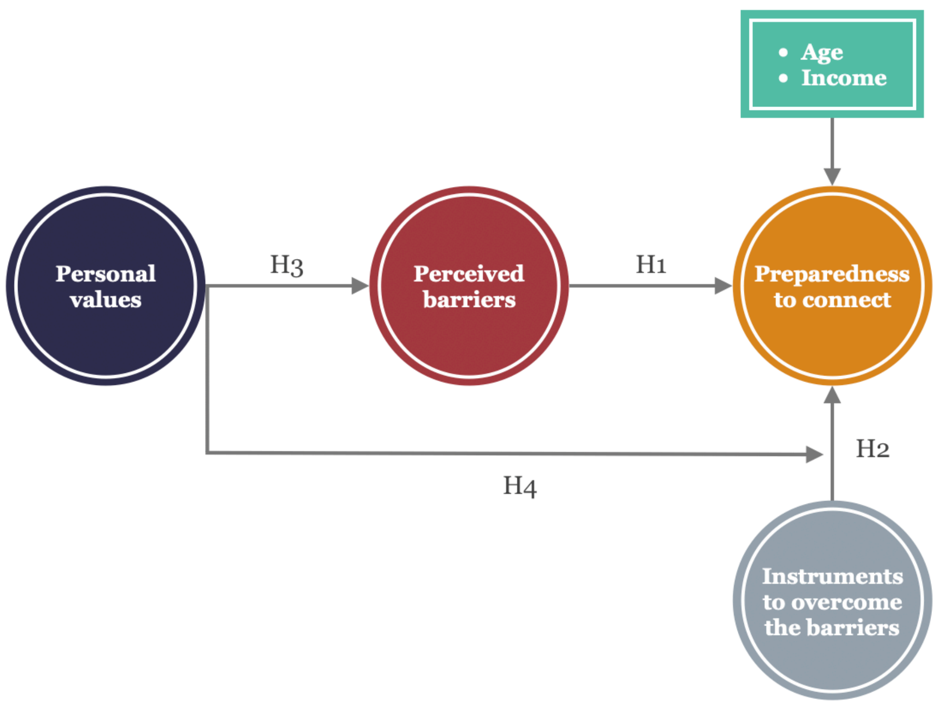


Figure 6: Conceptual model

3. Methodology

In this chapter, the methodology for this research is explained. Firstly, the research design is elaborated on and the case study is introduced. After that, the data collection and analysis methods are set out.

3.1. Research design

This explorative study uses a single case study approach. Since the main research question consists of a quantitative (what barriers) and qualitative (how to overcome them) aspect, a mixed-method approach is considered most suited (Tashakkori & Creswell, 2007). To answer the first, second, third, and fifth sub-questions, a survey has been set out. To reflect on these results and to answer the fourth sub-question, in-depth expert interviews are conducted. The literature review of chapter 2 forms the basis for the survey, interview guide, and code tree. The results of the survey and interviews help to answer the main research question and form the outcome of this study. The unit of analysis is represented by homeowners in Groningen, the Netherlands. In figure 7 a visual overview of the research design is shown.

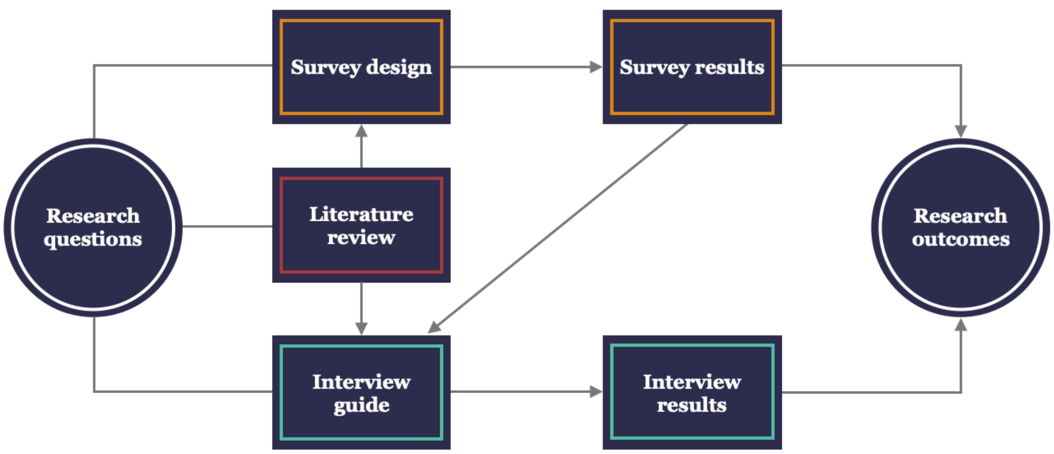


Figure 7: Schematic overview of the research design

3.2. Case study

This research makes use of a case study approach, which refers to the detailed examination of a specific social system (Clifford *et al.*, 2010). The case study approach is appropriate for this research, as it helps to gain concrete, contextual knowledge about the subject, which is important for research into social phenomena, such as personal values and perceptions (Flyvbjerg, 2006; McCombes, 2019). In addition, case studies are useful in the case of time or cost constraints (McCombes, 2019). While this research will hopefully present interesting findings for municipalities in the Netherlands, the results from case studies must be treated carefully concerning generalization (Cliffort *et al.*, 2010). As case studies are conducted in a specific setting, the results may not be sufficient to identify universal, predictive theory (Harvey, 1969). However, while formal generalization may not be possible, the results can present a valuable example that can be linked to circumstances outside the study's bounds (Flyvbjerg, 2006). Chapter 5 will discuss the potentially valuable implications of this study's results for planning practice.

3.2.1. Case selection

In 2011, the Municipality of Groningen announced its target to become free of natural gas before 2035 (Routekaart, 2018). This was already before similar agreements were made on national and international levels. Groningen identifies itself as the "*energy city*" and, therefore, wants to be ahead of other Dutch municipalities in the energy transition (Routekaart, 2018). The Municipality of Groningen is one of the few municipalities in the Netherlands that has set its target to be free of natural gas before 2040. In addition, Groningen was the first municipality to draw up a Heat Transition Vision which explains how the municipality will reach this target.

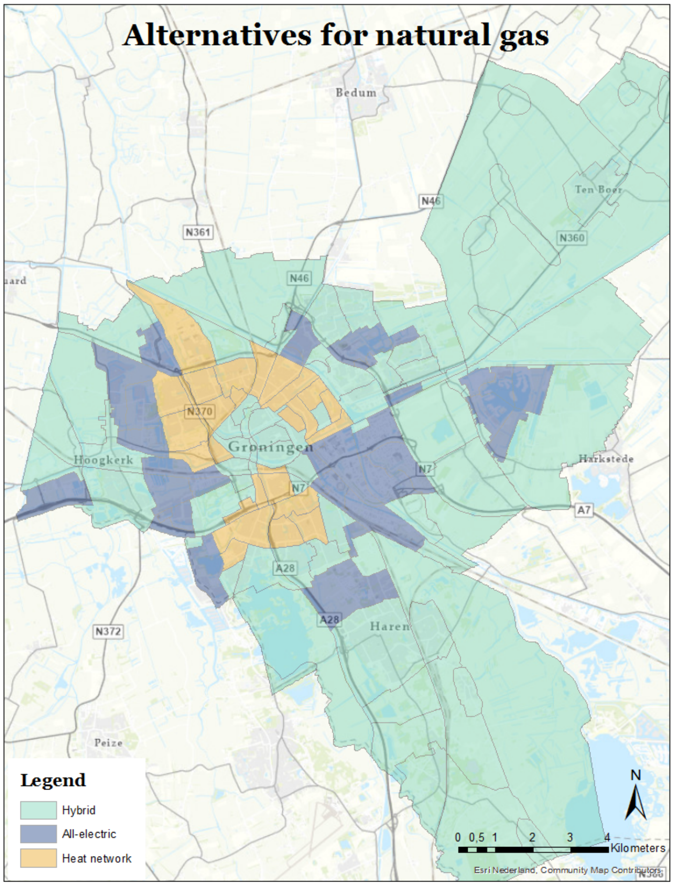
In 2014, as part of its strategy to become free of natural gas, the municipality started the development of a heat network. The first part of the heat network has been installed in the neighborhoods of Zernike and Paddepoel and the heat network is currently being expanded to Selwerd and Vinkhuizen (WarmteStad, 2021c). The municipality has started the development of the network in these neighborhoods because a substantial portion of the properties in these neighborhoods is owned by housing corporations, and hence there are few parties with whom to collaborate. At the end of 2021, however, the municipality has started to explore the opportunities for connecting owner-occupied houses to the heat network (Gemeente Groningen, 2021). Homeowners play an important role in the implementation of a heat network, as they must willingly adjust the energy systems of their houses. Therefore, homeowners present an interesting unit of analysis.

This shifting focus toward owner-occupied houses, in combination with the leading position of Groningen in the energy transition, makes the city an interesting case to explore what barriers homeowners perceive that influence their preparedness to connect to the heat network and what instruments may support homeowners to overcome the barriers. The results may help Groningen to scale up the current heat network, but it may also provide valuable lessons for other municipalities in the Netherlands that are still in more early stages of the energy transition.

3.2.2. Case description

In Groningen, the production, distribution, and supply of heat via the heat network is managed by WarmteStad. WarmteStad is a utility company of the Municipality of Groningen and Waterbedrijf Groningen (Water Company). The utility company is a social enterprise and, as such, does not aim to make a profit. The company aims to invest in making the city more sustainable while keeping the costs for residents as low as possible (WarmteStad, 2021c). The heat network that is being installed is called the "Warmtenet Noordwest" and currently provides heat to 3,000 households in four different neighborhoods. In the future, the intention is that this will reach up to 20,000 households in 26 neighborhoods that have been identified by the municipality as neighborhoods for which a heat network is seen as the most suitable alternative for natural gas (figure 8) (WarmteStad, 2021c).

As mentioned, the municipality has recently started to explore the possibilities for connecting more owner-occupied houses to the heat network. This is done in collaboration with WarmteStad and the local energy cooperative Grunneger Power. Together with homeowners in Groningen, Grunneger Power explores which follow-up steps are necessary to connect owner-occupied residences to the heat network (GrunnegerPower, n.a.). As such, the cooperation tries to include homeowners in the heat transition. In 2021, 42.7% of the residences in Groningen were owner-occupied (Basismonitor, 2021).



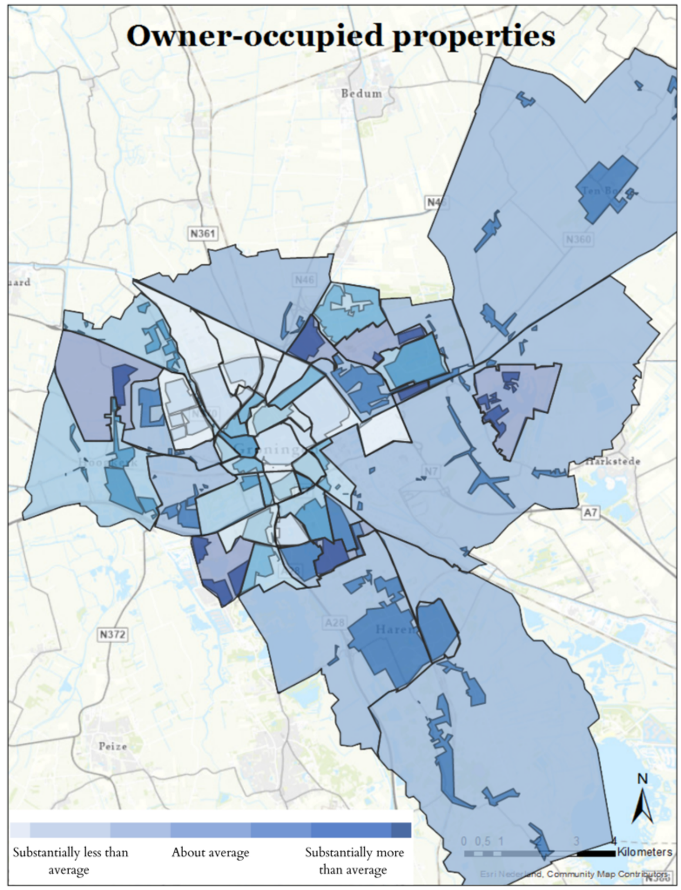


Figure 8 (left): Alternatives for natural gas (source: Gemeente Groningen, 2019, edited by author)
Figure 9 (right): Owner-occupied properties (source: Basismonitor, 2018, edited by author)

3.3. Data collection methods

3.3.1. Literature & document review

A review has been conducted of academic literature and reports from Dutch and international research organizations. As mentioned, this review formed the basis for the survey, interview guide, and deductive code tree. The databases SmartCat and Google Scholar are used in the search for academic publications. In addition, grey literature in the form of research reports from (independent) research organizations were included, such as TNO and Ecorys. The used literature mainly comes from organizations in the Netherlands, the United Kingdom, and Scandinavia. Most countries in Scandinavia have relatively advanced heat networks and may, therefore, present interesting best practices (Bouw, 2017). The United Kingdom is going through a similar transition as the Netherlands, where heat networks are gaining popularity as an alternative to the widely used gas-fired heating systems (Upham & Jones, 2012).

3.3.2. Survey

To answer the first, second, third, and fifth sub-questions, a survey will be used to acquire an understanding of citizens' perceptions regarding the barriers to connecting to a heat network and their influence on the preparedness to connect. The use of surveys is suitable for exploring people's attitudes, perceptions, and experiences (Clifford *et al.*, 2010) and is, therefore, appropriate for the variables in this study. In addition, surveys are useful to acquire a wide sample (Clifford *et al.*, 2010).

The survey has been built using the software Qualtrics XM. The survey design mainly consists of fixed-response questions, where respondents were asked to answer the questions using multiple choice or Likert items. The advantages of fixed-response questions are that they are relatively easy to answer and, also, to analyze as all responses are similar (Clifford *et al.*, 2010). The questions in the survey are partially based on items from prior research (Bouman *et al.*, 2018; Upham & Jones, 2012). The complete operationalization of the variables in this study can be found in appendix A. Before the survey was distributed, it was completed by two test persons to confirm whether the questions are understandable and to estimate the duration.

The strategy for conducting the survey is by means of an internet survey, which is beneficial in case of time and cost constraints (Clifford *et al.*, 2010). The sampling is done using a probability sampling technique, whereby potential respondents are personally approached house-to-house in the neighborhoods that have been identified by the municipality of Groningen as neighborhoods for which a heat network is seen as the most suitable alternative for natural gas (figure 8). As distributing the survey to each residence in the neighborhoods would be too costly, the target residences are identified using a random cluster sampling technique whereby residences from randomly selected streets in the neighborhoods received a flyer. The sampling was conducted from May 18th till May 29th, 2022. The full survey as well as a summary of the sampling procedure can be found in appendix B.

3.3.3. Interviews

To answer the fourth sub-question and to reflect on the survey results, the literature review was combined with in-depth expert interviews. The experts helped to gain a better understanding of the survey results. In addition, the interviews helped to reflect on the literature regarding the potential instruments to overcome the perceived barriers and identify the most appropriate instruments to support homeowners in Groningen. For this purpose, semi-structured interviews were used. Semi-structured interviews are based on a standardized list of questions, while at the same time allowing for a degree of flexibility, whereby the interviewee can discuss unanticipated topics (Clifford *et al.*, 2010). The interview guide (appendix C) is developed based on the literature review and the results from the survey. The participants for the interviews have been recruited using a purposive sampling technique by which participants are selected based on pre-set criteria (Clifford *et al.*, 2010). The first criterion is that the participants represent a balanced mix of academic experts and practical experts to be able to combine these different perspectives. Where practical experts can provide detailed information based on their familiarity and experience with a case, academic experts usually derive ideas from the comparison of cases and have more creative freedom (Van Assche *et al.*, 2020). Academic experts had to be academics or researchers in a relevant research area, such as the energy transition. The practical experts had to be people who have been extensively involved in the development of a heat network. Variation was also sought among the practical experts, by combining insights from someone with a municipal perspective with the perspective of a cooperative. An overview of the participants in the in-depth expert interviews is shown in table 3.

Table 3: Overview of participants in in-depth expert interviews

ID	Name	Function	Date & duration	Type of expert
Expert 1 (E1)	Dr. H. J. van der Windt	Associate Professor	07/06/2022, 00:34:10	Academic expert
Expert 2 (E2)	*	Project manager	08/06/2022, 00:42:38	Practical expert
Expert 3 (E3)	Dr. ir. A. L. Kooijman	Senior researcher	10/06/2022, 00:43:34	Academic expert
Expert 4 (E4)	A. Huizinga	Neighborhood counselor at Grunneger Power	13/06/2022, 00:46:04	Practical expert
Expert 5 (E5)	S. Volkers	Director at Grunneger Power	13/06/2022, 00:46:04	Practical expert

*Participant did not want to be mentioned by name.

3.4. Data analysis

3.4.1. Quantitative data

The data from the survey is analyzed using the statistical software platform SPSS. Qualtrics XM, the software that has been used to build the internet survey, automatically converts the survey responses to a dataset compatible with SPSS. All variables in this study, apart from the demographic characteristics, are treated as interval variables. The eleven perceived barriers and the preparedness to connect are measured using Likert items ranging from 1 to 10. According to Wu & Leung (2017), Likert items ranging to 10 are appropriate to treat as interval data, since more Likert scale points will result in a more even and normal distribution of points. For measuring one's personal values, the Environmental Portrait Value Questionnaire (E-PVQ) has been used which consists of Likert-type questions ranging from 1 to 7 (Bouman *et al.*, 2018). This theorized value structure, created by Bouman *et al.* (2018), treats the Likert items as interval data to create composite values for each value cluster. The internal consistency associated with the composite scores for the four value clusters has already been confirmed by Bouman *et al.* (2018). The EPV-Q is a valid method to aggregate composite scores for the values (Bouman *et al.*, 2018). As such, this study adheres to the use of the E-PVQ by treating the data as interval as well.

To answer the first sub-question, the Likert-type questions for the barriers have been analyzed using descriptive statistics. Descriptive statistics reveal which items were indicated by the respondents as being a barrier to connecting to the heat network. By comparing the confidence intervals of the mean of each barrier, it has been possible to indicate which barriers have been rated significantly higher than others, and, as such, form a larger barrier. When the confidence intervals showed inconclusive differences, Paired Samples T-tests were used to confirm.

In order to answer the second sub-question, the relationship between the respondents' personal values and perceived barriers was tested by performing separate correlation analyses between the composite scores for the values and each separate barrier. The correlation coefficient indicates the strength and direction of the relationship.

To test the relationship between the perceived barriers and the preparedness to connect, separate correlation analyses have been used. In addition, to explore the influence of the combination of predictor variables on the preparedness to connect to the heat network, a Multiple Linear Regression has been performed that included age and income as control variables. Multiple Linear Regression is suitable in this case, as it allows for the inclusion of multiple explanatory factors that can be interval as well as categorical variables (Burt *et al.*, 2009).

Lastly, to answer sub-question five, correlation analyses are used again, that correlate the composite scores for the personal values with the scores for the scenario questions and with a computed variable for the differences between the answers on the three scenario questions.

3.4.2. Qualitative data

To analyze the in-depth expert interviews, the interviews have been recorded using the audio recorder software Dictaphone. The recordings were transcribed using Trint and oTranscribe and coded using the coding tool ATLAS.ti. For the coding, a deductive code tree, as well as an inductive codebook, have been used (appendices D and E). The deductive code tree was created prior to the interviews based on the literature review of chapter 2. The inductive codebook was created after the interviews were conducted to be able to include codes that were identified during the data analysis process.

3.5. Ethical considerations

As a researcher, it is important to consider a variety of ethical matters while conducting research, as it will help to increase the credibility of the research (Clifford *et al.*, 2010). To make sure that relevant ethical matters were considered, the Ethical Checklist of the Research Ethics Committee of the Faculty of Spatial Sciences has been used. To avoid privacy issues, it was decided based on the checklist to avoid a possible identification of the respondent based on the zip code in combination with the sampled street. Therefore, the zip code of the respondents was only used to verify that the respondent was part of the target group and then removed.

The survey starts with a statement in which the respondent is informed about the aim of the study, that participating in the study is fully anonymous and voluntary, and that participation can be terminated at any moment. The respondents were only able to start the survey when they agreed to these terms. To ensure that interviewees were comfortable with answering the interview questions, a consent form (appendix F) needed to be signed by the interviewees in which the aim of the study was explained, and the question was posed whether their names could be used in the results. Before starting the interview, the interviewees needed to agree with the interview being recorded and at the end, they were thanked for their participation.

Lastly, it is important to reflect on the position of the researcher and the effect that it may have on the research outcomes. The background of the researcher, namely, influences how questions are formulated, data is filtered, and conclusions are drawn (Berger, 2015). Knowledge does not emerge from the gathered data but is constructed within a certain context. Firstly, it may, therefore, be important to note that the researcher has limited experience doing research. Therefore, the aim was to co-construct knowledge on the barriers, by reflecting on the results of the survey with several experts. In addition, as a student in the field of planning, the researcher is aware of the necessity and urgency of the energy/gas transition and knows, to some extent, about the pros and cons of different energy alternatives, which may have influenced how questions were formulated and answers were interpreted.

4. Results & Discussion

This chapter shows the results of the study per sub-question. The sub-questions are answered, where possible, by combining the results from the quantitative and qualitative data analysis.

4.1. About the quantitative dataset

A total of 77 survey responses have been recorded. Of these responses, eight respondents did not complete the full questionnaire and five respondents did not fit the target group requirements since they were not homeowners. These responses were, therefore, removed from the dataset. As such, the quantitative data analysis was performed on a dataset with 64 valid cases. Due to the low number of cases in the dataset, not every category of each variable in this dataset will have at least 30 cases. While it depends on the type of analysis that is to be done with the data, a minimum of 30 cases is generally seen as the rule of thumb to be able to draw strong conclusions from the analysis (Hogg & Tanis, 2006). Therefore, the limited number of cases must be kept in mind while interpreting the results.

One adaptation was made to the variables before starting the data analysis. Since the age category "75+" of the age variable did not include any cases, the category was merged with the age category "65 – 74".

Lastly, in the following chapters, the barriers that were presented to the respondents in the survey are referred to using labels. Table 4 describes the full barriers as presented to the respondents in the survey and the accompanying labels that are used in the following chapters.

Table 4: Labels for the barriers

Barrier	**Label**
The knowledge and/or time you need to make the necessary arrangements yourself to switch to the heat network (such as signing a contract and arranging any renovations to make your home suitable).	*Organizational concerns*
The temporary nuisance as a result of the construction work (such as breaking open the street and the installation work in your house).	*Hassle of construction*
Any consultation that is necessary with your neighbors to make collective agreements about the design process and the construction of the heat network in your neighborhood.	*Collective action*
The one-off investment costs (for, among others, the grid connection and adjustments to your home).	*Investment costs*
The monthly tariffs you expect to pay for heat from a heat network compared to the tariffs for your current heating system.	*Heat tariffs*
The monopoly of heat suppliers, which makes it impossible to switch heat suppliers (as is possible with energy suppliers).	*Monopoly supplier*
The trust you have in the technology of heat networks.	*Functional reliability*
Your lack of control over the heat source with which the water is heated.	*Control heat source*
The investments you have already made for your current energy system (for example for a domestic boiler or gas stove).	*Sunk investments*
The control you expect to have over the temperature in your home.	*Control temperature*
Having to cook on an induction cooktop instead of a gas stove.	*Electric cooking*

4.2. Perceived barriers

This section will provide an answer to the secondary research question "*What barriers do homeowners in Groningen perceive to connecting to a heat network?*" To answer this question, insight into the perceived barriers was gathered in three ways: by presenting the survey respondents with potential barriers, by allowing respondents to add barriers in an open question, and by asking the experts for their observations during the expert interviews.

4.2.1. Descriptive statistics

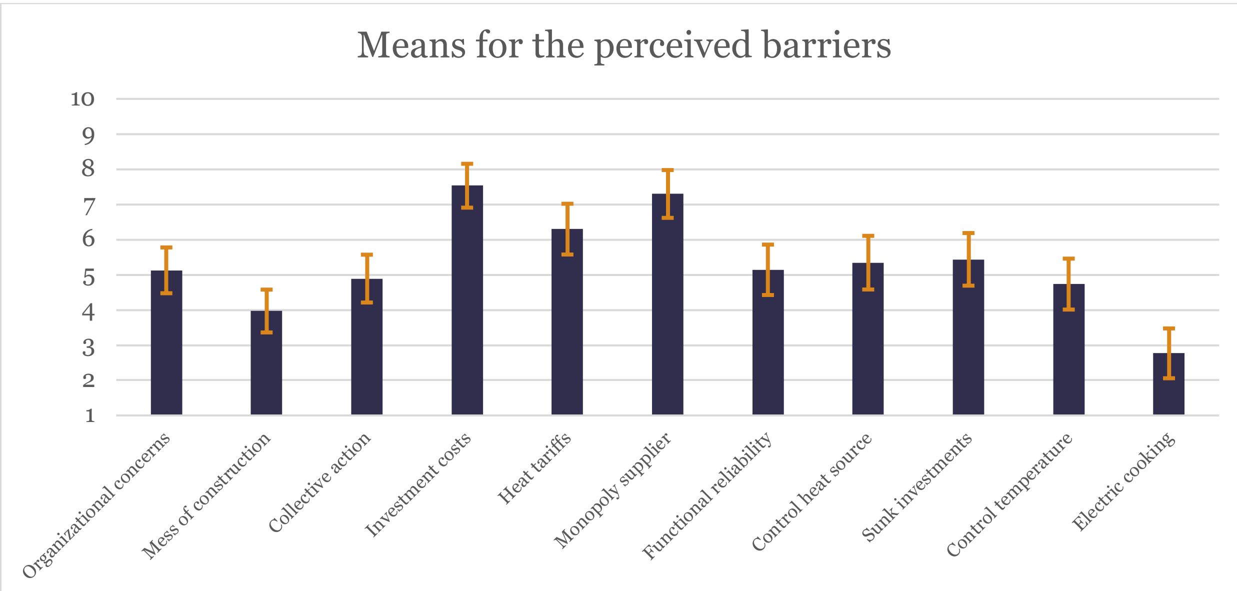


Figure 10: Means for the barriers with error bars representing the confidence intervals

To answer the first sub-question, first, a literature review was conducted that resulted in eleven potential barriers (see chapter 2.1.). The respondents of the survey were asked to score these potential barriers on a scale of 1 to 10, where 1 means no barrier and 10 means large barrier. The mean scores that were given by the respondents for the potential barriers are shown in a bar chart with error bars (figure 10). The numbers on the Y-axis refer to the items on the 10-point Likert scale and the error bars show the 95% confidence interval of the means. It can be said with 95% confidence that the lowest score (associated with electric cooking) is at least 2, which indicates that all eleven potential barriers to some extent form a barrier for homeowners in Groningen to connect to a heat network.

The three potential barriers with the highest means, regarding the investment costs, monopoly of the heat supplier, and the expected heat tariffs (table 5), scored significantly higher than all other barriers (see appendix G). Of the respondents, 64% scored the investments costs a 7 or higher and 72% scored the monopoly of the supplier a 7 or higher. For the expected heat tariffs, this was 47%. Electric cooking, as indicated in figure 10, is seen as a significantly lower barrier compared to the rest. Only 21% of respondents gave the potential barrier a score higher than 3.

Table 5: Descriptive statistics for the barriers

	Minimum	Maximum	Mean	Std. Deviation
1) Organizational concerns	1,00	10,00	5,1250	2,60342
2) Hassle of construction	1,00	10,00	3,9687	2,43629
3) Collective action	1,00	10,00	4,8906	2,72039
4) Investment costs	1,00	10,00	7,5312	2,49424
5) Heat tariffs	1,00	10,00	6,2969	2,88774
6) Monopoly supplier	1,00	10,00	7,2969	2,71784
7) Functional reliability	1,00	10,00	5,1406	2,86671
8) Control heat source	1,00	10,00	5,3438	3,05099
9) Sunk investments	1,00	10,00	5,4375	2,99139
10) Control temperature	1,00	10,00	4,7344	2,89632
11) Electric cooking	1,00	10,00	2,7656	2,83259

4.2.2. Most common barriers to be removed

As could be expected from 4.2.1., of the 64 respondents 24 mentioned in an open question that the costs needed to be lower or that they would need subsidies to increase their preparedness to connect to the heat network and 12 respondents referred to the concerns regarding dependency. While all other potential barriers scored relatively equally on the scale of 1 to 10, the responses to the open question revealed that the functional reliability of the technology was mentioned frequently as a barrier that needs to be removed to increase homeowners' preparedness to connect to the heat network. Nine respondents referred to the functional reliability in some way, for example, respondent 35 states: "*My biggest barrier is my lack of confidence in this expensive system and losing heat in transit*". In addition, respondents 32, 44, 55, and 58 referred to the *"security of the supply*". Another frequently mentioned barrier that needs to be removed is a lack of (objective) information. Ten respondents indicated that they have too little information about the pros and cons of heat networks and/or that they need to be informed better to potentially increase their preparedness to connect to the heat network. For example, respondent 62 wrote:

> "*I have little knowledge about the heat network and the difference compared to other heat sources and/or generating heat with electricity. I would like more independent information on how this technology compares to alternatives.*"

4.2.3. Reflection on the perceived barriers by the experts

These common barriers were also recognized by the experts during the interviews. As illustrated in the quotes below, the costs and the concerns about being dependent on one supplier were recognized as being main barriers. Also, the reliability of the network was mentioned by the experts. They mostly experienced concerns about whether people can still heat their homes in the same way (E2, E4). In addition, the lack of information was recognized by the experts as a barrier. Expert 2 noted that there is a large part of homeowners that do not yet understand why it is even necessary to get houses off gas. Expert 3 also indicated that it has not yet dawned on many residents that we need to get rid of gas and especially not in what time frame. One barrier that was not explicitly included in the survey but was added by all experts is regarding the expected changes that are needed inside the home. They noted that homeowners are concerned about the renovations that need to take place inside the house (see quotes below).

> "*The monopoly position and the expected cost, to pay more, I think is at the top. And what I also still notice is really the expected work inside the house.*" (E4)

> *"What I've taken away from [...] round table meetings is ambiguity about pricing and price development, ambiguity about control and dependence. Lack of clarity about comfort, and the fear of what all needs to be changed in the house." (E1)*

> "*So we've noticed in recent years that we're still on a crusade to tell people that we're going to get rid of gas. And if you then want to discuss the fact that this has to be done in this way, at this cost, and with a heat network, [...] that is ten steps further than realizing that we are going to get rid of the gas here and that something will have to replace it."* (E2)

What was interesting is that the interviews with the experts suggested that a large part of the barriers may arise from an underlying cause: a lack of trust in the municipality and the process by which the heat network is implemented. Expert 3 explained that research they had been involved in revealed that trust in the actors and the process in which a heat network comes about may be more important than the product or costs. Similarly, expert 2, as a practical expert, made the following statement:

> "*What I do notice is that people have to believe you.* [...] *Distrust in the government is something that we encounter from time to time. You can tell people that there is no investment and that the heat tariffs are lower than the gas prices and that you can get a good loan. But if they distrust the government, you don't need to have that conversation. Then the conversation is very different."* (E2)

This suggestion was also visible in some comments that were left by the survey respondents at the end of the survey, as illustrated in the examples below:

> *Survey respondent 4: "Warmtestad is an unknown organization to me.* [I have] *no confidence in the municipality of Groningen when it comes to these kinds of projects. After the pilot project with KEMA in our neighborhood,* [I have] *no desire for a heat network (it's a totally different mindset again)."*

> Survey respondent 6: "*I have no trust in the municipality to make and implement decisions in consultation with its citizens. The citizen is often the victim and participation is only for the show. (Unfortunately this is based on experience)".*

Expert 2 mentioned that the trust in the municipality is shaky, as people interact with the municipality in many ways. Homeowners may be dissatisfied with the parking policy in the neighborhood or with a tree that has been cut down, and that affects their willingness to engage with the municipality regarding the heat network (E2, E5). Because of this distrust, it may be that homeowners do not want to be dependent on the municipality as the sole supplier of heat. And because they don't trust the supplier, this may also feed into concerns about the functional reliability of the network, such as the security of the supply. The barrier regarding the lack of objective information may also stem from a lack of trust in the municipality as they are often the main provider of information.

4.2.4. Discussion of the perceived barriers

To answer the first sub-question, the eleven potential barriers that were included in the survey all to some extent form a barrier for homeowners in Groningen to connect to heat networks. In line with previous research, the costs appear to be among the most important barriers (De Koning *et al.*, 2020; Steenbekkers & Scholte, 2019). This concerns both the investment costs and the expected monthly tariffs. Although the monthly tariffs, as also indicated by the experts, are currently lower than the gas prices, homeowners still appear to be concerned about this. This is in line with the conclusion of De Koning *et al.* (2020) that for residents who have not yet received a concrete offer, the uncertainty about the costs leads to concerns. In addition, the monopoly position of the supplier appeared to be among the largest barriers, which is again in line with previous research (Haffner *et al.*, 2016; Upham & Jones, 2012).

Through analysis of the responses to the open question, a lack of (objective) information and the reliability of the technology were added to the list as most common barriers. The experts recognized the barriers in this list, and all interviewees added a sixth most common barrier: the needed changes inside the home. What was also shown in the qualitative data is that most of these barriers may be related to a lack of trust in the municipality and the process by which the network is implemented. Although the concrete lack of trust in the heat supplier has been encountered more frequently in previous literature (Haffner *et al.*, 2016; Bouw, 2017), the influence of the lack of trust in the government/municipality on the preparedness to make a connection was generally less described in the literature. However, research by Emmerich *et al.* (2020) on public acceptance of emerging energy technologies in Germany, specifically hydrogen fuel stations, biofuel plants, and stationary battery storage, also revealed that trust in the municipality has a significant influence on the general, but especially local acceptance of energy technologies. Their research explains that this has to do with the fact that municipalities are responsible for providing for their citizens' needs (such as energy) and are, therefore, generally involved in the implementation of energy technologies (Emmerich *et al.*, 2020). In addition, research by Jansma *et al.* (2020), who explored the perceptions toward the gas transition in the Netherlands, showed that trust in the municipality is an important factor influencing attitude toward the gas transition and showed that homeowners have doubts about whether the municipality has the capacity to manage the gas transition and consider their interests (Jansma *et al.*, 2020).

What was interesting to see from the descriptive statistics (table 5) is that each potential barrier has received a minimum score of 1 and a maximum score of 10, meaning that for each potential barrier there has been at least one respondent that has evaluated the potential barrier as being no barrier and at least one respondent that has evaluated the potential barrier as being a large barrier. This confirms the suspicion that the evaluation of the barriers may differ a lot from person to person. To try to provide an insight into how these differences come to be, the next section, 4.3., will look at the influence of one's personal values on the perceived barriers.

4.3. The influence of personal values on perceived barriers

This section will provide an answer to the secondary research question *"To what extent do one's personal values influence the perceived barriers?"*

4.3.1. Correlation analysis

To get an insight into one's personal values, the respondents were presented with 17 statements divided into four value clusters and were asked to score the statements on a scale of 1 to 7. The composite scores for the four value clusters were computed by calculating the mean of the scores for the items associated with the respective value. These composite scores were then used to explore the influence of personal values on the perceived barriers.

As several outliers were noted in the data (which was to be expected based on the wide range of answers to the potential barriers), it was chosen to use the Spearman's Rank Correlation analysis instead of the initially planned Pearson Correlation analysis. The Spearman Correlation, namely, is less sensitive to outliers (Kajuri, 2018). In addition, the Spearman Correlation is more suitable for monotonic relationships. With monotonic relationships, when the independent variable increases, the dependent variable tends to either increase or decrease, though perhaps not in a linear fashion (Kajuri, 2018). As the scatterplots indicated several weak linear relationships, this test is regarded to be more suitable to test the influence of one's personal values on the perceived barriers. Separate Spearman's Rank Correlation analyses were performed between each of the four value scores and each separate barrier. The general null hypothesis for the tests is as follows:

H0: In the population, there is no monotonic relationship between the personal value and the perceived barrier to connecting to heat networks.

Table 6: Overview Spearman's Rank Correlation coefficients

Spearman Correlations				
Value / **Barrier**	**Biospheric**	**Altruistic**	**Hedonic**	**Egoistic**
1) Organizational concerns	0.063	0.114	0.103	0.055
2) Hassle of construction	0.079	-0.138	-0.031	0.034
3) Collective action	0.008	**-0.251***	-0.041	-0.057
4) Investment costs	0.210	0.162	0.168	-0.030
5) Heat tariffs	0.066	0.133	-0.008	0.229
6) Monopoly supplier	0.090	0.129	0.043	0.172
7) Functional reliability	0.123	0.070	0.069	-0.070
8) Control heat source	**0.332***	0.161	-0.075	0.088
9) Sunk investments	0.106	0.054	-0.142	0.092
10) Control temperature	**0.273***	0.164	-0.084	0.093
11) Electric cooking	0.056	-0.105	**0.266***	0.134

*Correlation is significant at the 0.05 level (2-tailed).

An overview of the Spearman's Rank Correlation coefficients can be found in table 6. Four significant correlations were found. The first significant correlation is found between biospheric values and control over the heat source. The correlation coefficient indicates a weak positive relationship ($\rho = 0.332$), which means that as a homeowner scored higher on the biospheric value, they scored the lack of control over the heat source as being a larger barrier. The second significant correlation is found between biospheric values and control over indoor temperature. The correlation coefficient again indicates a weak positive relationship ($\rho = 0.273$), which means that as a homeowner scored higher on the biospheric value, they scored the expected control over their indoor temperature as being a larger barrier. The third significant correlation is found between altruistic values and collective action. This correlation coefficient indicates a weak negative relationship ($\rho = -0.251$), which means that as a homeowner scored higher on the altruistic value, they gave a lower score for the barrier regarding the collective action. The last significant correlation is found between hedonic values and electric cooking. This correlation coefficient indicates a weak positive relationship ($\rho = 0.266$), which means that as a homeowner scored higher on the hedonic value, electric cooking is regarded as a larger barrier.

4.3.2. Discussion of the influence of personal values on perceived barriers

To answer the second sub-question, one's personal values do, to some extent, influence the perceived barriers. This research has been able to find a significant influence of personal values on four perceived barriers, for which the following hypothesis can be accepted: "*Personal values influence the perceived barriers*".

The first significant correlation between the biospheric value and the barrier regarding control over the heat source is in line with our suspicion (see 2.4.1.), as homeowners who are concerned with the environment can be expected to care about the heat source, as the source of a heat network may not always be renewable (Steg *et al.*, 2015). This was also indicated by two respondents in the comment section, who mentioned that their preparedness to connect to the heat network would be greater if they were sure that the heat source is "*environmentally sound*". In line with this, the significant result for the correlation between the biospheric value and the control over indoor temperature may be explained by the fact that homeowners who are concerned with the environment can also be expected to be conscious about their energy use.

The third significant correlation between the altruistic value and the barrier regarding collective action is again a logical result, as people with dominant altruistic values are concerned with the well-being of others (Steg *et al.*, 2015) and may, therefore, be expected not to mind the need for making collective agreements and the consultation with neighbors that comes with it.

The last significant correlation was found between the hedonic value and the barrier regarding electric cooking. People with dominant hedonic values are concerned with their own comfort (Steg *et al.*, 2015). As explained in chapter 2.1.4., electric cooking may be regarded as less satisfactory than cooking on gas (De Koning *et al.*, 2020) and it was, therefore, already expected that people with hedonic values find electric cooking to be a larger barrier. As these values may influence homeowners' evaluation of the heat network, it will be beneficial to take these values into account when designing appropriate instruments to overcome the barriers. More information on how this can be done is set out in chapter 4.6.

As explained in chapter 2.4.1., it was expected that altruistic values would show a positive correlation with the hassle of construction, since people with dominant altruistic values may feel uncomfortable when other residents in the neighborhood are inconvenienced by the construction work. However, the correlation analysis did not show a significant result. Another expectation was that egoistic values would positively correlate with the investment costs. Yet, again, no significant result was found. An absence of significant results can often be explained by one of three reasons: the effect or the sample size is too small, or the variance in the data is too large (Wilhelm, 2018). As already mentioned at the beginning of this chapter, the sample size is small (N=64) making it more difficult to find significant results. However, for the barrier regarding the investment costs, it may also be explained by the fact that the investment costs are generally one of the largest barriers for homeowners in Groningen (see 4.2.1.). As the barrier is scored relatively high by all types of homeowners, this may explain why the investment costs do not show a significant correlation with egoistic values.

4.4. Perceived barriers & the preparedness to connect to the heat network

This section will provide an answer to the secondary research question *"To what extent do the perceived barriers influence the preparedness to connect to a heat network?"*

4.4.1. Descriptive statistics

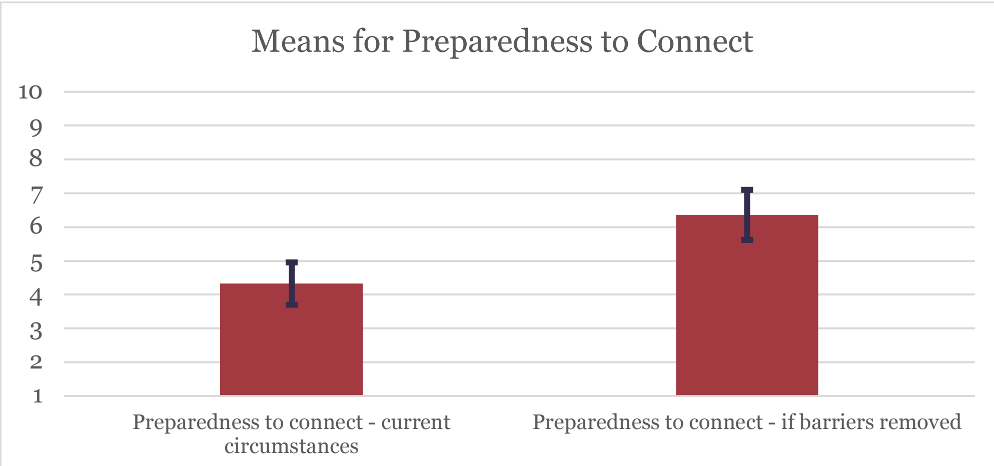


Figure 11: Means of the preparedness to connect with error bars representing the confidence intervals

The mean score given by the respondents for their preparedness to connect to the heat network in the current situation is **4.3** on a scale from 1 to 10, where 1 means not at all prepared and 10 means fully prepared. After that, respondents were asked to indicate their preparedness to connect to the heat network if the barriers as indicated by the respondent would be removed. The mean score if the barriers would be removed is **6.4**. As shown in figure 11, the confidence intervals of the means do not overlap, indicating that the preparedness to connect is significantly higher if the barriers would be removed. This difference in means hints at the existence of a relationship between the barriers and the preparedness to connect to the heat network.

4.4.2. Multiple Linear Regression

To test the influence of the separate barriers on the preparedness to connect, first, the correlations were analyzed. The correlation matrix (appendix G) indicated that all barriers show a significant correlation with the preparedness to connect to the heat network, except for *organizational concern* (r = -0.169, p = 0.091) and *electric cooking* (r = -0.125, p = 0.162). All barriers show a negative correlation coefficient, meaning that as the score for the barrier is higher, the preparedness to connect to the heat network is lower. The barriers *collective action* (r = -0.388), *investment costs* (r = -0.338), and *control over indoor temperature* (r = -0.392) show weak negative relationships with the preparedness to connect to the heat network. The barriers *hassle of construction* (r = -0.528), *heat tariffs* (r = -0.481), *monopoly of the supplier* (r = -0.560), *functional reliability* (r = -0.408), and *control over the heat source* (r = -0.565) show moderate negative relationships with the preparedness to connect to the heat network. Lastly, the barrier regarding the *sunk investments* shows a strong negative relationship with the preparedness to connect to the heat network (r = -0.604). The control variables age and income did not show a significant correlation with the preparedness to connect to the heat network.

To be able to explore the extent of the influence on the preparedness to connect, it was analyzed how much of the variance in the preparedness to connect can be explained by the combination of the predictor variables. Therefore, a Multiple Linear Regression (MLR) was used. To include age and income as control variables in the analysis, a hierarchical MLR has been used where the first model consists of the predictor variables, which are the eleven barriers, and the second model includes the control variables age and income. The null hypothesis for this test is as follows:
H0: In the population, there is no linear relationship between the preparedness to connect to the heat network in the current situation and the predictor variables.

Dummy variables were created for the ordinal control variables. The reference group for the income variable is represented by the income level of €0 to €15.000. The reference group for the age variable is represented by the age group 65+. Before the results were interpreted, the assumptions for the MLR were checked (see appendix G). The results of the ANOVA were significant for model 1 (p = 0.000), which means the H0 is rejected, and it can be assumed that there is at least one linear relationship. Model 2, where the control variables were added, was not significant.

Table 7: Summary hierarchical regression analysis

Model		**1**			**2**		
		B	**S.E.**	**Beta**	**B**	**S.E.**	**Beta**
1	*Organizational concerns*	-0.008	0.116	-0.008	-0.032	0.135	-0.034
	Hassle of construction	-0.197	0.136	-0.191	-0.246	0.158	-0.239
	Collective action	-0.019	0.114	-0.021	0.047	0.133	0.051
	Investment costs	-0.087	0.115	-0.087	0.032	0.132	0.032
	Heat tariffs	-0.018	0.118	-0.021	-0.103	0.137	-0.118
	Monopoly supplier	-0.211	0.136	0.128	-0.157	0.172	-0.170
	Functional reliability	-0.026	0.117	-0.030	0.081	0.134	0.092
	Control heat source	-0.151	0.144	-0.184	-0.231	0.151	-0.259
	Sunk investments	**-0.244***	**0.114**	**-0.292**	**-0.334***	**0.129**	**-0.398**
	Control temperature	0.034	0.122	0.040	-0.111	0.139	-0.128
	Electric cooking	0.142	0.093	0.161	0.115	0.099	0.130
2	*Income 15.000 – 25.000*				-0.836	1,725	-0.071
	25.000 – 35.000				-0.397	1.338	-0.068
	35.000 – 45.000				0.070	1.187	0.012
	45.000 – 55.000				-0.035	1.303	-0.005
	55.000 – 65.000				0.463	1.388	0.058
	65.000+				-0.594	1.442	-0.075
	Age 20 - 24				-3.730	2.442	-0.186
	25 - 34				**-2.504***	**1.154**	**-0.350**
	35 - 44				-0.630	1.020	-0.088
	45 - 54				-0.906	0.900	-0.166
	55 - 64				0.482	0.866	0.080
	R2	**0.534***			0.632		
	R2 change				0.098		

*Significant at the 0.05 level (2-tailed).

Table 7 shows the results of the hierarchical regression analysis, in which the preparedness to connect to the heat network in the current situation is the dependent variable. Model 1, consisting of the potential barriers, provides a statistically significant contribution to predicting the outcome (F change = 0.000). Therefore, it can be assumed that if all barriers are removed the preparedness to connect to the heat network would increase. The potential barriers account for 53.4% of the variance in the outcome (R2 = 0.534). The second model, in which the control variables were added, did not provide a statistically significant contribution to predicting the outcome (R2 change = 0.098, F change = 0.472).

In the first model, the only significant predictor was the potential barrier regarding the sunk investments (β = -0.292, p = 0.036). The B-coefficient of -0.244 indicates that as the score given for the barrier regarding the sunk investments increases by one, the preparedness to connect decreases by 0.244 on average. For the other barriers, the MLR did not show any significant results, meaning the MLR is not able to predict the size of the effect of the barriers on the preparedness to connect.

After adding the control variables in the second model, the strength of the relationship between the sunk investments and the preparedness to connect increased, yet the relationship remained weak (β = -0.398, p = 0.013). The second model also showed a significant outcome for the age group of 25 – 34 (β = -0.350, p = 0.036), which indicates that homeowners in the age group 25 – 34 gave lower scores for the preparedness to connect to the heat network compared to homeowners in the age group 65+.

4.4.3. Discussion of the perceived barriers & the preparedness to connect

The significant difference between the mean score for *preparedness to connect to the heat network in the current situation* and the mean score *if the barriers as indicated by the respondents had been removed* hinted at a relationship between the perceived barriers and the preparedness to connect. The correlation analyses confirmed the existence of a negative relationship between the preparedness to connect to the heat network and nine of the eleven barriers. For these nine barriers, the first hypothesis can be accepted that "*Homeowners who perceive barriers to a high extent are less prepared to make a connection to a heat network compared to homeowners who perceive barriers to a low extent*". The barriers regarding electric cooking and organizational concerns did not show a significant relationship with the preparedness to connect. As electric cooking is regarded as a significantly lower barrier than the other potential barriers, it is logical to assume that the barrier does not significantly influence the preparedness to connect. However, as the organizational concerns scored relatively equally to the other barriers, the insignificant result is more unexpected, and no reasonable theoretical explanation was found. Yet, the p-value of the barrier is relatively low (p = 0.091) and would have been significant if a higher significance level of 0.1 would have been chosen.

The barriers together explain 53% of the variance in the preparedness to connect. The other half of the variance may be explained by factors that were not included in the survey. For example, six respondents mentioned in the comments that they had already switched to other heating alternatives, such as a heat pump, and were, therefore, not prepared to make the connection to the heat network. As stated by respondent 6:

> "*I have already done a lot to make the house more sustainable. Solar panels, heat pump, insulation, heat recovery system. I am not prepared to leave the current path. In my street there has already been a shift toward sustainability and a heat network would be a step backwards.*"

Another explanation may be the influence of a lack of trust in the municipality, which was mentioned in the survey comments as well as by the experts during the interviews (see 4.2.3.). With the MLR, it has not been possible to explore the size of the effect of the barriers on the preparedness to connect for all but one variable. A reason for the limited significant results may be that the dataset included too few values to be able to explain the variance.

Furthermore, conflicting with the expectations, age and income did not show a significant correlation with the preparedness to connect to the heat network and did not provide a significant contribution to predicting the outcome of the MLR. Concerning age, based on the research by Mahapatra & Gustavsson (2008) and Gaspari *et al.* (2021), the expectation was that the preparedness to connect would decrease as age increases, since older homeowners may be concerned that they are not able to recoup their investment and because younger people often have a more positive attitude toward the gas transition. The conflicting results of this research may be explained by the fact that, in practice, the relationship may be parabolic or quadratic as homeowners at younger age levels may have less financial capacity (Isaksson, 2005). However, this has not been visible in the scatterplot.

4.5. Potential instruments to overcome the barriers

This section will provide an answer to the secondary research question "*What instruments may support homeowners to overcome the barriers in order to increase the preparedness to connect to the heat network?*"

To overcome the barriers, a wide range of instruments can be deployed, of which an exploration has been set out in chapter 2.3. Through the expert interviews, in combination with the scenario questions from the survey, a set of instruments has been indicated that may be effective to support homeowners in Groningen to overcome the most common barriers to connecting to the heat network.

4.5.1. Building trust

As explained in section 4.2.3., it is plausible that a part of the barriers originates from a lack of trust in the actors and process of implementing a heat network. Therefore, building trust between homeowners and the municipality (and heat supplier) may be an important first step. As indicated by the quote below, this lack of trust is often due to the fact that homeowners link different issues and experiences they have had with the municipality to each other. Experts 2 and 5, therefore, advocate using an integrated planning approach, where the energy issue is not seen as an isolated issue but is combined with other issues in the neighborhood, such as social issues, redevelopment of public space, or renovation of homes. In this way, the neighborhood renewal will likely address the concerns of different types of homeowners, increasing the preparedness of homeowners to connect to the heat network.

> "*As a citizen, you encounter a municipality in many ways. That can be from the counter where you have to pay for your driver's license and you don't agree with it, to when a tree is chopped down in front of your house and you don't agree with it, and you just didn't get a letter of notification. So, it can all be down to such small things that trust in the government can be shaky quite quickly, I believe. [...] We are therefore trying to combine the construction of the heat network with the redevelopment of public spaces in as many places as possible to minimize the inconvenience to residents."* (E2)

In addition, to increase trust, experts 3 and 4 mentioned the importance of engaging and informing citizens throughout the whole process of implementing the heat network. Making sure that homeowners are structurally updated about the implementation of the heat network might help to make homeowners understand what is happening and, consequently, increase their preparedness to connect to the heat network. As stated by expert 4:

> *"The most important thing about this kind of project is that you work on trust. And trust is formed in the process. You must make agreements with the residents that you will meet on a structural basis in order to keep each other informed about developments."* (E4)

Next to having regular meetings with homeowners ("*every month or two months*"), expert 4 adds that to increase trust these meetings should be with the same person so that homeowners can rely on familiar faces. Yet, there may also still be a need for complementary objective sources to increase trust in the process of implementing heat networks.

4.5.2. A central heat authority & energy coaching

As homeowners find themselves lacking objective information about the pros and cons of heat networks, expert 1 proposes a central heat authority. This central heat authority can offer objective information about the heat network to homeowners, but also municipalities that (are planning to) implement a heat network (E1). Through such a heat authority, experiences gained in different cities (and even in other countries) can be brought together in one central point of information that is accessible to municipalities and homeowners. In addition, this authority can employ energy coaches that can help to give homeowners tailored information on what would be the best alternative for heating their homes. The idea of the energy coaches is explained well in the following quote:

> "*What I have seen operating successfully in many places are energy coaches. These are often people from the neighborhood who are trained briefly, who know the houses well, who know the technology reasonably well, who also have connections with others and who can thus remove a lot of barriers."* (E1)

Besides, as proposed by expert 1, they can organize low-threshold street meetings, where the energy coaches inform a neighborhood about the effects of different heating alternatives for that neighborhood. The idea of the street meetings is that they enable homeowners to also get in contact with each other and let ideas arise from the interactions between them (E1). Expert 1 spoke from experience that if you take residents seriously, they can come up with their own solutions for their concerns that companies may not think of.

4.5.3. Distributed ownership

One of the main barriers for homeowners in Groningen is the monopoly position of the heat supplier. As this was already expected to be a large barrier, respondents of the survey were asked to indicate their preparedness to connect to the heat network in three scenarios with different ownership options.

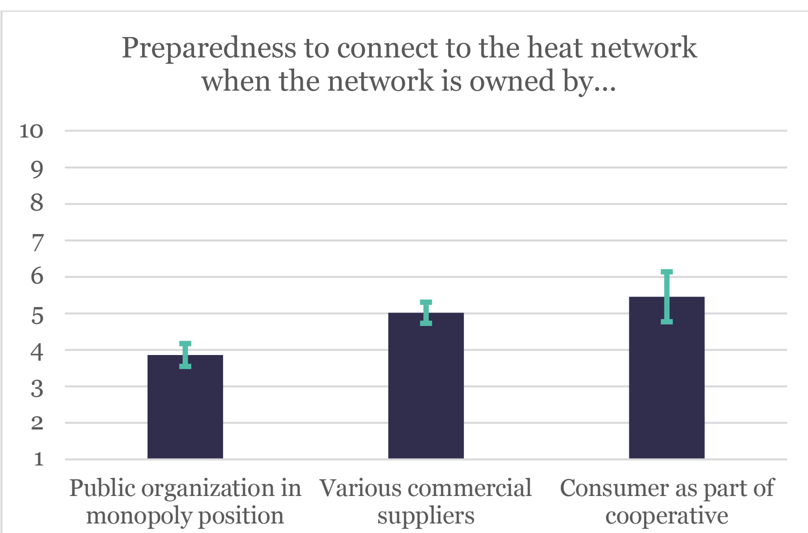


Figure 12: Means for the preparedness to connect – ownership

As could be expected, figure 12 shows that the confidence intervals of the mean for the scenario where the network is owned by a public organization in a monopoly position do not overlap with the confidence intervals of the other means, indicating that the preparedness to connect to the heat network is significantly lower when the network is owned by a public organization in a monopoly position compared to when the network is owned by various commercial suppliers or by the consumer as part of a cooperative.

As the figure did not show a conclusive difference between the latter, a Paired Samples T-test was performed for the difference between the other two means. The test was not significant ($p = 0.138$), indicating that there is no difference between the preparedness to connect to the heat network when it is owned by various commercial suppliers or by a cooperative. Changing the ownership of the heat network from a public organization in a monopoly position to either an open network or to ownership by the consumers as part of a cooperative may, therefore, increase the preparedness of homeowners to connect to the heat network.

According to most experts, however, a completely open network will likely not happen in the Netherlands (E1, E2). As mentioned by expert 5, the Municipal Council of Groningen has stated that the network itself will never be commercial, but there may be commercial sources connected to the network in the future. Experts 1, 2, 4, and 5 do advocate the involvement of cooperatives. Cooperatives do not only help to increase the direct influence of citizens, but they can also help to keep costs low, as is illustrated by the quotes below:

> "*What I think is very much behind that barrier of the monopoly position is that people have no choice, and they have no influence.* [...] *With a cooperative, you get back that feeling of autonomy and having your own influence."* (E4)

> "*That* [cooperative] *runs without profit. That means there are much lower costs. And so that means you can also keep the tariffs very low. Also, the members can intervene immediately if they think things are going wrong, so they have an influence and they are already starting with lower costs."* (E1)

The network will likely not be fully in hands of cooperatives in the future either, as such major infrastructural changes cannot be done without collaboration with the municipality (E5). Rather than a fully public or fully cooperative network, it was mentioned that distributed ownership by the municipality together with local energy cooperatives may be more viable to increase the preparedness of homeowners to connect to the network (E5, E1). The parties involved in this distributed network should be democratically controlled (E1). In such a case, the cooperative can act as an advocate between homeowners and heat supplier/municipality (E5). Expert 1 notes that it is important that legislation is well thought through to enable distributed ownership in practice.

4.5.4. A good offer

Two of the other most common barriers are the investment costs and the expected monthly tariffs for heat. As the costs were also already expected to be among the main barriers, a similar scenario question was used as was done for the ownership. Respondents were asked to indicate their preparedness to connect to the heat network when the payback period of the investments is 20 years, 10 years, and 5 years. As can be seen from figure 13, the preparedness to connect to the heat network is significantly higher if the payback period is 5 years compared to 10 and 20 years.

As the figure did not show a conclusive difference between the 10- and 20-year payback scenarios, a Paired Samples T-test was performed again. The test was significant (p = 0.000), which indicates that there is also a significant difference between these two means. It may, therefore, be expected that lowering the costs to decrease the payback period will increase the preparedness to connect to the heat network.

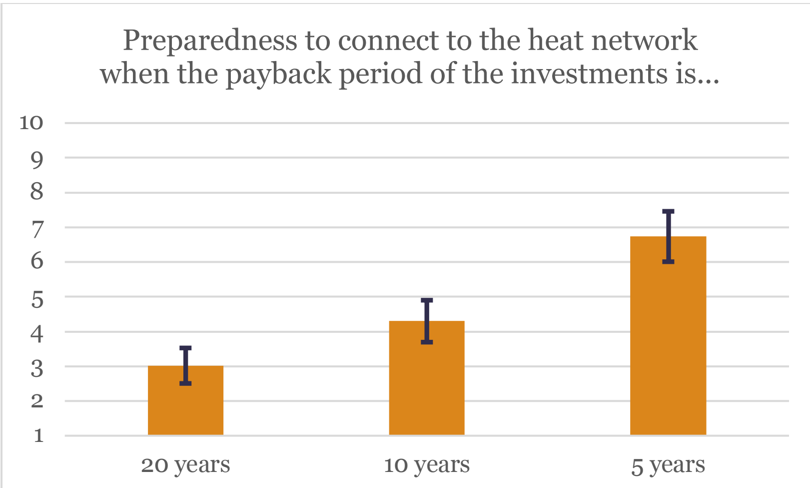


Figure 13: Means for the preparedness to connect - payback period

Experts 1 and 3 do not believe that 5 years is a realistic payback period. Yet, different from what the quantitative data implies, they also believe that drastically lowering the costs will not necessarily increase the preparedness of homeowners to connect to the heat network. Expert 3 stated:

> *"I think clarity in expectations and clarity in what degrees of freedom they* [homeowners] *will have matters a lot. More than ten percent subsidy. Or even more than a hundred percent subsidy."*

Experts 4 and 5 do argue that a good offer is crucial to make people join a heat network: "*We have really learned from pilot projects that only with an attractive offer will you get people on board"* (E4). Yet they also argue that a good offer does not only include minimal costs, but also clarity about what homeowners can expect, and a guarantee that they will have an influence on the process. In addition, experts 4 and 5 indicated that it is important that these offers are created in consultation with the homeowners as each neighborhood has its own local context that must be considered to make a "good offer".

The offer that has been created by the energy cooperative in Groningen contains the following 5 aspects:

1) Zero investment costs (the investment costs must be paid but will be completely refunded using a subsidy).
2) The opportunity to have a personalized calculation of the energy costs with a connection to the heat network.
3) A level of control through input sessions with the heat supplier, organized by the cooperative.
4) A free induction cooktop.
5) And advice from a project leader "Behind the Front Door" to help make the necessary arrangement inside the home.

4.5.5. Ambassadors & personal counseling

Lastly, to increase homeowners' trust in the technology of heat networks and to lower the barrier regarding the renovations inside the home, heat companies can deploy ambassadors and personal counselors. Ambassadors are homeowners who have a connection to the heat network themselves, are satisfied with it, and want to propagate this (E2, E3). As stated by expert 2:

> *"We are also really looking for ambassadors. People who have taken a certain step towards making their homes more sustainable or who have a connection to that heat network and who are also going to tell their stories.* [...] *Because the signals we've received so far from complexes that are now connected is that people experience very little inconvenience there or they experience very little differences.* [...] *I think you must experience it. And if you haven't experienced it yourself, I think it's most convincing if you hear it from someone who has."*

As the first homeowners are now connected to the heat network in Groningen (Gemeente Groningen, 2021), their experiences may be used to convince potential adopters to take the same step. Especially when homeowners do not trust the municipality, they may consider the stories from other homeowners in Groningen as a more credible source of information.

While the experiences from these ambassadors may also help to decrease the barrier regarding the fear of what needs to be changed inside the house, as these changes are usually regarded as being minimal, another instrument to overcome this barrier is to assist homeowners in making the necessary arrangements (E4, E5). Also, for this potential instrument, a question was asked to the survey respondents using three scenarios regarding the responsible party for arranging the necessary measures to one's residence.

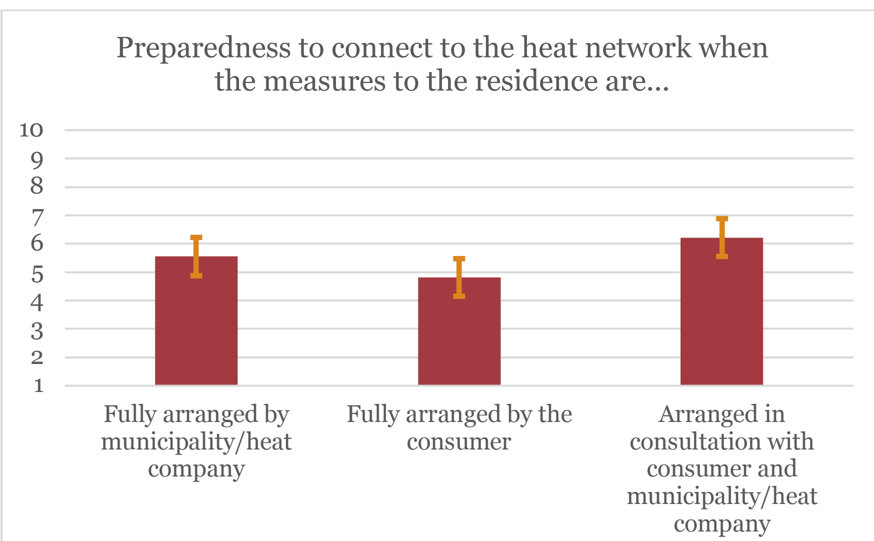


Figure 14: Means for the preparedness to connect – responsibility arrangements

Figure 14 showed no clear differences. Therefore, tests were performed to compare the means (see appendix G). All tests showed a significant result, meaning that the preparedness to connect to the heat network is significantly higher when the measures are arranged in consultation than when the measures are fully arranged by the municipality/heat company ($p = 0.008$) or when the measures are fully arranged by the consumer ($p = 0.000$). In addition, the preparedness to connect is significantly higher when the measures are arranged by the municipality/heat company than when the measures are fully arranged by the consumer ($p = 0.008$). As such, making the necessary arrangements in consultation may increase the preparedness of homeowners to connect to the heat network.

In line with these results, experts 4 and 5 proposed to deploy personal counselors (or, in the case of Groningen, called "project leaders Behind the Front Door"), who can personally assist homeowners with applying for subsidies, choosing a new cooktop, and with other questions (E4). Expert 4 mentioned that they noticed in practice that unburdening homeowners in this way has greatly helped to remove the barrier regarding the expected renovations inside the home.

4.5.6. Discussion of the instruments to overcome the barriers

To answer the fourth sub-question, the following instruments may support homeowners to overcome the most common barriers in order to increase their preparedness to connect to the heat network:

1) Building trust through using an integrated planning approach and through engaging citizens during the whole process

This step resonates with the literature, as several studies have mentioned the importance of engaging homeowners early and appropriately in the development of a heat network (Kort *et al.*, 2020; De Koning *et al.*, 2020). Emmerich *et al.* (2020), who researched the public acceptance of emerging energy technologies in Germany, recommended that to increase trust, the municipality must clarify how the decision-making process was set up and give each involved actor a say in the implementation process. According to expert 4, this can best be done using structural up-date moments between homeowners and fixed representatives. Having a personal point of contact in the neighborhood has shown to help increase trust in the provider (Kort *et al.*, 2020).

2) Distributed ownership over the heat network by the municipality and local energy cooperatives

According to the experts, involving local cooperatives will help to keep costs low and increase the direct influence of homeowners to overcome the barrier regarding the monopoly of the supplier. According to De Bakker *et al.* (2020), such co-ownership works well as the parties are complementary. Where one has the right connections with the environment, the other has the knowledge and power to execute such projects (De Bakker *et al.*, 2020). Furthermore, as stated in 2.3.3., being part of a cooperative may increase the involvement of homeowners in the topic of sustainability (Kort *et al.*, 2020).

3) A central heat authority & energy coaches that provide objective information and help homeowners to find the most appropriate heating alternative for their homes

Giving homeowners the opportunity to access these sources of information, will help to overcome the barrier regarding the lack of (objective) information. Furthermore, expert 1 added that the energy coaches can, next to providing information, also gather knowledge and ideas from the citizens. As was also mentioned by Beauchampet & Walsh (2021), citizens can bring local knowledge to the table, which can be useful during the implementation process.

4) A good offer including a fair price, clarity about what to expect, and a guaranteed level of control

As mentioned by the experts, the offer can help to remove cost- and trust-related barriers and can best be drawn up in consultation with the homeowners of a neighborhood, as each neighborhood has its own local context and demands. The comprehensive offer that is now offered to homeowners in Groningen (see 4.5.4.) may even help to alleviate organizational concerns, as it offers a standard package of measures as proposed by Kort *et al.* (2020) (chapter 2.3.8.).

5) Ambassadors & personal counseling to increase trust in the technology and lower the barrier regarding the renovations inside the home

The ambassadors and personal counselors are expected to form a credible source of information for potential adopters. Mahapatra & Gustavsson (2008) referred to this as the importance of interpersonal communication in the decision-making process of potential adopters of energy technologies. According to their research, the decisions of potential adopters are influenced by recommendations of neighbors, relatives, and friends, whose information is preferred over information provision via mass media channels (Mahapatra & Gustavsson, 2008).

While the instruments as set out above may be effective, experts 2 and 3 do warn that the approaches that are currently being used are very time- and cost-consuming. Also, expert 4 admits that to be able to make a similar offer to other neighborhoods in Groningen as the cooperative has done so far, a lot of additional funding is necessary. Experts 2 and 5, however, state that the experiences that are being gained now can be used in the future to be able to scale up the implementation process. Not only as the good experiences of homeowners can be used to propagate heat networks, but also since it will help to standardize parts of the process. Yet, as stated by expert 5, not everything can or should be standardized:

> "*I always say that you have certain parts in that approach that you can scale up at some point and there are also certain parts that just remain customized. And you will need those as well.* [...] *I think good experiences are going to help enormously in terms of communication in the neighborhood, which means you don't have to go out of your way as much as you do now. But I think that such an approach at the residents' homes, so really unburdening them, is something you will continue to need.*"

4.6. Potential instruments & personal values

This section will provide an answer to the secondary research question *"How do one's personal values influence what instruments one is susceptible to?"*

4.6.1. Correlation analysis

To gain insight into whether one's personal values influence what instruments one is susceptible to in general, first, the values were correlated with the scores given by the respondents for their preparedness to connect in the different scenarios as introduced in chapter 4. 5.. In addition, to gain insight into how one's personal values influence how strongly one's preparedness to connect to the heat network increases/decreases when the instruments are offered, new variables were created for the differences between the answers in the different scenarios. These new variables were also correlated with the composite scores for the four values. As the scatterplots again showed potential monotonic relationships, it was chosen to use the Spearman's Rank Correlation analysis. The general null hypotheses for the tests are as follows:
H0: In the population, there is no monotonic relationship between the personal value and the preparedness to connect to the heat network in the different scenarios.
H0: In the population, there is no monotonic relationship between the personal value and the difference in the preparedness to connect to the heat network between the scenarios.

Table 8: Overview Spearman's Rank Correlation coefficients

Spearman Correlations				
Value **Differences**	**Biospheric**	**Altruistic**	**Hedonic**	**Egoistic**
Payback period 20 year	0,088	0.044	0.064	-0.038
Payback period 10 years	0.011	-0.088	-0.043	0.026
Payback period 5 years	-0.097	-0.147	0.007	0.164
Ownership public monopoly	-0.079	-0.095	-0.115	-0.187
Ownership multiple commercial parties	0.016	0.027	0.030	0.129
Ownership cooperative	0.010	-0.021	0.103	0.187
Arrangements residence by municipality/supplier	-0.151	0.049	0.157	-0.008
Arrangements residence by consumer	0.040	0.017	0.186	0.167
Arrangements residence in consultation	-0.010	0.131	0.127	0.40

Table 9: Overview Spearman's Rank Correlation coefficients

Spearman Correlations				
Value **Differences**	**Biospheric**	**Altruistic**	**Hedonic**	**Egoistic**
Difference means payback period scenario 1 & 2	-0.126	-0.183	-0.188	0.081
Difference means payback period scenario 2 & 3	-0.217	-0.091	0.103	0.150
Difference means ownership scenario 1 & 2	0.102	0.098	0.152	0.213
Difference means ownership scenario 2 & 3	0.001	-0.034	0.023	0.098
Difference means responsibility arrangements scenario 1 & 2	0.108	0.013	0.033	0.217
Difference means responsibility arrangements scenario 2 & 3	-0.153	-0.025	-0.109	-0.232

The correlation matrices did not show any significant results. Therefore, the H0 is accepted for each test, and it can be assumed that there is no monotonic relationship between the personal values and the preparedness to connect to the heat network in the different scenarios, nor between the personal values and the differences in preparedness to connect to the heat network between the scenarios.

4.6.2. Discussion of the influence of personal values on the instruments

To answer the fifth sub-question, this research has not been able to find significant correlations between personal values and the effect of instruments on preparedness to connect. For example, it was suspected that homeowners with more dominant biospheric values would need less financial support to increase their preparedness to connect, and so, it could be expected that the difference in preparedness to connect between the payback period scenarios would be smaller for people with dominant biospheric values (or in other words, there would be a negative relationship between the biospheric value and the difference in means between the payback period scenarios). While, for people with dominant egoistic values, a decrease in the payback period could be expected to have a larger effect on the preparedness to connect (in other words, a positive relationship between the egoistic value and the difference in means between the payback period scenarios). As there were no significant relationships, the following hypothesis cannot be accepted: "*Personal values influence the relationship between the instruments to overcome the barriers and the preparedness to connect to the heat network.*" However, this research has only been able to test this relationship for three types of instruments as set out above. There may be correlations to be found regarding other types of instruments that have not been tested in this research. In addition, the absence of significant results may again be attributed to the sample size.

While no significant relationships were found, one's personal values did show to influence the perception of the barriers to connecting to the heat network (see 4.3.). Therefore, it may still be important to consider these values when deploying an instrument to increase the preparedness of homeowners to connect to the heat network. To be able to do so, experts 4 & 5 indicated that it is good to make sure that the information that is spread addresses aspects that appeal to all values. In addition, the offer that is made to homeowners should contain aspects that appeal to these different types of homeowners. Expert 4 explained it as follows:

> "*When you design a website or make an information leaflet always look at those different personalities where people choose to participate from a certain motivation. For example, we organize a sustainable cooking workshop. Well, that's typically for people who wonder: does an induction stove work like it does now, and how do I clean it easily, and do I like it or not without a gas flame? And so from those different motives you really look at what you can organize for those particular types of residents.*"

Concretely, this could mean that for homeowners with dominant biospheric values, information sessions can be held about how the heat network may contribute to reducing CO_2 emissions and increasing local air quality (Reynebeau, 2019). For homeowners with dominant altruistic values, this may mean providing neighborhood sessions where they can discuss their wishes and concerns with their neighbors, and for homeowners with dominant hedonic values, a cooking workshop as explained in the quote may be organized. The same should be done with regards to the offer and information leaflets that are provided, which will need to address aspects related to comfort, the environment, and finances.

5. Conclusion

This chapter will give an answer to the central research question. The answers to the sub-questions, that have been given in the previous chapter, have provided the information necessary to answer the central question. After presenting these findings, this chapter will elaborate on potential further research directions and the implications of the findings for planning practice.

5.1. Key findings

The aim of this study was to acquire an understanding of the barriers that influence the preparedness of homeowners to connect to a heat network. In addition, this research aimed to identify what instruments may support homeowners to overcome these barriers. Therefore, the central research question was formulated as follows:

"*Which barriers influence the preparedness of homeowners to connect to a heat network and what instruments may support homeowners to overcome the barriers?"*

To answer the first part of this research question, the following barriers showed a negative association with the preparedness of homeowners to connect to the heat network: the need for collective action, the investment costs, the expected control over indoor temperature, the hassle of construction, the expected monthly heat tariffs, the monopoly of the heat supplier, the functional reliability, the lack of control over the heat source, and sunk investments in homeowners' current heating systems. While the correlations found in this research should not be over-interpreted with regard to causality, the barriers can be assumed to have a negative influence on homeowners' preparedness to connect to the heat network.

Of these barriers, the investment costs, the monopoly of the supplier, and the expected monthly tariffs for heat appeared to form the largest barriers for homeowners. While the other barriers were scored relatively equally, the open question revealed that, next to the costs and the monopoly position of the supplier, the reliability of the technology (functional reliability) was mentioned frequently as a barrier that would need to be removed in order to increase the preparedness of homeowners to connect to the heat network. In addition, the answers to the open question and the expert interviews revealed that a lack of (objective) information and the expected renovations that are needed inside the home were frequently mentioned as important barriers that influence the preparedness of homeowners to connect to the heat network.

Although it was possible to identify some most common barriers, this research also made clear that the perceived barriers may differ a lot from person to person and are, to some extent, influenced by one's personal values. While, again, these correlations should not be confused with causal relationships, the barriers regarding the control over the heat source and the control over indoor temperature showed to form larger barriers for homeowners with more dominant biospheric values. In addition, the barrier regarding electric cooking showed to be a larger barrier to homeowners with more dominant hedonic values. Lastly, for homeowners with more dominant altruistic values, the barrier regarding collective action showed to be less of a barrier. These key findings provide an understanding of the barriers that influence the preparedness of homeowners to connect to a heat network.

To answer the second part of the main research question, this research has been able to identify a set of instruments that can support homeowners to overcome the most common barriers as found in this research. As the results suggested that a part of the above-mentioned barriers may originate from a lack of trust in the actors and process of implementing the heat network, the first step to increasing the preparedness of homeowners to connect to the heat network is to build trust. The first instrument that may help to build this trust is by using an integrated planning approach. Homeowners have an understandable tendency to link other issues in the neighborhood to the implementation of the heat network. To increase the preparedness to connect to the network, the interrelatedness of these issues must be acknowledged. With an integrated planning approach, the implementation of the heat network can be seen as a linking opportunity where other issues in the neighborhood are also addressed, such as the redevelopment of public space but also social issues. In addition, trust is also formed through engaging homeowners throughout the whole process of implementing the heat network. Structural update moments where homeowners are personally informed about recent and upcoming developments may help to gain trust.

Secondly, the findings suggest deploying a central heat authority and energy coaches. As homeowners find themselves lacking (objective) information, a central heat authority may provide homeowners with the opportunity to access objective information about the pros and cons of different heating alternatives. In addition, the authority can deploy energy coaches that may help homeowners to find the most appropriate heating alternative for their specific home and situation. This will help homeowners to make an informed decision.

Thirdly, the results suggest distributed ownership over the heat network by the municipality and local energy cooperatives. Firstly, the involvement of local cooperatives will increase the direct influence of homeowners over their heat supply. As members of a cooperative, homeowners are given a say, allowing them to intervene when they disagree with the course of action. At that point, the cooperative can act as an advocate between homeowners and the municipality. In addition, the involvement of local cooperatives may help to keep costs low. As such, this instrument may support homeowners to overcome the barrier regarding the monopoly position of the heat supplier, as well as the cost-related barriers.

Furthermore, the findings of this research showed the importance of a good offer. A good offer does not only include a fair price, but it should also include clarity about what homeowners can expect, and a guaranteed level of control. As what is considered a "good offer" may vary depending on the local context of the neighborhood to which the offer is made, the offer should be drawn up in consultation with the homeowners of a neighborhood. As the research showed that personal values influence which barriers are regarded by homeowners as being more important, the offer should include aspects that appeal to all values.

Lastly, the findings suggest deploying ambassadors and personal counselors. Because homeowners often perceive "second-hand" experiences as a credible source of information, ambassadors, who themselves have a connection to the network and are satisfied with it, can help increase the trust of homeowners in the functional reliability of the heat network. In addition, to lower the barrier regarding the renovations inside the home, personal counselors can personally assist homeowners with applying for subsidies, choosing a new cooktop, and with other questions. Unburdening homeowners in this way may greatly contribute to the preparedness of homeowners to make a connection to the heat network.

5.2. Further research directions

Despite the limitations to the sample size and foundation of expert-knowledge (see chapter 6 for an elaboration on the limitations), this study was able to provide interesting insights into the factors that influence homeowners' preparedness to connect to the heat network. This gives rise to the expectation that follow-up research with a larger dataset could provide even stronger and more reliable results. In addition, the results suggest that there are other variables that play a role in homeowners' preparedness to connect besides those that were included in this study, which may be further explored. For example, survey respondents indicated in the comment section that they already have an alternative to gas. Also, further research may pay more attention to the influence of the relationship between homeowners and the municipality.

While the instruments that have been identified in this research may be effective to increase the preparedness of homeowners to connect to the heat network, it was also mentioned that such approaches are very time- and cost-consuming (see 4.5.6.). In order to reach the climate goals, the implementation process of heat networks must at some point be accelerated (TwynstraGudde, 2022). Further research may focus on exploring what is needed to scale up the implementation of heat networks in the Netherlands in terms of legislation, institutions, and finances. This study failed to determine the size of the effect of the separate barriers on the preparedness to connect to the heat network (see 2.3.4.). Further research could attempt to determine the size of the effect of different barriers (with a larger sample size) in order to identify which barriers influence the preparedness to connect the most and should, thus, be prioritized. This can be helpful in scaling up the implementation of heat networks.

Lastly, further research may explore the effectiveness of instruments to overcome the barriers. While this research has been able to indicate a set of instruments that may help to increase the preparedness of homeowners to connect to the heat network, the actual influence of the instruments has not been researched.

5.3. Implications for planning practice

With this research, the researcher hoped to identify lessons for municipalities in the Netherlands in order to further enhance their usage of heat networks in achieving the gas transition. This research provides municipalities and other actors in the process of implementing heat networks with an understanding of the barriers as experienced by homeowners. The instruments as set out in this research may provide a guideline for practitioners to increase the preparedness of homeowners to connect to the heat network. It must be kept in mind, however, that the quantitative findings reflect the specific case of homeowners in Groningen, the Netherlands, and may not be fully generalizable to homeowners in other municipalities. However, in combination with the qualitative findings, this research does present an example that can be linked to the circumstances in other municipalities, if contextual particularities are considered.

One of the key findings of this research is that there should first be a focus on increasing trust. Trust in the municipality is shaky, as people link different issues to one another. Consequently, this lack of trust may feed into concerns about matters such as dependency and control over the costs and heat source. Combining the issues in a neighborhood into an integrated approach for implementing the heat network, such as by linking it to the redevelopment of public space, may already help to increase homeowners' preparedness to connect to the heat network. The other four steps that have been identified in this research can be used specifically to overcome the most common barriers. These steps do not have to be executed in chronological order.

6. Reflection on Research Methods

This final chapter critically reflects on the used research methods. Critical reflection encourages researchers to question how knowledge is produced, who provides it, and what consequences it has, and allows researchers to improve their work (D'Cruz *et al*., 2007). With regard to this thesis, reflecting on the research methods revealed some limitations or points of improvement.

6.1. Quantitative methods

First, the quantitative data analysis has been done using a small sample (N=64) which influenced the ability to find significant results and the reliability of the outcomes. There are several potential reasons for the limited number of responses. Since it was chosen to reflect on the survey results with the experts during the expert interviews, the sampling and data analysis had to be done before a strict deadline. As the writing process before starting the sampling procedure took a few days longer than initially planned, there were only 12 days left to complete the sampling. In addition, the chosen sampling method of approaching homeowners house-to-house was more time-consuming than expected. These time constraints have impacted the sample size. However, reflecting on the survey results with the experts during the interviews has attributed to the validity of the results. Therefore, this method is still considered appropriate. Time savings were perhaps to be gained on the writing process before sampling.

The second limitation is regarding the formulation of the survey. To keep the survey and data analysis comprehensible, it was chosen to present the survey respondents with potential barriers to which the survey respondents were asked to answer using a 10-point Likert scale. However, because the barriers were presented to the respondents "on a silver platter", this may have led to the questions being assumptive, meaning the statements already contained the assumption it would be perceived as a barrier and, as such, were also scored by the homeowners as being one. If the barriers were not presented to the respondents in this way, some potential barriers may not have been mentioned by the respondents themselves. This could explain why all eleven potential barriers showed to form a barrier to homeowners.

6.2. Qualitative methods

As mentioned, it is assumed that the research has benefited from reflecting on the survey results with the experts during the expert interviews. However, as the researcher conducted the interviews with the results from the surveys already in mind, this may have led to confirmation bias. Confirmation bias means the researcher tends to interpret information in a way that it confirms one's preconceptions. Although the researcher made an effort to enter the conversations open-mindedly, this may have had an unconscious effect on the results wherein the barriers as found in the quantitative data were also confirmed with the qualitative data.

In addition, it must be noted that the qualitative data analysis is based on a limited number of interviews, which means the conclusions are built on a relatively small base of expert-knowledge.

6.3. Expected results

In the theoretical framework, the expected results have been formulated using four hypotheses. During the discussion of the results, it has become clear that these hypotheses were formulated too broadly. Due to the broad formulation of the hypotheses, it has been difficult to either accept or reject the hypotheses as the hypotheses could often be accepted/rejected for only part of the results (as is stated in chapters 4.3.2. and 4.4.3.). In addition, the second hypothesis "*As instruments to overcome the barriers are provided, the preparedness of homeowners to connect to the heat network will increase.*" could not be rejected nor confirmed using the results of this study. While the interviews were used to indicate the instruments that may help to increase the preparedness of homeowners to connect to the heat network, there was no way of confirming the effect of the instruments on the preparedness to connect. From the results, it can be assumed that the instruments increase the preparedness to connect, yet there is no absolute certainty of their effect. This has, therefore, also been mentioned as a direction for further research in chapter 5.2..

6.4. Personal reflection

Then, lastly, I would like to reflect on my personal process. The main struggle has been to find a logical structure for presenting the results. I have tried to increase the validity of my results by combining the results from the quantitative and qualitative data analysis as much as possible. However, it proved to be challenging to find a fitting way of combining these results in an understandable matter, as the analysis of the quantitative data often required an explanation of the performed tests, which influenced the readability of the results. In addition, as I had no experience analyzing qualitative data during my bachelor's project last year, I found that it was challenging from time to time to not let my own preconceptions influence the interpretation of the qualitative data.

Another struggle for me was not to take the rejections too personally during the quantitative data collection. While spreading my door-to-door survey, I often had to take no for an answer and as someone who doesn't always handle rejection well, these afternoons were sometimes quite demanding.

To end on a positive note, this research has fueled my already-present interest in the energy transition and its social and spatial integration. Particularly, I found the expert interviews to be very engaging and positive. I reflect on a productive process, and I am eager to put the knowledge I gained from this thesis into practice.

7. References

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Appendix A: Operationalization

Respondents' characteristics
To be able to verify that the respondents fit the target group, the respondents are asked in which zip code area they live and whether they (together with their partner) are owners of the residence. Both questions must be answered using multiple choice items. After verification of the target group, the variables are not needed in the remainder of the study. The age and income of the respondent are asked for, as these variables need to be controlled for when exploring the influence of the perceived barriers on the preparedness to connect to the heat network. The age and income are asked using multiple choice items. Lastly, this part of the survey asks the respondents to indicate their gender and type of residence using multiple choice items.

Personal values
After the respondents' characteristics, the respondents are asked about their personal values. This is done using the Environmental Portrait Value Questionnaire (E-PVQ). This theorized value structure, created by Bouman *et al.* (2018), is used to measure human values that underlie environmental beliefs. The measurement consists of seventeen statements that can be divided into four value clusters: hedonic, egoistic, altruistic, and biospheric. The seventeen statements describe people (e.g., It is important to this person to have fun). Respondents are asked to respondent to these statements using a seven-point Likert-item (1 = the described person is totally not like the respondent, 7 = the described person is totally like the respondent) (Bouman *et al.*, 2018). For each value cluster, a composite score can be calculated using the mean of the items belonging to that cluster (Bouman *et al.*, 2018). These composite scores can then be used to test against other variables.

Barriers
After the personal values, the survey presents respondents with eleven potential barriers and asks them to rate the barriers using 10-point Likert-type questions (1 = no barrier, 10 = large barrier). The eleven potential barriers are based on the findings in the literature review of chapter 2.

Preparedness to connect
To get an insight into the respondent's preparedness to connect to a heat network, the respondents are asked to indicate to what extent they are prepared to connect to the heat network under the current circumstances by using a scale from 1 to 10. In addition, the respondent is asked to indicate which barriers must at least be removed to increase their preparedness to connect by means of an open question. After that, the respondent is asked to indicate their preparedness to connect to the heat network if these conditions have been met on a scale of 1 to 10 again.

Scenarios
Lastly, the survey includes three scenario questions that are related to what were expected to be the three main barriers: investment costs, monopoly position of the heat supplier, and the planning of the connection. To already get an insight into how these barriers may be lowered or removed, the respondents are presented with three fictional scenarios and are asked to indicate their preparedness to connect to the heat network in each scenario using a scale of 1 to 10. The scenario questions were inspired by survey items from Upham and Jones (2012).

Appendix B: Survey

Enquête over warmtenet Groningen

Beste deelnemer,

Hartelijk dank dat u mee wilt doen! Uw bijdrage is zeer waardevol.

Het doel van deze enquête is om inzicht te krijgen in de barrières die huiseigenaren in Groningen ervaren met betrekking tot het maken van een potentiële aansluiting op het warmtenet (ook wel 'stadsverwarming' genoemd). U wordt gevraagd om een vragenlijst te beantwoorden. Dit duurt ongeveer 8 tot 10 minuten.

De resultaten van deze enquête worden gebruikt voor het schrijven van een Master scriptie bij de Rijksuniversiteit Groningen en de enquête heeft dus educatieve doeleinden. Het invullen van de enquête is volledig anoniem. Daarnaast is het invullen van de vragenlijst vrijwillig en kunt u op ieder gewenst moment besluiten te stoppen.

Dit onderzoek is specifiek gericht op huiseigenaren die woonachtig zijn in één van de buurten waarvoor de gemeente het warmtenet als een haalbaar alternatief voor gas ziet. De eerste paar vragen zijn daarom bedoelt om vast te stellen of u binnen de doelgroep valt. Als u niet binnen de doelgroep valt, zal de enquête voor u beëindigd worden.

Heeft u vragen? Aarzelt u niet om contact op te nemen met Tess ten Have via t.f.ten.have@student.rug.nl

Vraag 1 Door het invullen van deze vragenlijst gaat u ermee akkoord dat uw anonieme antwoorden gebruikt worden in het onderzoek.

Gaat u hiermee akkoord?

a. Ja (1)

Vraag 2: Wat is uw postcode?

a. 9713 (1)
b. 9714 (2)
c. 9715 (3)
d. 9716 (4)
e. 9718 (5)
f. 9721 (6)
g. 9722 (7)
h. 9725 (8)
i. 9726 (9)
j. 9727 (10)
k. 9728 (11)
l. 9731 (12)
m. 9741 (13)
n. 9742 (14)
o. 9743 (15)

p. 9747 (16)
q. Anders... (17)

Vraag 3: In welk type huis woont u?
a. Appartement (1)
b. Vrijstaand (2)
c. Twee-onder-één kap (3)
d. Rijtjeswoning (4)

Vraag 4: Bent u samen met uw partner eigenaar van de woning?
a. Ja (1)
b. Nee (2)

Vraag 5: Wat is uw leeftijd?
a. 20 – 24 (1)
b. 25 – 34 (2)
c. 35 – 44 (3)
d. 45 – 54 (4)
e. 55 – 64 (5)
f. 64 – 74 (6)
g. 75+ (7)

Vraag 6: Wat is uw geslacht?
a. Man (1)
b. Vrouw (2)
c. Niet binair (3)
d. Dat zeg ik liever niet (4)

Vraag 7: Wat is uw gemiddelde netto jaarinkomen?
a. €0 - €15.000
b. €15.000 - €25.000
c. €25.000 - €35.000
d. €35.000 - €45.000
e. €45.000 - €55.000
f. €55.000 - €65.000
g. €65.000 of meer

Vraag 8:
Om een inzicht te krijgen in hoe verschillende beelden over barrières ontstaan, ben ik benieuwd naar een aantal persoonlijke waarden.

Hieronder beschrijf ik verschillende personen. Voor elke persoon beschrijf ik wat er erg belangrijk voor deze persoon is. Ik wil u vragen elke beschrijving te lezen en aan te geven in welke mate deze persoon op u lijkt.

De betekenis van de scores is als volgt: 1 betekent dat de persoon helemaal niet op u lijkt; en 7 betekent dat de persoon heel erg veel op u lijkt. Hoe hoger het cijfer, hoe meer de beschreven persoon op u lijkt.

Het is belangrijk voor deze persoon om het milieu te beschermen. ()	1 – 7
Het is belangrijk voor deze persoon om respect te hebben voor de natuur. ()	1 – 7
Het is belangrijk voor deze persoon om milieuvervuiling te voorkomen. ()	1 – 7
Het is belangrijk voor deze persoon dat iedereen dezelfde kansen krijgt. ()	1 – 7
Het is belangrijk voor deze persoon dat iedereen rechtvaardig behandeld wordt. ()	1 – 7
Het is belangrijk voor deze persoon om zorg te dragen voor mensen die minder goed af zijn. ()	1 – 7
Het is belangrijk voor deze persoon dat er geen oorlog en conflict is. ()	1 – 7
Het is belangrijk voor deze persoon om behulpzaam te zijn. ()	1 – 7
Het is belangrijk voor deze persoon om plezier te hebben. ()	1 – 7
Het is belangrijk voor deze persoon om te genieten van de mooie dingen in het leven. ()	1 – 7
Het is belangrijk voor deze persoon om dingen te doen die de persoon fijn vindt. ()	1 – 7
Het is belangrijk voor deze persoon om invloedrijk te zijn. ()	1 – 7
Het is belangrijk voor deze persoon om controle te hebben over wat andere mensen doen. ()	1 – 7
Het is belangrijk voor deze persoon om gezag te hebben over anderen. ()	1 – 7
Het is belangrijk voor deze persoon om hard te werken en ambitieus te zijn. ()	1 – 7
Het is belangrijk voor deze persoon om geld en bezittingen te hebben. ()	1 – 7

Het doel van dit deel van de enquête is om inzicht te krijgen in de barrières die huiseigenaren in Groningen ervaren met betrekking tot het maken van een potentiële aansluiting op het warmtenet.

Een warmtenet is een netwerk van leidingen onder de grond waar warm water doorheen stroomt. Dat warme water wordt gebruikt om gebouwen te verwarmen en warm water uit de kraan te leveren. Het water wordt verwarmd door een warmtebron in de buurt, zoals aardwarmte of restwarmte van industrie.

In hoeverre vormen de volgende zaken voor u een potentiële barrière bij het maken van een aansluiting op het warmtenet?

U kunt bij iedere stelling reageren met een cijfer van 1 tot en met 10. De betekenis van de scores is als volgt: 1 betekent dat de aangegeven zaak voor u geen barrière vormt; en 10 betekent dat de aangegeven zaak voor u een zeer grote barrière vormt.

Bij enkele stellingen is het mogelijk om extra uitleg te krijgen. Wanneer u de enquête op uw telefoon invult kunt u op het woord 'Uitleg' klikken om de uitleg te lezen en vervolgens op de tekst klikken om de enquête te vervolgen. Wanneer u de enquête op uw laptop/PC maakt moet u met uw muis op het woord 'Uitleg' blijven staan om de uitleg te lezen.

Vraag 9: De kennis en/of tijd die u moet hebben om zelf de nodige regelingen te treffen om over te stappen op het warmtenet (zoals het tekenen van een contract en het regelen van eventuele renovaties om uw woning geschikt te maken).

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Vraag 10: De tijdelijke hinder als gevolg van de aanlegwerkzaamheden (zoals het openbreken van de straat en de installatie werkzaamheden in uw huis).

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Vraag 11: Het eventuele overleg wat nodig is met uw buurtbewoners om collectieve afspraken te maken over het ontwerpprocess en de aanleg van het warmtenet in uw buurt.

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Vraag 12: De eenmalige investeringskosten van gemiddeld 10.000 tot 14.000 euro (voor o.a. de netaansluiting en aanpassingen aan uw huis).

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Vraag 13: De maandelijkse tarieven die u verwacht te betalen voor warmte van een warmtenet ten opzichte van de tarieven voor uw huidige verwarmingsinstallatie.

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Vraag 14: Het monopolie van warmteleveranciers, waardoor het niet mogelijk is om van warmteleverancier te wisselen (zoals dat bij energieleveranciers wel kan).

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Vraag 15: De hoeveelheid vertrouwen die u heeft in de techniek van warmtenetten (ofwel functionele betrouwbaarheid).

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Vraag 16: Uw gebrek aan invloed op de warmtebron waarmee het water wordt verwarmd.

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Vraag 17: De investeringen die u al heeft gedaan in uw huidige energiesysteem (bijvoorbeeld voor een cv-ketel of gasfornuis).

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Vraag 18: De controle die u verwacht te hebben over de temperatuur in uw huis.

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Vraag 19: Het moeten koken op inductie in plaats van op een gasfornuis.

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Vraag 20: Op een schaal van 1 tot 10, in hoeverre bent u bereidt om in de huidige situatie een aansluiting op het warmtenet te maken?

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

Vraag 21: Welke barrière(s) moet(en) in ieder geval weggenomen worden om uw bereidheid tot het maken van een aansluiting op het warmtenet te vergroten?

____

____

Vraag 22: Op een schaal van 1 tot 10, in hoeverre bent u bereidt om een aansluiting te maken op het warmtenet als de door u aangegeven barrières worden/zijn weggenomen?

a. 1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10

In de volgende vragen worden u een paar fictieve scenario's voorgesteld, waarbij ik u opnieuw vraag om aan te geven in hoeverre u in dat scenario bereid zou zijn om een aansluiting op het warmtenet te maken.

Vraag 23: In hoeverre bent u in de volgende scenario's bereid om een aansluiting op het warmtenet te maken? 1 = helemaal niet bereid, 10 = zeer bereid

- Wanneer u de kosten voor het maken van een aansluiting op het warmtenet binnen 20 jaar terugverdient. ()
- Wanneer u de kosten voor het maken van een aansluiting op het warmtenet binnen 10 jaar terugverdient. ()
- Wanneer u de kosten voor het maken van een aansluiting op het warmtenet binnen 5 jaar terugverdient. ()

Vraag 24: In hoeverre bent u in de volgende scenario's bereid om een aansluiting op het warmtenet te maken? 1 = helemaal niet bereid, 10 = zeer bereid

- Wanneer het warmtenet wordt beheerd door één publieke organisatie in een monopoliepositie ()
- Wanneer u de keuze hebt uit het aanbod van verschillende commerciële warmteleveranciers. ()
- Wanneer u zelf, als onderdeel van een coöperatie, de warmtebron en warmtelevering beheert. ()

Vraag 25: In hoeverre bent u in de volgende scenario's bereid om een aansluiting op het warmtenet te maken? 1 = helemaal niet bereid, 10 = zeer bereid

- Wanneer u niet zelf hoeft uit te zoeken welke maatregelen u in en om uw woning moet nemen (het warmtebedrijf/gemeente zoekt dit voor u uit) ()
- Wanneer u zelf volledige regie heeft over aanvullende maatregelen in en om uw woning (dit wordt niet voor u gedaan) ()
- Wanneer u in samenspraak kan beslissen over welke maatregelen u in en om uw woning moet nemen (samen met het warmtebedrijf/gemeente) ()

- Dit is het einde van de enquête. Hartelijk dank voor uw deelname! (Graag nog één keer op de pijl rechtsonder klikken om uw antwoorden op te slaan.)

Mocht u nog andere opmerkingen hebben dan kunt u deze hieronder achterlaten.

Mocht u nog vragen hebben, aarzelt u niet om contact op te nemen met mij (Tess ten Have) via t.f.ten.have@student.rug.nl

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____

____

Table a: Overview sampling strategy

Neighborhood	Streets	Date and time of sampling
Zernike Campus*	-	-
Paddepoel-Noord**	-	
Paddepoel-Zuid	Weegschaalstraat	27/05/2022 14:00 – 15:00
Vinkhuizen-Noord	Topaasstraat/Turkooistraat	25/05/2022 15:00 – 15:45
Vinkhuizen-Zuid	Basaltstraat & Porfierstraat	25/05/2022 15:45 – 16:45
Selwerd**	-	
Tuinwijk	Magna Petestraat	23/05/2022 16:00 – 17:00
Kostverloren	Eerste Spoorstraat	24/05/2022 14:00 – 15:00
Hoendiep	Hoendiep	24/05/2022 15:30 – 16:00
De Hoogte	Poortstraat	23/05/2022 15:15 – 16:00
Indische Buurt	Billetonstraat	24/05/2022 16:15 – 16:45
Professorenbuurt	Van Swinderenstraat	23/05/2022 14:00 – 15:00
Vogelbuurt	Paradijsvogelstraat	21/05/2022 15:15 – 16:15
Gorechtbuurt	Gerbrand bakkerstraat	21/05/2022 14:15 – 15:15 27/05/2022 16:00 – 16:30
UMCG*	-	-
Florabuurt	Damsterdiep (210 – 328)	19/05/2022 14:00 – 15:00
Damsterbuurt	Holstek	19/05/2022 15:00 – 15:30
Stationsgebied*	-	-
Rivierenbuurt	Rabenhauptstraat	21/05/2022 12:30 – 13:30
Grunobuurt	Hoornsediep & Lorentzstraat	21/05/2022 11:30 – 12:30
Martini Trade Park*	-	-
Sterrebosbuurt	Thomsonstraat	18/05/2022 15:00- 16:00
Corpus den Hoorn	Pasteurlaan & Einthovenlaan	20/05/2022 14:30 – 16:00 27/05/2022 15:15 – 15:45
Helpman	Van Royenlaan	18/05/2022 16:00 – 17:00
De Wijert	Bilderdijklaan & Betje Wolffstraat	18/05/2022 17:00 – 18:00
Van Swieten*	-	-

**The neighborhoods Zernike Campus, UMCG, Martini Trade Park, Stationsgebied and Van Swieten were excluded from the sample, since the properties in the neighborhood mainly have functions other than residential (such as office, education, and health care functions).*
***The neighborhoods Paddepoel-Noord and Selwerd were excluded from the sample, since the researcher was warned about these neighborhoods being over-solicited.*

Appendix C: Interview guide

Introductie

Hallo, mijn naam is Tess ten Have en ik volg de masteropleiding Environmental and Infrastructure Planning aan de Rijksuniversiteit Groningen. Als laatste onderdeel van mijn opleiding schrijf ik een masterscriptie waarvoor ik de resultaten van dit interview ga gebruiken. Ik wil je daarom alvast bedanken voor je tijd en hulp bij mijn onderzoek.
Bij mijn onderzoek kijk ik naar de mogelijke barrières die huiseigenaren ervaren m.b.t. het maken van een aansluiting op het warmtenet en de instrumenten die ingezet kunnen worden om huiseigenaren te ondersteunen bij het wegnemen van deze barrières.

Voor we beginnen wil ik graag nogmaals bevestigen dat u ermee akkoord gaat dat het interview wordt opgenomen.

U mag mij gedurende het interview op ieder moment onderbreken wanneer u een vraag heeft of het gesprek wilt beëindigen.

Heeft u voordat wij beginnen nog vragen?

1. Kunt u uzelf voorstellen?
2. Op welke manier(en) heeft u ervaring met warmtenetten/ de sociale integratie van warmtenetten?

Barrières

3. Voordat ik de resultaten van mijn enquête met u deel ben ik benieuwd wat vanuit uw ervaring het algemene denkbeeld van huiseigenaren over warmtenetten is?
    a. Welke specifieke barrières bent u tegengekomen die huiseigenaren mogelijk ervaren?

4. Uit de resultaten van mijn enquête is gebleken dat de investeringskosten, de tarieven die zij verwachten te betalen, de monopolie positie van het warmtebedrijf en de onafgeschreven investeringen in mensen hun huidige energiesysteem vier van de voornaamste barrières zijn.
    a. Denkt u dat dit reële barrières of meer zorgen zijn?
    b. Wanneer zorgen: Waar denkt u dat deze zorgen vandaan komen?

Instrumenten om de barrières weg te nemen

5. Ten eerste de kosten. Huiseigenaren zien de investeringskosten als barrière, maar ook de tarieven die zij verwachten te betalen voor warmte van het warmtenet ten opzichte van de huidige tarieven die zij betalen. Heeft u enig idee over hoe huiseigenaren ondersteund zouden kunnen worden bij het wegnemen van deze barrières?
    a. In hoeverre denkt u dat de volgende aspecten een deel van de oplossing kunnen zijn? (Leningen, subsidies, schaalvergroting, socialisering)
    b. Zijn er verschillen tussen typen mens/bevolkingsgroep (wil wel, kan niet etc.)
    c. Uit mijn enquête is gebleken dat de bereidheid tot het maken van een aansluiting op het warmtenet significant hoger is als huiseigenaren hun investering binnen 5 jaar terugverdienen in vergelijking met 10 of 20 jaar. Zou dit een haalbare terugverdientijd zijn?

6. Dan de barrière met betrekking tot de monopolie positie van het warmtebedrijf. Heeft u enig idee over hoe huiseigenaren ondersteund zouden kunnen worden bij het wegnemen van deze barrière?

   a. Uit mijn enquête is gebleken dat de bereidheid tot het maken van een aansluiting op het warmtenet significant hoger is als het warmtenet wordt beheerd door verschillende commerciële aanbieders (dus een open netwerk) of door de huiseigenaren zelf als onderdeel van een coöperatie. Zijn dit haalbare oplossingen?

7. Ik heb huiseigenaren gevraagd welke barrières volgens hen in ieder geval weggenomen moeten worden om hun bereidheid tot het maken van een aansluiting op het warmtenet te vergroten. Hierbij noemden mensen, naast de te verwachten kosten en het monopolie, ook dat zij te weinig kennis hebben over de voor- en nadelen van warmtenetten en beter geïnformeerd willen worden. Wat wordt er op dit moment, naar uw weten, aan informatieverstrekking gedaan en hoe kan dit verbeterd worden?

8. Daarnaast gaven mensen aan weinig vertrouwen te hebben in de techniek van warmtenetten. Twee respondent gaven bijvoorbeeld aan dat zij negatieve verhalen hebben gehoord van andere bewoners. Heeft u enig idee over hoe huiseigenaren ondersteund zouden kunnen worden bij het wegnemen van deze barrière?
   a. Wie is hiervoor verantwoordelijk?

9. Zijn er andere instrumenten die volgens u zouden kunnen helpen bij het wegnemen van barrières?

Persoonlijk waarden

10. *Uit de resultaten van mijn enquête is gebleken mensen hun persoonlijke waarden tot op een zekere hoogte invloed hebben op welke barrières zij ervaren. Zo scoren huiseigenaren die meer waarde hechten aan het milieu het gebrek aan controle over de warmtebron als een grotere barrière en scoren huiseigenaren die meer waarde hechten aan comfort het moeten koken op inductie als een grotere barrière.*
    a. Heeft u enig idee hoe we zouden kunnen inspelen op deze persoonlijke waarden bij het ontwerpen van de meest geschikte instrumenten?

Einde

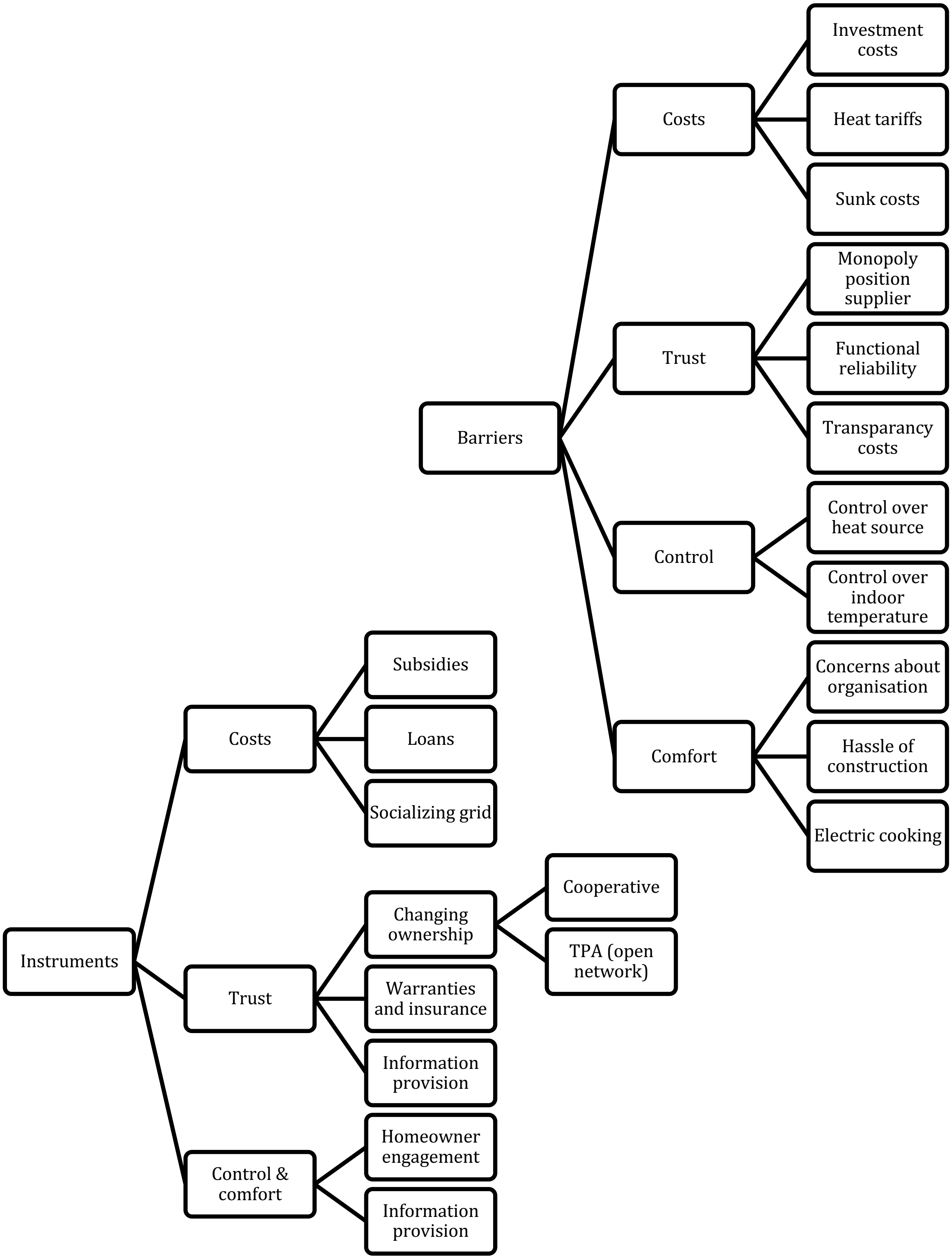
11. In hoeverre ziet u het warmtenet als deel van de oplossing voor de energietransitie? Hoeveel zal het warmtenet ingezet worden?
    a. Waar zal deze warmte voornamelijk vandaan moeten komen?

Dank u wel voor al uw antwoorden. Is er nog een onderdeel waar u graag op terug zou willen komen? Heeft u wellicht nog vragen en of opmerkingen?

Mocht u op een later moment toch nog terug willen komen op één van uw antwoorden of uw deelname aan mijn onderzoek, dan hoor ik dat graag uiterlijk 22 juni.

Hartelijk bedankt!

Appendix D: Deductive code tree



Appendix E: Inductive code book

Code	Code group	Concept
Renovations indoor	Barriers (comfort)	Fear of the needed renovations/changes inside the house
Trust in municipality	Barriers	A lack of trust in the actors/municipality
Dependency	Barriers	Fear of dependency on the actors
Fairness	Barriers (costs)	Concerns about the fairness of who is bearing the costs
Integrated neighborhood approach	Instruments	Integrated neighborhood approach that combines issues
Ambassadors	Instruments	Ambassadors that promote the heat network based on experience
Legislation	Instruments	Legislation and the new Heat Act
Energy coaching	Instruments	Energy coaching that provides information about the heat network
Good offer	Instruments	A good offer for potential consumers of heat
Awareness	Other	Awareness of the need to have an alternative for natural gas
Time-intensive	Other	Time-intensiveness of engaging citizens
Scaling-up	Other	Challenges surrounding scaling-up the use of heat networks
Heat sources	Other	Heat sources that can potentially be used

Appendix F: Consent form

Toestemmingsformulier interview masterscriptie

Betreft: Onderzoek naar de barrières die huiseigenaren vernemen bij het maken van een aansluiting op het warmtenet en de instrumenten die ingezet kunnen worden om huiseigenaren te ondersteunen bij het wegnemen van de barrières.

Beste [naam geïnterviewde],

Allereerst bedankt dat u bereidt bent de tijd te nemen voor het interview en mij zo te helpen bij mijn onderzoek. Het doel van het interview is om met u te reflecteren op de resultaten van een enquête die is uitgezet onder huiseigenaren in Groningen. In deze enquête zijn huiseigenaren gevraagd naar de potentiele barrières die zij vernemen met betrekking tot het maken van een aansluiting op het warmtenet in Groningen. Daarnaast is het doel van het interview om met u mogelijke instrumenten te identificeren die ingezet kunnen worden om de vernomen barrières weg te nemen.

Het interview zal plaatsvinden op: [datum], [tijdstip], te [locatie]. Indien u met de onderstaande voorwaarden akkoord gaat, zal het interview worden opgenomen en de resultaten worden verwerkt in mijn onderzoek. Het interview zal ongeveer 30 tot 45 minuten duren.

Mocht u nog vragen hebben, dan kunt u contact met mij opnemen via t.f.ten.have@student.rug.nl

Hierbij verklaar ik dat:

Mijn deelname aan het onderzoek geheel vrijwillig is en ik begrijp dat ik op ieder moment kan besluiten te stoppen. ja/nee

De resultaten verwerkt mogen worden in het onderzoek. ja/nee

Ik toestemming geef om het interview op te laten nemen. * ja/nee

Ik toestemming geef voor het gebruik van mijn naam in het onderzoek. ja/nee

Wanneer "nee":
Een pseudoniem gebruikt kan worden ja/nee
(Voorbeeld: respondent 1)

Ik te allen tijde mij kan terugtrekken uit het onderzoek ja/nee

De volgende functietitel genoemd mag worden in het onderzoek: ....

Datum ....

Handtekening...

*De opname zal na uitwerking vernietigd worden.

Appendix G: Quantitative data analysis outputs

Paired Samples T-tests (4.2.)

Table a: Overview p-values Paired Samples T-tests for the mean scores of the barriers

	Heat tariffs	Electric cooking
1) Organizational concerns	0.019	0.000
2) Hassle of construction	0.000	0.003
3) Collective action	0.002	0.000
4) Investment costs	0.006	0.000
5) Heat tariffs	-	0.000
6) Monopoly supplier	0.001	0.000
7) Functional reliability	0.003	0.000
8) Control heat source	0.011	0.000
9) Sunk investments	0.018	0.000
10) Control temperature	0.000	0.000
11) Electric cooking	0.000	-

As the confidence intervals of the means for the investment costs and the monopoly of the supplier did not show overlap with other confidence intervals, there was no need for Paired Samples T tests.

Multiple Linear Regression (4.4.)

Table b: Pearson Correlation Coefficients

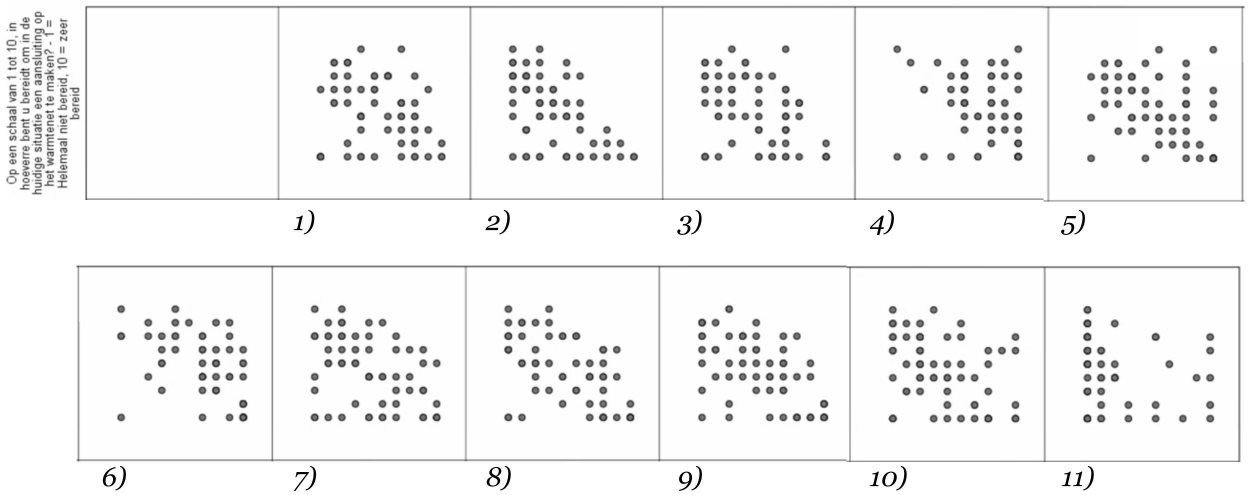
	Preparedness to connect
1) Organizational concerns	-0.169
2) Hassle of construction	**-0.528****
3) Collective action	**-0.388****
4) Investment costs	**-0.338****
5) Heat tariffs	**-0.481****
6) Monopoly supplier	**-0.560****
7) Functional reliability	**-0.408****
8) Control heat source	**-0.565****
9) Sunk investments	**-0.604****
10) Control temperature	**-0.392****
11) Electric cooking	-0.125

**Correlation is significant at the 0.01 level (2-tailed).

Tabel c: Spearman Rank Correlation Coefficients (ordinal variables)

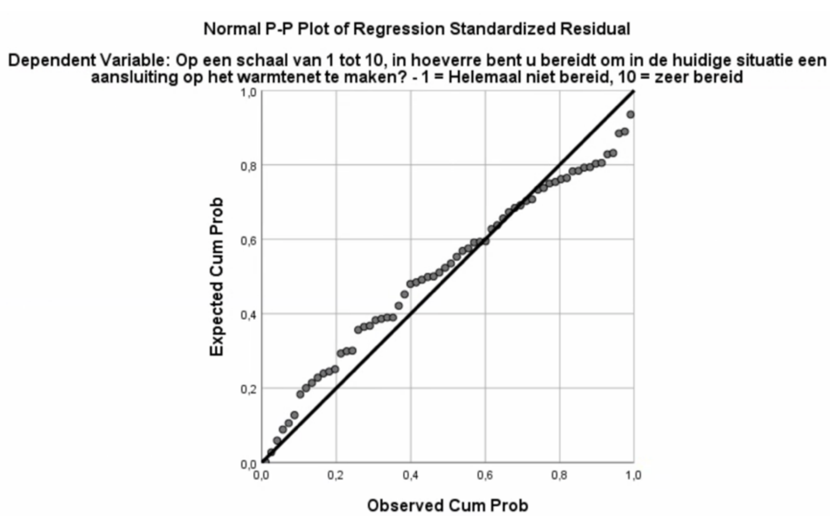
	Preparedness to connect
Age	0.051
Income	-0.083

<u>Assumption 1 linearity between outcome and predictor variables:</u> Scatterplots were drawn to check the first assumption. The outcome variable (preparedness to connect to the heat network) is plotted on the X-axis, the predictor variables on the Y-axis. While the scatterplots show no strong linear relationships, weak linear relationships can be found.

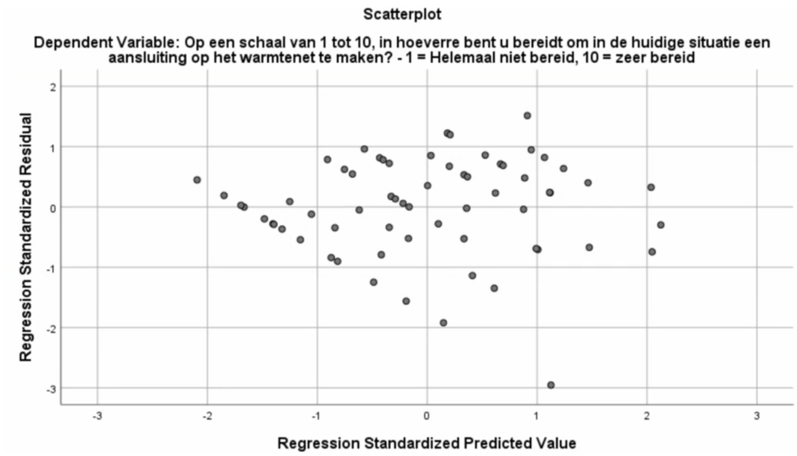


<u>Assumption 2 no multicollinearity:</u> Significant correlations were also shown between the potential barriers. Because a linear relationship between explanatory variables can lead to a poorer estimate of the regression coefficients in the regression model, a check was made for multicollinearity using the Tolerance and Variance Inflation Factor (VIF). Tolerance refers to the part of the variance of the independent variable that is not explained by the other independent variables. The Tolerance must be > 0.1 or the VIF (which is 1/Tolerance) must be < 10 (Hair Jr. *et al.*, 2013). All Tolerance values in the regression analysis are between 0.173 and 0.803 and all VIF values are between 1.245 and 5.776. Based on these values, it can be assumed that there is no multicollinearity.

<u>Assumption 3 normal distribution of the errors:</u> A P-P plot was drawn that shows the points are on a reasonably straight line, which indicates that the errors are normally distributed.



Assumption 4 homoscedasticity: To check for homoscedasticity, the scatterplot for the standardized predicted values and the standardized residuals was checked. The plot showed no cases that had a standardized residual value of below -3 or above +3.



These results indicate that there are no indications of undue influence on the ability of the MLR to predict the outcome.

Paired Samples T-tests (4.5.)

To check the assumptions for the Paired Samples T-test, a new variable was computed for the differences between means that are being tested.

Assumption 1 normal distribution of the mean differences: The difference between the means can be assumed to be normally distributed if the values for skewness are between -2 and +2 and the values for kurtosis are < 10 (Kline, 2011). This was true for all mean differences.

Table d: Overview descriptives – Skewness & Kurtosis

	Skewness	**Kurtosis**
Difference means payback period scenario 2 & 3	0.423	-0.579
Difference means ownership scenario 2 & 3	-0.685	1,996
Difference means responsibility arrangements scenario 1 & 2	-0.391	1.151
Difference means responsibility arrangements scenario 2 & 3	0.757	0.032
Difference means responsibility arrangements scenario 1 & 3	0.631	3.324

Assumption 2 no outliers: Boxplots were plotted for each mean difference. No variable showed influential outliers, except for the variable for scenario 1 & 3 regarding the responsible party for arranging the measures to one's residence, which showed four stars (case 10, 19, 39, and 46).

The difference variables were all normally distributed and showed no influential outliers, except for one. Therefore, the assumptions were met for all, except one test. For the test that did not meet the assumptions, a Wilcoxon Signed-Rank test was performed.

Spearman's Rank Correlation (4.6.)

Table e: Overview Spearman's Rank Correlation coefficients

Spearman Correlations				
Value **Differences**	**Biospheric**	**Altruistic**	**Hedonic**	**Egoistic**
Difference means payback period scenario 1 & 2	-0.126	-0.183	-0.188	0.081
Difference means payback period scenario 2 & 3	-0.217	-0.091	0.103	0.150
Difference means ownership scenario 1 & 2	0.102	0.098	0.152	0.213
Difference means ownership scenario 2 & 3	0.001	-0.034	0.023	0.098
Difference means responsibility arrangements scenario 1 & 2	0.108	0.013	0.033	0.217
Difference means responsibility arrangements scenario 2 & 3	-0.153	-0.025	-0.109	-0.232