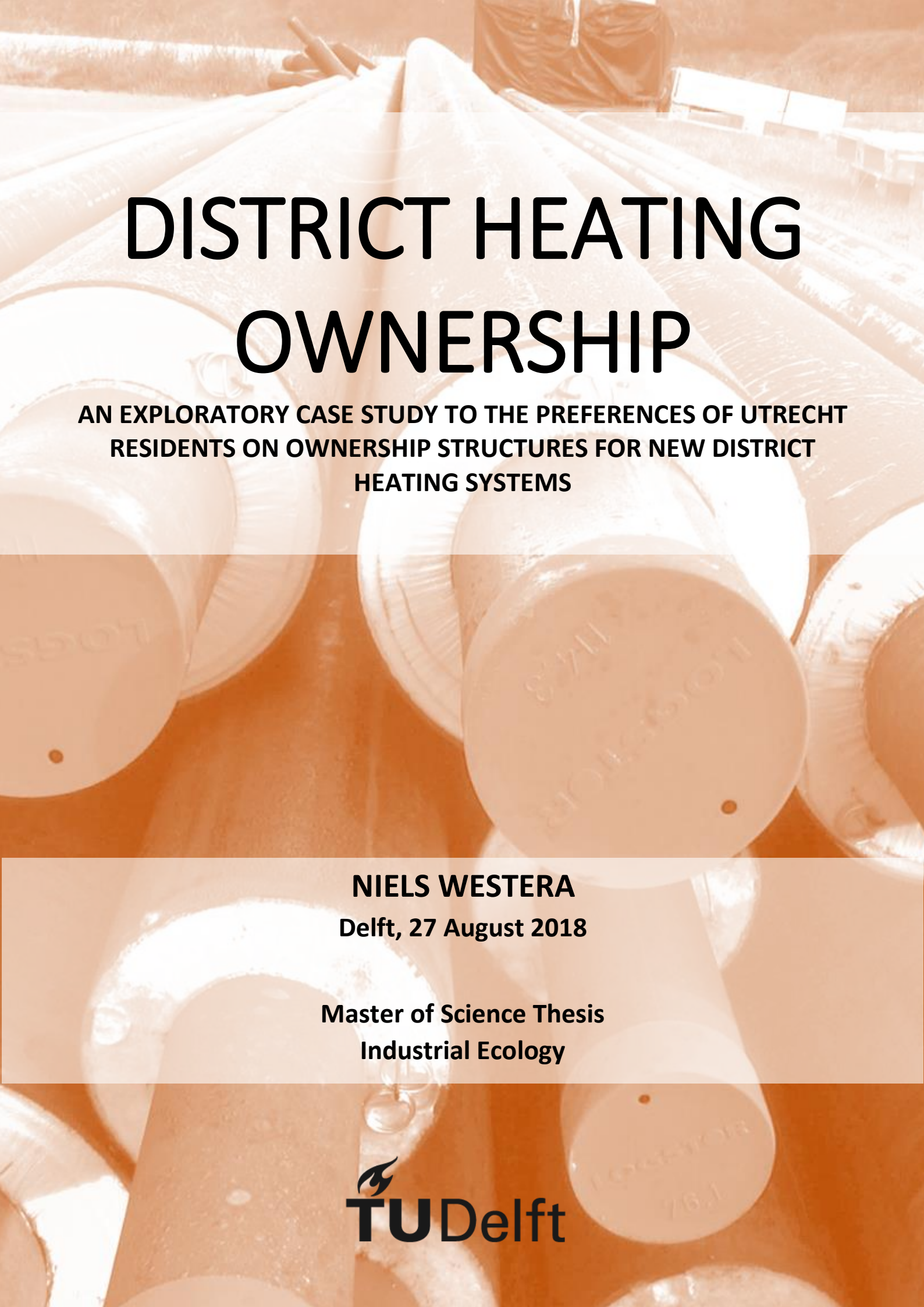

DISTRICT HEATING OWNERSHIP

AN EXPLORATORY CASE STUDY TO THE PREFERENCES OF UTRECHT RESIDENTS ON OWNERSHIP STRUCTURES FOR NEW DISTRICT HEATING SYSTEMS

NIELS WESTERA

Delft, 27 August 2018

Master of Science Thesis
Industrial Ecology

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Cover photo

Brand-new pre-insulated bonded pipe systems with leakage surveillance system (Nordic system), are stored at building site, with dew on casing pipes. Attribution goes to 'Mike1024'. Release into the public domain. Derived from Wikipedia (2018).

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Master Thesis

In partial fulfilment of the requirements for the degree of Master of Science of Industrial Ecology

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By

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Summary

Since the Netherlands possesses the largest natural gas reserve in Western Europe, most households depend on this resource for their heat provision. Of the total consumption of natural gas, 51% is used for heat provision to households. Both social problems with earthquakes related to natural gas exploitation and environmental problems with greenhouse gas emissions, challenge the country to find alternatives. One of these alternatives is using district heating in combination with renewable heat generation. Where district heating is already present, public resistance highlights price and inflexibility as unjust – as perceived by the monopolistic infrastructure (Janssen, 2015; Mulder, Paping, & Huis in 't Veld, 2014). While customers perceive injustice on one hand, on the other hand district heating is being considered as one of the alternatives for natural gas provision during the so called 'heat transition'. Hence, the problem of injustice would affect more and more residents.

Different types of ownership of district heating networks (e.g. private, public, cooperative) may offer opportunities to overcome or manage some of these downsides and improve the perceived energy justice. Considering this, the following question was researched: what ownership structures for new district heating systems would Utrecht residents prefer? Perceived energy justice is taken as a core concept supporting the preferences of Utrecht residents.

Based on literature we proposed a conceptual model on energy justice including the main two types of energy justice: procedural and distributive justice (Gross, 2007; Jenkins, McCauley, Heffron, Stephan, & Rehner, 2016). Exploring procedural justice is completed with the concepts of participation, information and trust (Jenkins et al., 2016; Langer, Decker, & Menrad, 2017); distributive justice is explored with the concepts of cost and benefit, access, and responsibility (Jenkins et al., 2016). These concepts are used to support the analysis of public preferences on ownership.

Design concepts for asset ownership (X-axis=Ownership Options, Y-axis=Design concepts, Red=large scale network only)						
1	*Generation*	Public	Private	Cooperative		
2	*Transportation*	Public	Private	Cooperative		
3	*Exchanger*	Public	Private	Cooperative		
4	*Distribution*	Public	Private	Cooperative		
5	*Delivery*	Public	Private	Cooperative		
Design concepts for combining ownership						
6	*Joint ventures*	Public private partnership	Private cooperative partnership	Public cooperative partnership	No partnership	
7	*Stock division*	Public majority	Private majority	Cooperative majority	No partnership	
8	*Preferred shares*	Yes	No			
9	*Level of integration*	No integration	Two parts of value chain	Three parts of value chain	Four parts of value chain	All parts
10	*Contract type*	Concession (ESCO)	Lease	Management	Municipal support	No contractual agreement

Table 0-1 Design Space

To explore what ownership structures for new district heating systems would be preferred, a case study of the city of Utrecht in the Netherlands is used. Here, space heating in some neighbourhoods is based on natural gas. A design space to describe ownership structures is proposed, to obtain the necessary insights for both survey design and the interpretation of findings. Often, division of assets of district heating is paralleled with the electricity infrastructure (R. Haffner, Til, Jong, Mans, & Graaf, 2016; Rooijers et al., 2015; Woerden, 2015). The extent in which a complete analogy with electricity infrastructure is feasible for district heating, depends on technical and institutional aspects and is heavily debated. A visualisation of all options is produced and proposed in Table 0-1. The design concepts are asset-based or methods of combining these assets.

The identified ownership types (public, private and cooperative) are comparatively reviewed by expert interviews on their strengths, weaknesses, opportunities and threats influencing their success in the heat transition. It was found that (1) there are external factors influencing all ownership types equally (like tax increase), (2) the institutional context often influences ownership structures contrastingly (e.g. market tradition). Also it was found that arguments in favour of private ownership often included business-oriented reasons. Arguments in favour of cooperative ownership often included influence-oriented reasons. Argument in favour of public ownership often included social-oriented reasons. Mixed ownership arguments often argue that – possibly – win-win situations occur, but at the cost of increasing transactions costs.

The design space and its insights on ownership types, are used to perform an online survey to explore energy justice within residents (N=198). Respondents having higher education level than the average Utrecht population and a lower percentage of respondents living in social housing (-32%) limit the sample's representativeness. Also, generalisability for places and neighbourhoods where less apartments are present, is limited (52% of respondents lived in apartments). We found indication (Figure 1 Ownership preferencesFigure 1) that most respondents appreciate the role of public organisations (e.g. public electricity grid operators and municipalities). Findings also suggest that network activities are the most suited for public ownership. Energy companies were most selected (61%) for the ownership of the generation activities. While community-owned heat cooperatives offer opportunities to enhance justice, this model was selected fewer times (45%-50%).

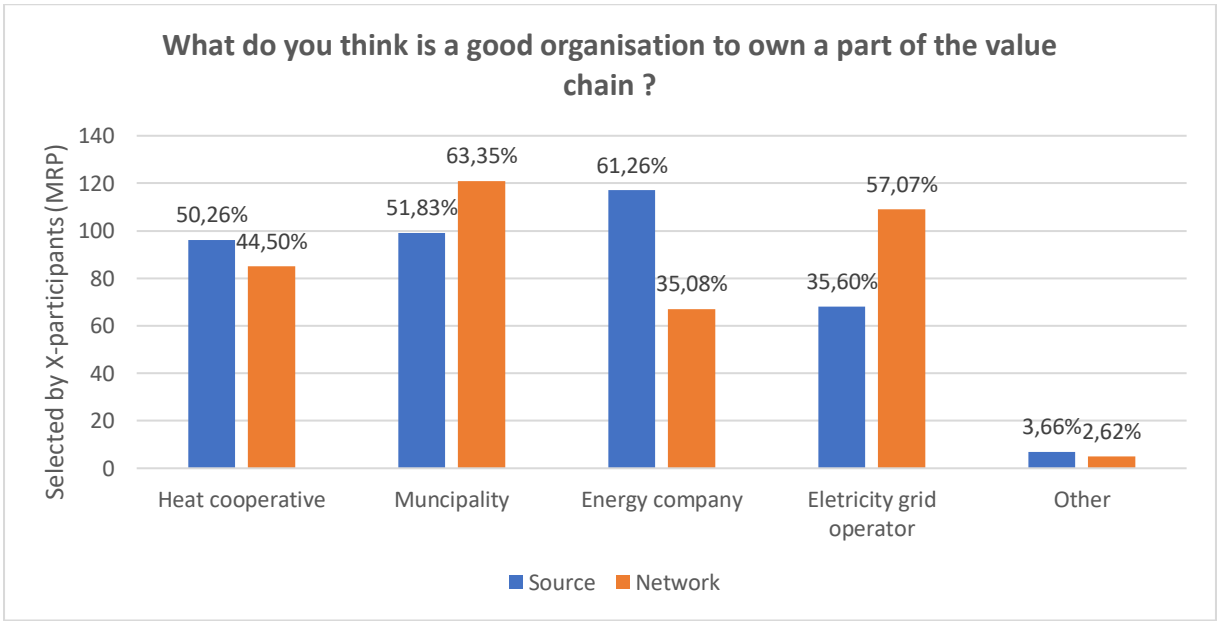

Figure 1 Ownership preferences

Regarding procedural justice, we expected respondents to indicate a wish to be informed about the changes in their heat provision situation (Langer et al., 2017). Instead, the majority of respondents wanted to have the right to consent (47%). A moderate relation was also found with house ownership: being a house owner increased the level of participation. Municipalities and grid operators were often indicated as trusted organizations, with smaller numbers for energy companies and neighbourhood organizations (Figure 2). Answers revealed a slightly higher trust for public organisations owning parts of the district heating value chain and a preference to be able to consent to the deployment of technology. Municipal and grid-operator trust levels are in accordance with the direct selection of ownership, supporting the preference finding.

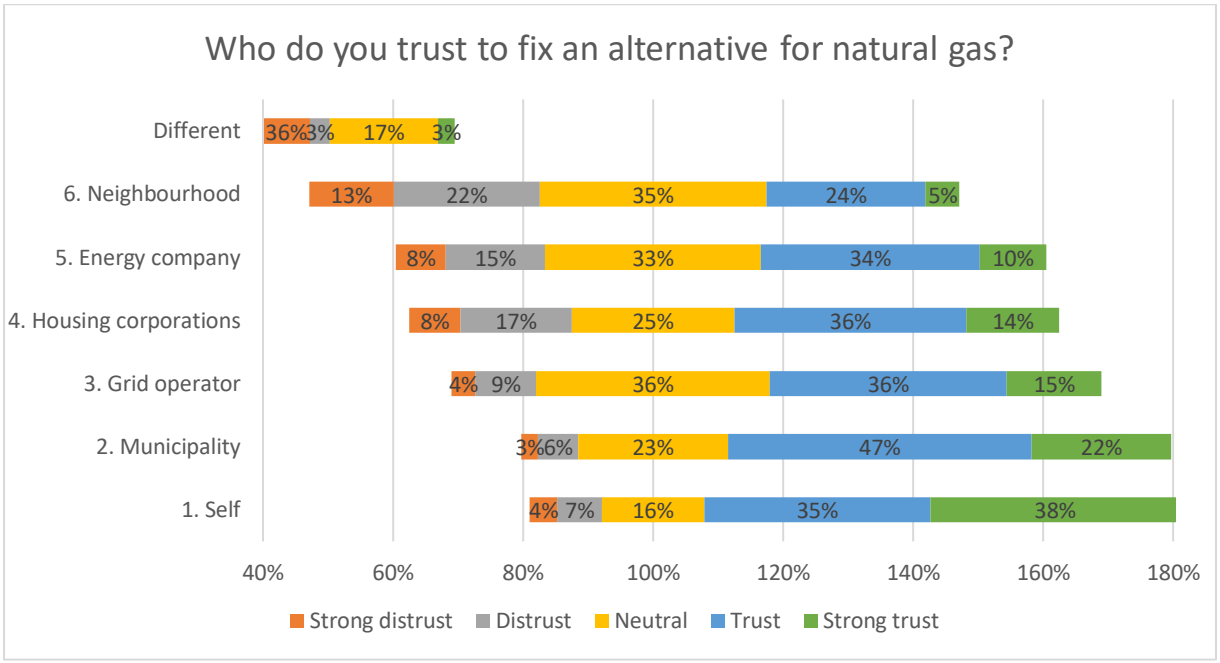

Figure 2 Organizational trust (100% = half-way 'neutral')

Regarding distributive justice, financial participation by becoming shareholder was preferred by a minority of respondents (10%). This seems to be unrelated to the willingness to invest, as more than 30% was willing to invest upfront in connection fees or heat cooperatives. In terms of responsibility 67% of the people found the municipality responsible, with almost half of the people also indicating themselves and energy companies responsible. Despite their sense of responsibility, they indicate (almost) not to be willing to spend time on this (90%). Thus, distributive justice indicates no specific preference for ownership in terms of cost-benefit, but the municipality is mostly indicated to be responsible.

Hence, we could answer the main question: what ownership structures for new district heating systems would Utrecht residents prefer? Linking the energy justice preferences with the direct preferences on ownership it is concluded that three ownership structures are preferred ('three streams'): integrated public ownership, competition on public network and integrated cooperative ownership. Within the context of the heat transition, we expect increasing the public influence – aiming for equal responsibility, socialised cost and benefits – would best address perceived injustice in new district heating monopolies. We also expect that in well-defined spatial communities, integrated heat cooperatives could offer perceived justice of the district heating natural monopoly. Thus far, aiming for competition was found to be limited due to the high costs. Despite being preferred, it seems to be less feasible (R. Haffner et al., 2016).

Nevertheless, designing an exact ownership structure using the design space highly depends on local contexts and stakeholders. In addition, other goals than the perceived energy justice by consumers might be determinations for exact ownership configurations, such as investments in sustainable heat. The design space is recommended to be used in the local decision process. Other recommendations include the exploration of joint ventures among private and cooperative organisations. Further economic and technical research is needed to explore the possibility of competition on the heat network; social research should focus on more generalisable findings supporting decision processes in the heat transition. In addition, it is needed to explore what role energy justice has in the modelling process by decision makers, because perceived justice of collective heat provision methods might be key for the (collective) acceptation and thereby cost-effectiveness of these alternatives.

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List of abbreviations

ACM	Authority for consumers and market
AEB	Waste Energy Company
CBS	Central Bureau of Statistics
CIQ	Comparative Interval Question
CLSQ	Comparative Likert Scale Question
Cn	Consultant
Co	Cooperative
DH	District Heating
DHN	District Heating Network
DSO	Distribution Service Operator
ESCO	Energy Service Company
ETS	Emission Trading Scheme
EZK	(Ministry of) Economics Affairs and Climate
GJ	Gigajoule
Go	Government
GRS	Gas Receiving Stations
Gs	Group of stakeholders
I	Interval
LSQ	Liker Scale Question
M&R	Metering and Regulation
MRQ	Multiple Response Question
N	Nominal
NAM	Dutch Oil Company
NEA	Netherlands Enterprise Agency
NG	Natural Gas
NMDA	Not more than otherwise
NvhN	Newspaper of the North
O	Ordinal
Pps	Public-private partnership
Pr	Private
Pu	Public
RVO	Netherlands Enterprise Agency
SCQ	Single Choice Question
SWOT	Strength, Weakness, Opportunity, Threat
VAT	Value Added Tax
VVE	House owner unions

1. Introduction

This chapter introduces the subject of this thesis: the role of ownership in district heating in the Netherlands. It starts with giving the context in which district heating is under considerations to develop. It continues by explaining what district heating entails. It finally demonstrates why ownership is important to study when developing new heating district heating networks.

1.1. Context

1.1.1. The end of the natural gas era

To heat residential areas, the Netherlands is currently relying on natural gas as the main source of heat provision. Due to the discovery in the 1960s of the natural gas field in the province of Groningen in the Netherlands, natural gas has become the foremost heat provision (NAM, 2017; NvhN, 1963). In 2017 the total consumption of natural gas in the Netherlands was 41,079 billion cubic meters (CBS, 2018). Of which 51% is used for the built environment (Aardgas-in-Nederland, 2018). 96% of Dutch households are direct or indirect dependent on natural gas (Aardgas-in-Nederland, 2018).

However, the use of natural gas is under pressure. The first reason embeds in the requirement to decrease the impact of human life on the planet. More specifically, the carbon footprint needs significant reduction (Rockström et al., 2009). Natural gas (NG) is a fossil fuel with a climate impact. The second reason why NG is under pressure originates in the accumulation of man-made earthquakes the last few years in the province of Groningen, hence resistance for exploitation has grown. The responsible minister recently acknowledged the dangers and therefore proposes a significant reduction in NG-exploitation (Bestuur, 2018). The most important natural gas field in Groningen will be closed in 2030 (Wiebes, 2018). To remain largely energy independent, finding other heating solutions for commercial and residential areas is therefore urgently needed. This process is the so called 'heat transition'.

1.1.2. Technological alternatives

Several climate friendly alternatives for the current natural gas distribution exist. According to HIERverwarmt (2018a) the future for sustainable heating will concentrate among three alternatives: green gas, electrical solutions, and heat networks. The first could use the same (type of) infrastructure there is today. Currently most used is 'biogas', which has been produced by fermentation of organic waste, manure, and sewage sludge (HIERverwarmt, 2018a). By fermentation methane can be subtracted which is called *biogas*. Other innovative synthetic options are hydrogen based (CO_2 + H_2 or pure H_2). There is currently no large-scale experience in the built environment with these clean alternatives for heat provision, but results from labs are promising (Mortelmans, 2018). The second solution is using electricity-generated heat. This can be achieved by using a *heat pump,* possibly combined with pellets, infrared heating, or biogas (HIERverwarmt, 2018a). This type of heat is of low temperature. The last option is heating with waste - or carbon neutral heat by *district heating (DH)*. The DH technology has no direct carbon impact since it only uses the temperature difference[1]. This type of heat provision is proven technology, it emerged already in the 1930's and has been extended after the 1970 oil crises: especially in Denmark (Rezaie & Rosen, 2012).

[1] In this way, it is comparable with electricity as an energy carrier, as where natural gas needs to be burned before delivering the product 'heat'.

Municipalities have been assigned by the government to find the most societal cost-effective ways to meet climate goals[2]. Opportunities for new heating technologies are subjected to the public goals to which heat provision is being measured (Kamp, 2017):

- *Affordability* – Since the natural gas reference is not given anymore, the affordability goal of district heating is measured along the available alternatives for natural gas. These other alternatives in some cases are more expensive than district heating. So, new DHNs are likely to play a role in cost-effective future energy systems of selected sites (Hoog, Steen, Twist, & Oorschot, 2013).
- *Sustainability* – district heating originated in optimization of resource-use in combined heat and power plants (Kelly & Pollitt, 2010). This model is under pressure, because electricity generation using carbon intensive resources like coal and natural gas is subject to changed public values in terms of climate goals (Szendrei & Spijker, 2015). New sustainable alternatives for heat generation are based on industrial surplus of heat (waste heat), biomass, heat pumps etc.
- *Security of supply* – the social standards of heat provision are very high: people are already used to the fact that their (1) natural gas-fired boilers are nearly always functioning and (2) the supply of natural gas never stocks. There is no doubt, people are willing to compromise on these certainties.

All the alternatives are evaluated to these goals and perform better or worse depending on the location. In general, the production of biogas is limited and the use of synthetic gas experimental, at the short-term proven technologies are *electric heat pumps* and *district heating*. Low temperature heat – which is produced by heat pumps or low temperature district heating – demands well insulated houses, which significantly affects the affordability of this strategy. Especially for older buildings, where easy insulation opportunities (e.g. filling cavity walls) are limited[3].

On a case by case basis, district heating offers a cost-effective solution for the heat transition (Kamp, 2014; Benno Schepers & van Valkengoed, 2009). High temperature heat networks offer an infrastructural solution, without the necessity of expensive and sometimes impossible insulation needs. Carbon neutral high temperature district heating networks rely on the ability to receive and distribute excess heat and waste incineration, being the central challenge in support of developing new heat networks (Persson & Werner, 2011). Furthermore, compact cities have better conditions for district heating (and cooling) than sparse cities, since the house densities are higher. Therefore the future competitiveness of district heating additionally involves socio-political decisions and demographic considerations (Persson & Werner, 2011). Overall, in this thesis we will not further assess the competitiveness of district heating in relation to other alternatives. District heating is assumed to impact the heat transition, wherever economic conditions are most preferable for this alternative.

[2] Where municipalities have direct control (ownership) over district heating companies, they have direct control over the method of the heat production (the climate intensive part) and the business case evaluation (which houses to connect) (7Pu, 2018; 15Go, 2018). To reach climate goals, steering the functioning of the DH is very effective.

[3] Insulating towards so called 'passive houses' is relatively costly, increases the electricity demand, offers less smart energy system solutions and is sometimes physically impossible (Heynen, Soppe, Melis, & Kolenbrander, 2017; Hoogervorst, 2017; Naber, Schepers, Schuurbiers, & Rooijers, 2016).

1.1.3. District heating

So, what is district heating exactly? District heating is a heating system in which centrally generated heat is distributed to residents (Collinsdictionary, 2018). It is supplied to houses and buildings through a network of insulated (underground) pipes, by water (or steam) as a heat carrier. Different specifications of heat networks arise in temperature difference: mainly 'low' or 'high' temperature (H. Lund et al., 2014). Apart from carbon-based heat generation (mostly cogenerated with electricity from coal or NG), sources of green heat can be waste heat (e.g. from datacentres), waste incineration[4], biomass, geothermal heat, aquathermics, solar thermal (Lindenberger, Bruckner, Groscurth, & Kümmel, 2000; H. Lund et al., 2014; Quoilin, Declaye, Tchanche, & Lemort, 2011; Zhen, Lin, Shu, Jiang, & Zhu, 2007). The heat source partially determines the temperature in the network (H. Lund et al., 2014).

There are three types of benefits following from a district system: efficiency, environmental and economic (Rezaie & Rosen, 2012). Efficiency is enhanced: waste heat can be utilised, economies of scale for production are in place and peak capacity can be tuned on collective peaks (Rezaie & Rosen, 2012)[5]. Environmental benefits are achieved by these efficiency measures but can be extended by using climate friendly heat production like biomass or geothermal heating. Economic benefits are present in densely populated areas, where the distribution losses of these systems are low.

According to Hoogervorst (2017) there still is a large potential of sites available in the Netherlands where district heating will be optimal (most likely when waste heat is available and the penetration of houses is rather high). In 2015 the number of district heating connections was not more than 410.000 (Menkveld, Matton, Segers, Vroom, & Kremer, 2017). This accounts for 4% of the heat provision, mainly opposing the large share of natural gas.

1.2. Problem definition

1.2.1. Injustice of DH-technology

Despite future opportunities of district heating, historical development has been limited in the Netherlands. There are three main reasons why district heating has not yet redeemed efficiency, environmental and economic benefits distinguished by Rezaie and Rosen (2012), like historically has been the case in many European cities (Magnusson, 2016; Oteman, Wiering, & Helderman, 2014; Westin & Lagergren, 2002; Zeman & Werner, 2004). These reasons are:

(1) The relative (economic) attractiveness of natural gas in the Netherlands
(2) The economic characteristics of the infrastructure.
(3) The perceived injustice in the producer-consumer relation

The first reason is particular for the Netherlands. The largest and one of the most accessible natural gas reserve of Europe is located in the north of the Netherlands. Transportation and distribution of this energy source is well developed and is become cost-effective (Gasterra, 2018). Additionally, national laws ensuring gas-grid connections to households made it even more important. This is the main reason why the situation of district heating is less favourable in the Netherland than in neighbouring countries (Oteman et al., 2014).

[4] In urban areas with a high urban metabolism, waste currently is a good source of energy. Despite the technical advantages of demand-based production – since 'fuel' is still used – this source is not carbon free. Also, from the 'circular economy' perspective and the social pressure of reducing waste, this type of fuel is likely to diminish.

[5] In winter, when everyone starts to shower and heat their houses to go work, a heat demand peak exists in district heating networks. This collective peak is lower than the sum of individual peaks and thus optimizes the needed capacity.

The second reason is more complicated: district heating networks require a large, bulky infrastructure, with very high sunk costs (Wårell & Sundqvist, 2009). The sunk costs of this network make it economically unviable to develop parallel heating infrastructures. This means district heating networks have the characteristics of a natural monopoly (Wårell & Sundqvist, 2009). As can be derived from basic economics, (natural) monopoly companies have large market power and are their profit-maximization will tend to exceed marginal costs (Berg & Tschirhart, 1988)

The third reason relates to the infrastructure characteristics of the second reason. Because of these characteristics, some customers are unsatisfied with their district heating connections and perceive their relationship with the monopolist as unjust. Justice in the energy sphere – including heat provision –is defined by the recently developed concept of '*Energy justice'*. This concept reflects challenges regarding energy in which "injustices emerge, which affected sections of society are ignored, which processes exist for their remediation in order to reveal and reduce such injustices" (Jenkins et al., 2016). In the Dutch case of district heating injustices can be defined by current dissatisfaction with district heating. There are three main reasons why some people are unsatisfied (Hoogervorst, 2017):

- Their tariff for heat delivery is perceived to be too high. One of the reasons for this, is that the regulated pricing is based in the so called 'natural gas reference' (NMDA), designed to protect customers for monopolist power (R. Haffner et al., 2016; Kamp, 2017). Ironically this regulation is still unsatisfying because it bases the tariff on the 'average natural gas consumer' instead of their specific situation (Mulder et al., 2014).
- Some aspects of the heat provision are not – or not explicitly enough – regulated, like the rent of their 'delivery sets' (GJ-meters). District heating companies decide on the standard-only delivery set, so customers perceive these to be unnecessarily expensive.
- It is frustrating to be dependent on a monopolist and not to be able to choose for you own heat supplier, which is (currently) inherent on the use of heat networks. This irritation is fuelled by a lack of transparency on heat tariffs and good service.

Janssen (2015), who has shown that people living in a house with collective heat supply can perceive discomfort, confirms the latter. He has found that one of the reasons originate in the impossibility of changing their heat supplier or influence prices. According to Janssen (2015) the feeling of impotence increases, when there is a lack of trust, less transparency and less possibilities to adjust the circumstances. District heating opposition groups confirm this and express the dissatisfaction less 'diplomatic'[6]

In more conceptual terms, it means that the dissatisfaction of consumers seems to be rooted in an unjust relation with the producer. This *injustice* expresses itself in the perceived overpricing of the (bits of the) product – implicating the feeling that district heating companies are making high profits on the heat supply at the cost of the consumer –, while consumers are unable to actively do something about this – e.g. change of supplier. The relation between the consumer and the monopolist is therefore one of the core issues in the justice debate[7].

[6]Resistance group 'Stadsverarming' summarizes its problems with DH as expensive, not sustainable, and unsafe. It also has high buy-out fees, bad measure and control apparatuses and is responsible for poorly insulated new-built houses. Also, being a monopoly no commercial incentive to be focused on customer demands is present. This decreases transparency and decent communication (Heuvel, 2015)

[7] Another justice issue is the reference pricing. It seems to be obvious that people are unhappy with the same product – heat – while perceived paying more than people using other heat provision methods – like natural gas. It is like an obliged purchase of an expensive coffee machine serving the exact same coffee as a cheaper one. With natural gas being phased out, it is unclear how district heating will be positioned in terms of the costs for consumers compared to other green heat provision methods (like all electric).

1.2.2. Ownership

One of the concepts influencing energy justice is ownership (Pitkin, 1981). For example, community ownership of energy is developing into a trend to 'promote sustainable communities' (Warren & McFadyen, 2010). The growth in interest is based 'partly from practical, instrumental considerations and partly from neo-communitarian discourses of local participation and empowerment' (Warren & McFadyen, 2010). Dutch society – as many other developed countries – is used to a centrally oriented 'energy infrastructure in which power stations are often remote from centres of population' (Warren & McFadyen, 2010). This remoteness to communities has created a psychological distance between people and energy generation (Warren & McFadyen, 2010). Renewable energy brings power close to the people: which gives the opportunity to individuals and communities to form new, active and participatory connections with generation and supply of energy (Warren & McFadyen, 2010). This is known as 'energy citizenship' (Warren & McFadyen, 2010). Because of this tendency community energy is perceived to be more 'just' than other types of ownership, illustrated by the evidence that citizen-based initiatives typically receive high levels of public support (Goedkoop & Devine-Wright, 2016).

Community ownership is a trend in the energy sector due to the technical possibilities with renewables (Dóci, 2017). For district heating it is unclear how community ownership is perceived and whether it is a solution for the injustice problems occurring – as it seems to be in the case of renewable energy generation. The question is also if the 'community definition' in the renewable energy trends (namely: locally owned bottom-up and participation-based energy) can be proposed for district heating as well. By contrast, in Denmark 'community heating' utilities are mostly organised on the municipal level: also with great public support in doing so (Oteman et al., 2014).

More specifically for the district heating infrastructure, ownership has influence on energy justice because of the natural monopoly. There are two reasons for this. First, the heat grid development is particularly cost-intensive. Consequently, there needs to be a *long-term relationship* established to use this infrastructure by the customers – to reduce the risk of the network development. This long-term relationship creates a lock-in, so justice cannot be created by flexibility (which implicates that people could use other infrastructures when they find district heating unjust). Second, there is internationally *no example of properly functioning competition* on heat grids. Therefore, justice created by competition is not easy achievable in the district heating case (R. Haffner et al., 2016; Ouden, 2017). Theoretically, 'justice by competition' establishes when producers are forced to develop fair price/quality levels to defend themselves for competing producers in the market. In the district heating monopolies, justice and trust is not automatically generated by these liberalised market principles – to which the Dutch public is very used to. Without this competition a market fails, because private companies are in theory dedicated to opportunistic and strategic behaviour, which is opposing 'just' price-setting (Becchis, Genon, & Russolillo, 2011). Despite the possibility of regulation, the problem of information asymmetry – which is creating a power imbalance in economic transactions (Hazeu, 2007) – is still in place (Becchis et al., 2011). Hence, the lack of flexibility, no competition and absence of information on the consumer side can influence the perceived justice and trustworthiness of the owner by the public.

Given different options (like community ownership, but also mixed categories (Goedkoop & Devine-Wright, 2016)) opposing private ownership, it is currently unclear how different types of ownership influence perceived energy justice by the public, given the current (natural) monopoly context in which district heating operates.

1.2.3. Social relevance

Research into *district heating* as an alternative for natural gas is relevant because of the need to get away from the natural gas in the Netherland, especially for heat provision. This is because of the problems with gas exploitation in Groningen (Kamp, 2017), but also because of the necessity to move towards zero-emission societies (Rockström et al., 2009). In *some cases* district heating will be the most cost-effective solution for society for sustainable heat provision (Kamp, 2014). According to B. Schepers and Aarnink (2014) there is a potential 86 PJ of renewable heat which can be used cost effectively by means of a heat network (collective solution). The sources for this 86 PJ of *cost effective* sustainable heat, can be taken from waste heat, deep geothermal or heat-cold storage in combination with heat pumps (B. Schepers & Aarnink, 2014). Some of these sources are location specific, so when cost effective opportunities are present in a particular site, the follow-up question is: how to achieve district heating *networks* as collective – thus cost-effective – as possible? Thus far it assumed that the more just the ownership of district heating is perceived, the more likely is the individual support for a network connection. Henceforward, many neighbouring supporters increase the collectiveness, achieving the necessary network scale to exploit the location-specific heat source in a cost-effective manner.

Therefore, there is a clear transition problem: the need to develop new district heating infrastructures in most cost-effective sites is large, because renewed interest has sprouted due to the societal and environmental problems occurring with the exploitation and use of natural gas. However, since this infrastructure has large sunk costs – the network – the need to 'do it just' is also important. Especially regarding the long term, that is to say in terms of ownership division. Questioning the technical feasibility of competition on heat networks[8], just and fair ownership of district heating systems is even more important. This is because it divests the influence people have by the 'freedom of choice' of the heat provision company (as is the current case with natural gas). Without this consumer power, it is important to research the energy justice of different types of ownership. Ownership influences perceived energy justice, from another angle than competition.

1.2.4. Scientific relevance.

The scientific contribution of this research project is mostly located in the application of energy justice concepts in the case of district heating. Thus far, energy justice is almost exclusively reviewed in the context of (wind) energy projects, especially regarding Not-In-My-Backyard-Effects (NIMBY) (Goedkoop & Devine-Wright, 2016; Gross, 2007; Jenkins et al., 2016). By looking into the justice issues through an example of large cumbersome natural monopoly infrastructure, the energy justice debate extents to other energy topics.

Previous research on district heating focusses on the public-private distinction regarding ownership (Woerden, 2015). Cooperatives are not so much considered in comparative research, despite its different potential in terms of energy justice. Cooperatives are defined as "*democratically managed by the 'one member, one vote' rule. Members share equal voting rights regardless of the amount of capital they put into the enterprise. They allow people to take control of their economic future and, because they are not owned by shareholders, the economic and social benefits of their activity stay in the communities where they are established*" (ICA, 2018). Only research in traditionally established

[8] This is on the short term: especially during the extension and development of district heating, competition creates too much investor-risk. Research for the long-term perspective on competition for district heating is also researched (Dervis & Nierop, 2015; Ende, 2014; R. Haffner et al., 2016; Ouden, 2017; Ouden, Hoeksema, & Graafland, 2015; Rooijers et al., 2015; Woerden, 2015). These reports and articles focus on recommendations for regulation, but question on the other hand the feasibility of competition on heat networks: there are no examples of properly functioning markets on heat networks.

‘cooperative friendly’ countries (like Denmark) are sometimes evaluated (Agrell & Bogetoft, 2005), but never as an ex ante design opportunity for district heating development. Based on the renewable energy literature, cooperatives are found to ‘combine renewable energy production with more overarching goals of environmental and social transformation, and a specific quest for civic participation (Becker, Kunze, & Vancea, 2017)’. Hence, also in district heating cooperative heat is potentially a game changer in perceived energy justice.

Taken this relevance more broadly, ownership has never been assessed as an ex ante design variable in the development of district heating networks. The only relevant literature on designing ownership is based in historical development of privatization of utility companies, aiming to acquire capital while studying regulatory needs (Megginson & Netter, 2001; Savas & Savas, 2000). These studies aimed for more efficiency, incorporating public goals by regulation, but neglecting preferences and expectations from citizens in these ownership designs. In designing ownership of infrastructures, we tend to use the knowledge of (technical) experts only, while losing sight of the citizens point of view.

In addition to including the cooperatives in the ownership debates, thus far, no research has been conducted on ownership of district heating as such. Only in the context of market creation or economic performance, but never on perceived fairness or justice of the (division of) ownership of a whole energy system. Jenkins et al. (2016) emphasize on the relevance of the holistic approach, because the ‘tendency to break our systems into small and understandable pieces (…) can be detrimental. Some of our solutions both cause and fail to recognise widespread externalities or negate the impacts (…).’ This emphasizes the importance of understanding the sociotechnical system, before drawing conclusions on upon specific aspects. Also, it shows that conclusions and recommendations need to be drawn with care, because of the complexity of these systems.

As was witnessed by Oei (2016) in the case of market regulations for district heating, in ownership literature it is also observed that authors have (normative) ideas on the type of ownership. However, none of the existing literature shows a comprehensive ‘design space’ on ownership of district heating. This thesis aims to overarch this gap by producing an overview of the different (combinations) of design structures for ownership, aiming to provide guidance on the decision-making process of looking for alternatives of status-quo heat provision systems (like the heat transition of natural gas in the Netherlands).

1.2.5. Contribution to industrial ecology

Industrial Ecology (IE) can be typified as the study of material and energy flows through industrial systems (Jelinski, Graedel, Laudise, McCall, & Patel, 1992). Reasoning from an ecological analogy, IE aims to loop material and energy flows within industrial processes. It seeks for minimising waste and material input, as well as maximising usefulness of input. It reasons from a system perspective, taking global impact into account (Jelinski et al., 1992). Development of district heating in the Netherlands as an alternative of natural gas, is aimed at using waste heat (Hoogervorst, 2017). Reducing the waste output of industrial processes. Preferred ownership of district heating relates to the perceived justice of the sociotechnical system.

Defining industrial ecology as ‘the science of sustainability’, this research contributes on the social aspects of technical solutions for sustainability. Research on energy justice gets limited attention in the field of industrial ecology, while industrial ecology aims to take a system perspective, including the end-user. This research highlights the importance of including energy justice in the system perspective.

1.2.6. Problem statement

The problem statement is defined to steer the formation of research questions and to guide the research project. Taking into account the social and scientific relevance and considering that:

- within the discussion on DH as an alternative in the heat transition there is no clear ex ante *assessment tool* for ownership considerations;
- no comparative and empirical research on ownership types for district heating has been conducted for district heating in the heat transition;
- there is no clear view on the *preferences of residents* for ownership structures, indicated by energy justice. Furthermore, there is a lack of knowledge on the effects of resident preferences on the sociotechnical system,

The following problem statement has been defined as the principal problem to be researched in this thesis project:

It is unclear what ownership structures for district heating systems would be preferred by Utrecht residents as an alternative for current gas-based heat provision

2. Research approach

In this chapter of the research, the approach is defined. First, objectives and products of the thesis are considered. Then, the scope is assessed, followed by the research questions and the audience. The last part shows the visualisation of the research flowchart and methods used throughout the thesis.

2.1. Research objective

The overarching goal of this research is to contribute to knowledge on preferences of ownership structures[9] of district heating infrastructures, because due their natural monopoly infrastructure some people perceive the infrastructure unjust. Therefore, it is needed to produce a clear visualisation of what ownership structures are and what they entail, to be able to measure preferences on residents. It is also key to evaluate the different ownership types on their differences and similarities in most detailed and complete assessment, since perceived justice might be influenced by being informed. By contributing to better perceived justice in the natural monopoly infrastructure, more people might be willing to join collective solutions – like district heating – to address climate change. After all, the cost-effectiveness of collective solutions is determined by the proximity of individual connections. The specific contribution of this this thesis to this objective is:

To explore what ownership structures for district heating systems would be preferred by residents as an alternative for current gas-based heat provision, taking Utrecht residents as a case-study

2.2. Research products

While keeping the objective in mind, the needed products to meet this objective are therefore:

- A *conceptual framework* aiming to visualize and clarify the relationship between energy justice and ownership of natural monopoly infrastructure, district heating in specific.
    - The goal of this part is to theoretically define some of the aspects energy justice. How can energy justice be defined? This definition leads to some aspects to consider in the analysis of *ownership* of district heating. How does justice relate to ownership?
- A *sociotechnical analysis* aiming to identify some of the complexities in district heating development in the case study of Utrecht.
    - The exploration of the exemplary sociotechnical system is the first part of the case study: the city of Utrecht. This case study is used as a method for scoping the exploration of the effects on the sociotechnical system. What are technical factors influencing ownership? What are the actors at stake and what institutional aspects are important to consider? The goal of this analysis is to define some of the necessary elements for producing the design space. Additionally, it gives context to the results of the public preferences study.
- An *overview of the design space for structuring ownership* in the Netherlands for new district heating systems;
    - The goal of the *design space structuring* is to provide a tool to overview the ownership choices. The design space for ownership is produced outside the scope of the case study: it can be used for both large and smaller scale networks. What are all the assets

[9] An *ownership structure* refers to the set-up of ownership among different institutional types of organisation. In free societies this does not have to mean that the classic public-private dichotomy is unaccompanied by other institutes rather than states and private companies (Becker et al., 2017; Kunze & Becker, 2015). Furthermore, it is not given that ownership needs to be done by a single type of institute: combinations are possible. (De Schepper, Dooms, & Haezendonck, 2014; James, 2000; Klijn & van Twist, 2007; Villani, Greco, & Phillips, 2017)

for ownership? What is the role of these assets in the system? What are the design concepts of the different assets?

- A qualitative exploration on the *differences and similarities of ownership types* for ownership structures:
    - The goal of the *design space review* is to explore the role of the ownership types in the context of the heat transition (in Utrecht). How do experts evaluate the ownership types? What distinct and what associates different ownership types? Likewise, to what extent can they be combined? The goal is to find what experts reflect upon ownership types, to discuss the findings of public preferences on ownership.
- A quantitative exploration of *preferences* of Utrecht residents for ownership structures of new district heating systems;
    - The goal of the last part of the research is to give a public assessment on the different ownership types in its design space context. These have been concretised in the case study of Utrecht by (hypothetical) organisations. Due to the explorative methods, no solid and generalizable conclusions are aimed to be set. Instead the derived 'conclusions' have a function as hypotheses for further, more generalisable, research.

2.3. Scope

These analyses focus on the *heat transition*, taking DH as an alternative for natural gas. Because of its explorative purpose, there is no thorough analysis on the question in what cases district heating is the most attractive alternative. This research is located beyond that question, assuming DH in some cases to be the 'chosen' technical alternative for natural gas.

Despite the holistic point of view towards the energy systems, the research project is positioned around the concept of energy justice. By scoping the research with the justice issues, other important aspects on district heating developments are neglected. These include optimising networks performances[10] and green heat production[11]. In addition, a case study provides guidance on contextual issues. Hence, it is not designed to consider local circumstances for cases in- and outside of the Netherlands. Despite this, there is no aim to come up with 'one design'. It is reckoned there will be always contingency aspects that influence the final decision on the ownership structures.

2.4. Research questions

The goal of this research to explore what ownership structures for district heating systems would be preferred by residents as an alternative for current gas-based heat provision, taking Utrecht residents as a case-study. To align the research, it is important to define the research questions, for focusing research and set boundaries. The main question is:

[10] One of the research fields on DH is to make existing DHNs more sustainable (Fisk, 2010; H. Lund et al., 2014; J. W. Lund & Boyd, 2016; Ouden et al., 2015; Rezaie & Rosen, 2012; Szendrei & Spijker, 2015). This topic can be clustered two main technical discussions: (1) how to enable the DH systems to use (low temperature) waste heat? This is important to use all heat potential in cities, so save as much energy as possible on a regional level. (2) how to enable the feed in of renewable sources? How to define heat networks in a way that intermitting sources can be used optimally: one of the challenges is therefore intraday and interseasonal storage facilities.

[11] One of the research fields is the optimization of (existing) DH networks. This relates to using economies of scale and operational effectiveness (Barelli, Bidini, & Pinchi, 2006; Lindenberger et al., 2000). This type of research is done to make the heat distribution more effective, less losses etc. So: optimize the sold output with the given amount of input there is.

What ownership structures for new district heating systems would Utrecht residents prefer?

1. How is energy justice related to ownership of natural monopoly infrastructures?
2. What are the actors, institutions and technology when the sociotechnical system of heat provision changes from natural gas to district heating in Utrecht?
3. What is the design space for structuring ownership of district heating?
4. What are the differences and similarities on strengths, weaknesses, opportunities and threats for ownership types of district heating at present in the Netherlands?
5. What choices in ownership of district heating systems reflect the preferences of Utrecht residents?

2.5. Research framework

The flowchart in Figure 3 gives the products in the thesis aiming to study on the public preference on the key stone. The products are yet described in 2.1. In addition, it is important to notice the relations among the different products and why they are important for the main question. The (1) conceptual framework provides a visualisation of the relations between justice and ownership preferences and is used to design the survey and to reflect upon in the discussion, this is important because of the injustice problem statement. The (2) sociotechnical system is needed to understand in what context the preferences need to be placed, as where the actors are very specific to this case study. The technical aspects give a technical view on the development of the physical part of the design space. The research on the design space is used to (3) design the survey and gives insight in (4) discussion of the results. It is needed as a definition of what ownership structures are and helps to visualize the effects. The keystone of the research is related to the case-study of Utrecht and combines the different efforts on the design space, sociotechnical system and justice theory by discussing the findings of a survey to public preferences (5).

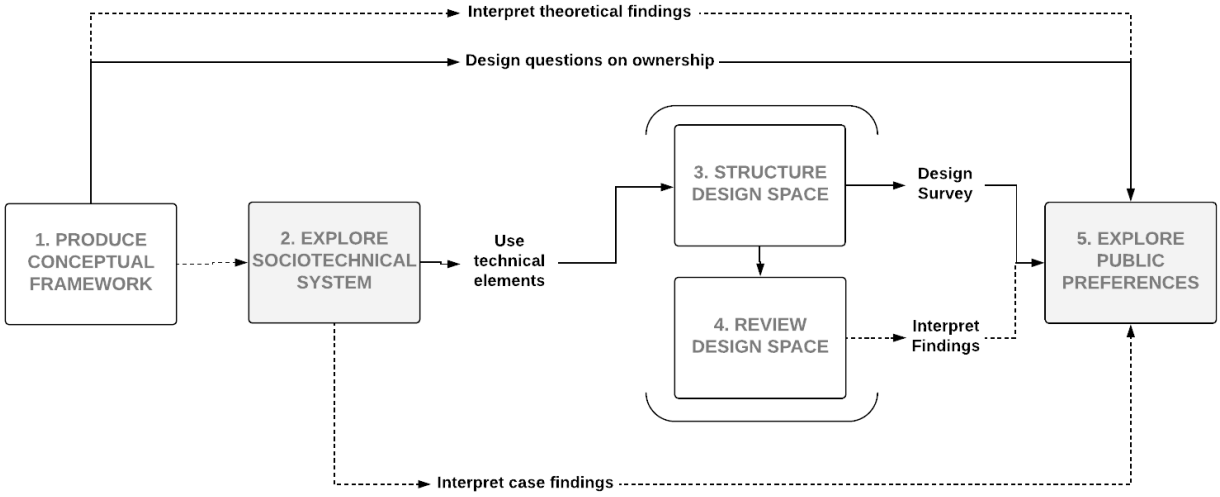

Figure 3 Research Framework (dotted line=interpretation; solid line=product use; grey box=case-study)

2.6. Audience

The audience of the research are the parties who can take initiative in developing a district heating system. The following groups can be distinguished:

- **Climate tables:** assigned as a municipal task by the Ministry of Economic Affairs and Climate, municipalities have formed 'tables' on which stakeholders are represented to decide – among other climate aspects – on the alternative for natural gas.

- **Municipalities**: municipalities are assigned problem owners to meet climate goals on a local level. District heating is a potential technology diminishing the CO2 output.
- **Cooperative initiatives**: some active neighbourhoods organise themselves because they want to reduce their climate impact. There are cases in which residents are more ambitious than their municipality.
- **Companies:** companies can gain customers when taking the initiative to transition neighbourhoods to district heating from natural gas.

2.7. Methods

All the methods guiding the research project are summarised in Table 2-1. The methods are ordered by chapter.

Questions		**Activities**	**Methods**	**Validation**
1	How is energy justice related to ownership of natural monopoly infrastructures?	Produce conceptual framework	- Literature review	- Expert validation
2	What are the actors, institutions and technology when the sociotechnical system of heat provision changes from natural gas to district heating in Utrecht?	Sociotechnical Analysis (Reed et al., 2009).	- Desk research - Semi-structured stakeholder interview	- Snowballing in stakeholder interview - Multi-actor interview
3	What is the design space for structuring ownership of district heating?	Structuring design space	- Literature review - Semi-structured *general expert* interviews - Semi-structured *experience experts* interviews	- Multi-actor interview
4	What are the differences and similarities on strengths, weaknesses, opportunities and threats for ownership types of district heating during at present in the Netherlands?	Reviewing design space	- Semi-structured *experience experts* interviews	- Comparing expert interviews
5	What choices in ownership of district heating systems reflect the preferences of Utrecht residents?	Public perception analysis	- Online questionnaire - Statistical analysis	- Comparing sub groups - Sample validation - (Utrecht decision makers interview)

Table 2-1 Table of methods

2.7.1. Conceptual framework

The conceptual framework is produced by literature review. This review is primarily based on the conceptual review of Jenkins et al. (2016). Also, the Scopus engine is used to review the keywords 'energy justice', 'procedural justice', 'distributive justice', 'district heating'. Due to the wider application of the energy justice concept in wind power development 'wind power' is also assessed. Furthermore, snowballing is used to find additional literature.

Validation of the conceptual framework is done by expert validation. A professor working in this field is requested to discuss the framework overview of combining the different concepts.

2.7.2. Sociotechnical Analysis

For describing the sociotechnical system, the elements in the framework of Ottens, Franssen, Kroes, and Poel (2006) are used. The interrelated elements are shown in Figure 4. There are three types of main elements distinguished: (1) technical elements, (2) actor elements, and (3) social elements (Ottens et al., 2006). These elements guide the description of the sociotechnical system of the selected case-study – offering a social relevant context for the explorative findings of energy justice and ownership. Furthermore, findings can be used as starting point in other chapters in this thesis (e.g. the exploration of physical changes in the system, function as a starter for forming the design space).

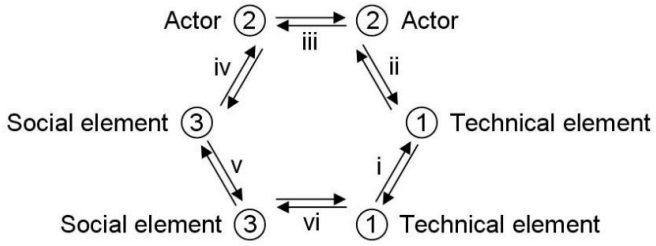

Figure 4 Elements (1-3) and relations (i-vi) in a sociotechnical system (Ottens et al., 2006)

2.7.2.1. Technical

The methods for describing the different elements distinct. Describing the *technical* elements of the sociotechnical change focus on the physical changes in terms of infrastructure. To do so, literature is reviewed to describe the current heat provision system (natural gas) and describe the heat provision by district heating systems. Comparative findings focus on the physical changes needed for the heat transition. There is no need to focus on the case study. Despite differences in precise technical configurations among case studies, the public perceives it equally – as long as temperatures are the same.

The technical aspects are validated by expert validation. An expert of a private district heating company is asked to discuss the system changes when heat provision is moved from the natural gas infrastructure to district heating infrastructure. Elements of improvement are considered and revaluated in literature.

2.7.2.2. Actor

Describing the *actor* elements do focus on the case study. This is because actors are perceived differently on a case-by-case basis, because they all interact with the public in their specific manner. The actor description is done be a stakeholder analysis, identifying different stakeholders and assess their formal relations. A meso perspective – taking the scale of a (city-sized) municipality – is chosen to define the stakeholders in place. This is because (1) a macro perspective (national) has no value due to the local institutional circumstances; (2) a micro perspective (community) is hard to determine due to the difficult definition of a community, the sensitivity of the topic. Moreover, a micro perspective

limits generalisability. Above all, defining the strategies to meet climate goals is assigned to local councils, because of opportunity for local customization (Naber et al., 2016).

Stakeholder analyses are generally used "in order to generate knowledge about the relevant stakeholders as to understand their behaviour, intentions, interrelations, agendas, interests, and the influence of resources they have brought to bear on decision-making processes" (Varvasovszky & Brugha, 2000). According to Reed et al. (2009) this can be done in three step approach: (1) identify stakeholder, (2) categorising stakeholder, (3) researching relationships between stakeholders. Desk research was the basis of the identification and categorisation. The final step in the three step approach of Reed et al. (2009) is the valuation of relationships. Since the explorative purpose, we do not aim to draw conclusions in terms who is important and who is not. We scope by aiming only for 'who' influences who, excluding information on 'how much' they influence each other. These relations are identified using a 'formal chart', describing formal relations among stakeholders (Enserink et al., 2010).

Validation of the stakeholder findings is done by two methods. First the snowballing *in the interviews* provides the identification of stakeholder and defining the categories: all interviewees are asked to add stakeholders on a predetermined list. The formal chart is validated in a *multi-actor interview* with the 'heat transition table in Utrecht'. This group of stakeholders have combined knowledge on stakeholders in Utrecht. A concept version of the formal chart is presented and discussed on the identified linkages. Improvements are subsequently passed by the researcher.

2.7.2.3. Technical

Describing the *social* elements of the sociotechnical change focus on the institutional changes in the heat transition. To do so, the framework of Williamson (1998) – identifying differences in layers of institutions – is used to review institutional changes in the course of the heat transition. These changes are found through literature review. The scope of the social elements is based on the case study, but the level of analysis is national. National institutions (like price, tax, market models, heat use etc) mostly determine how people perceive district heating. Since these technical changes are well described in literature and reports, they will not be validated by other means.

2.7.3. Design space structuring

For the configuration of the design space, the main technical assets in the heat chain are used as a basis. Desk research using reports and literature provides this basis. Desk research also serves as the main source for combining ownership strategies.

2.7.3.1. Interview set-up

The *consultants and experienced interviewees* on (the ownership of) district heating networks in the Netherlands are asked on their opinion on the challenge of the 'of the gas' challenge and the role of DH in this challenge. Also, are interviewed on *innovative* ownership structures and the likability of the specific ownership structures in the 'of the gas' transition.

The interviews serve as the main source for the 'table of effects' of the different ownership structures. This table is used to briefly present the effects of the (1) design concepts on the ownership structure, and the effect of the (2) ownership type on the design concept (Correljé & De Vries, 2008). The reason to present them here as effects is that it is value-free, thus being relevant for decision makers to assess all opportunities (Correljé & De Vries, 2008)

2.7.3.2. Selection of interviewees

The set of selected people is determined by the expertise of the participants. The expertise needed for these analyses was assessed on the role of ownership of district heating networks. First, expertise on

the developments in the district heating sector due to the phase-out of the natural gas was needed to get an overview of the opportunities and threats for district heating in the Netherlands. Second, experience expertise with different ownership structures were needed because of their insights in the current functioning (strengths/weaknesses), mission statements and knowledge on perceived injustice in their own situation. These interviewees were selected by reports (Benno Schepers & van Valkengoed, 2009; Schwenck, 2017; Schwencke, 2016). Interviewing from the company perspective limits the comparative empirical evidence of justice aspects but was chosen because the 'transition perspective' scopes the research. This means that we aim to assess hypothetical situations (NG to DH), of which assessment is limited with a nonprofessional. The third group of experts was chosen because expertise on the regulatory experience and regulatory development in the district heating sector was needed to get a public stance on the ownership discussion. Governments serve the public to strive for justice for the monopoly infrastructure, defined in their goals of security of supply, sustainability and affordability. They have a clear perspective on the collective interest, with social justice among them. Table 2-2 describes the anonymised interviewees (Cn=consultant, Co=cooperative, Pu=public, Pr=private, Go=government, Gs=group of stakeholders):

Nr.	**Description**	**Reason of selection**
1Cn	Consultant specialised in market and policy development, working at a company devoted to maritime, oil & gas, energy, business assurance and software consultancy.	Expertise in the role of district heating during the heat transition.
2Cn	Consultant specialised in heating the built environment, working at a company devoted to environmental and energy consultancy.	Expertise in the role of district heating during the heat transition.
3Co	Program manager of heating alternatives for natural gas, working at a climate-oriented non-profit.	Expertise in the development of alternatives to natural gas in the Netherlands.
4Co	Board member of an energy cooperative, aiming to develop a local heat source on an existing heat network.	Expertise in the development of a cooperative heat source in the Netherlands.
5Co	Committed member of a heat cooperative that is currently under development.	Expertise in the development of a heat cooperative in the Netherlands.
6Co	Director of an energy cooperative, aiming to realise the local energy transition and enhance sustainability by catalysing initiatives, distribute best practices and cooperation.	Expertise in co-designing g cooperative solutions for heating in city-context.
7Pu	Director of municipally-owned fully integrated district heating company	Expertise in a public heat company in the Netherlands.
8Pu	Manager heat delivery of shared municipally-owned waste incineration company, co-producing heat for district heating	Expertise in a public heat company in the Netherlands.
9Pr	District heating business developer at privately-owned energy company, with district heating department	Expertise in business development at a district heating company in the Netherlands.
10Pr	Advisor regulatory affairs specialised in district heating at privately-owned energy company with district heating department	Expertise in regulatory affairs at a privately-owned district heating company in the Netherlands.

11Pr	Policy advisor at privately owned district heating company	Expertise in policy advice at a privately-owned district heating company in the Netherlands.
12Pr	Director of privately owned operator of local, sustainable heating systems: specialised in aquifer thermal energy storage.	Expertise in a company that is a competitor on collective heat solutions.
13Go	Advisor sustainable heating and cooling systems in a governmental organisation	Governmental expertise on cooperatives, selected by internet research and author of relevant reports
14Go	Advisor market creation in a governmental organisation	Expertise in regulatory context in the heat transition.
15Go	Project manager and advisor energy transition of the built environment in governmental organisation	Expertise in the local governmental vision on the heat transition.
16Gs	Group interview of stakeholders involved in local decision-making.	Overview on the planning of the local heat transition and balancing of alternatives.

Table 2-2 Description and selection of interviewees

2.7.3.3. Validation

Validation is done by expert validation in a group: presenting the preliminary design space and assessing the missing and/or incorrect values. By means of a multi-actor discussion, it is assessed on the use of the design space as a conversation starter for considering ownership during the heat transition. They are asked on how useful this could be in their role on the decision making on the heat transition. Also, it is discussed on what level (neighbourhood, Utrecht, Netherlands etc.) ownership needs to be discussed.

2.7.4. Design space reviewing

The interviewees 3-12 in Table 2-2 are asked on their experience with the ownership structure (what is owned by who, what are their goals? Why do they do the things as they are doing them?) To assess their own status in the heat transition, the interviewee is asked to assess the *strengths, weaknesses, opportunities and threats (SWOT-analysis).* The SWOT-framework originates from business and marketing analyses. Due to its simplicity and coherence, it has been adopted in other fields of research including energy (Chen, Kim, & Yamaguchi, 2014).

Since the derived data for the SWOT framework is from interviews, the assessment needed to be easy to understand for the interviewee. A SWOT analysis is a common tool in business practice so was well known – or simple to introduce – by the participant. The main distinction in the framework is the division of an internal and external assessment. The internal assessment is to illustrate strengths and weakness of an ownership type. Strengths represent any characteristic that is positive on the performance – both financially and societal –, influencing the heat transition. Weaknesses are imperfections, which may decrease efficiency, financial resources or societal performance. The external assessment is used to discover opportunities and threats. Opportunities are external fluctuations that could contribute to additional development of the ownership structure, as where threats are outside factors that may cause problems (Chen et al., 2014).

SWOTs are typically used to analyse energy situations, policies or strategies. However, this paper aims to uses the SWOT analysis in a comparative way to explore differences among unalike types of ownership – in the case of district heating. In this analysis more value-based arguments are given, which has not been done often before (Chen et al., 2014).

The design space review has not been validated due to its explorative purpose. Findings are coded if they comply with literature. These arguments are most valid. Other arguments are based on opinions of experts, limiting the validity of the SWOT.

2.7.5. Public preferences analysis

The public preferences analysis aims to explore the ownership preferences directly and by considered aspects of energy justice. These preferences are assessed by means of an online-survey using the Qualtrics software. This online-survey is distributed in-person and online. The data is assessed using the SPSS and excel software.

A survey is chosen to derive the ownership preferences and energy justice support. Surveys are limited, according to Babbie (2010), because of their inflexibility of research. No changes can be adapted anymore, while that can be useful. Also, this survey only gathers collected self-reported and hypothetical actions and situations: no measurement of social action. Furthermore the 'artificiality problem' arises with the survey: people might give their opinion on aspects of society they had just learned in the survey, or the questions are not amenable by a questionnaire because in real life they are more complicated. These consequences of the chosen method are minimised by giving participants the opportunity to answer their own thoughts, giving them the opportunity to add qualitative insight in the data of the study. Missing the 'context of life' has been minimised by asking a significant amount of background questions.

For explorative purposes open interviews, focus groups or brainstorm events are alternatives, for which there is no need to design questions that are a least minimally appropriate to all respondents, which is limiting the survey because you may miss what is most appropriate to many respondents (Babbie, 2010). Nevertheless, other methods have problems of their own: interviews or focus groups can limit sample size and therefore representativeness, because it is time consuming and for the both the researcher and the respondent. The representativeness of the focus groups might also be problematic, because voluntarily joining these focus groups with people coming from different type of backgrounds is – as a student – complicated to achieve. Also, focus groups have to cope with 'group dynamics'.

Before elaborating on how the survey was set-up and interpreted, it should be noted that the findings of the public preferences study are not externally validated. Due to its explorative purpose it was aimed to find some of the patterns among Utrecht residents, not to generate generalizable and hard claims. Only strategies for internal validity of the survey is accounted for.

2.7.5.1. Type of questions

In the following table the types of questions are defined and explained. The CLSQ aspects, MCQ and SCQ values per question have been randomly ordered with every respondent, to maximize the response validity.

Abbrv.	**Name**	**Explanation**
LSQ	Likert scale question	This is an ordinal (O) question, which is assumed to have the same distances between values, as it can be treated as an *interval* – with discrete values – question. By filling in the survey, people where made aware of this. The values given to the respondents are based on 5 points: not at all, not, neutral, yes, very much. The question is closed-ended (Babbie, 2010)

CLSQ	Comparative Likert scale question	This is the same type of questions as a LSQ, but comparative assessments among aspects will also be assessed. It is used to split one broad question in the valuation of different aspects. The question is closed-ended (Babbie, 2010)
MRQ	Multiple response questions	This is a *nominal* (N) question. People are asked to choose one or more of the given options. The question is closed-ended (Babbie, 2010). There is a 'different, namely' added for qualitative input.
SCQ	Single choice question	This is a *nominal* (N) question. People are asked to choose one of the given answers. The question is closed-ended (Babbie, 2010). There is a 'different, namely' added for qualitative input.
CIQ	Categorical interval question	This type of question is comparable with an SCQ. Thus it is a nominal question where people are asked to choose a category. But these categories are on an interval scale. It will therefore be treated as an *interval* (I) value. The question is closed-ended (Babbie, 2010)

Table 2-3 Question types in public preferences survey

2.7.5.2. Population and sampling

Household in neighbourhoods which are currently using NG were favoured, their perceived position is more relevant to answer the main question than people who are already in a district heating scheme. Despite this, no exclusion is executed for this group. They do have a valuable opinion and are part of the Utrecht public preferences. Exclusion has been conducted on people who do not live in Utrecht. Background statistics are asked to the respondents to assess the generalisability of the sample, it is checked with the database of the Utrecht municipality (Onderzoek, 2018) and CBS.

2.7.5.3. Distribution

In order to achieve a reasonable sample size for explorative purposes 2000 business cards were spread among the Utrecht population. The business cards had a professional appearance to enthusiasm as much residents as possible. The business cards design can be found in Figure 5.

Figure 5 Distributed business cards (designed by researcher)

The business cards have been distributed in different locations, these include public transport, shopping centres, mailboxes and public locations. E-mail and social media were the methods for digital distribution.

- **Public transport:** rush hours (Utrecht Central Station 6x, Overvecht 2x)[12]. People arriving or departing by bike were targeted, due the chance they would live within the Utrecht municipality.

[12] Since their relative quietness Vaartsche Rijn and Lunetten have been skipped. The station of Leidsche Rijn, Terwijde and Vleuten have been skipped because they were situated in neighbourhoods with district heating

- **Shopping centres:** (preferably visited when outdoor markets were organised) have been selected to AH has been selected when no clear shopping centre set-up is available in the neighbourhood. Especially in the Binnenstad the chance of meeting people not in living in Utrecht is substantial. Personal contacts in the city are contacted to fill in the survey. These seven locations are posted for at least two hours (Table 2-4).
- **Public locations**: in accordance with the owners of some public spot the business cards have been distributed within their properties. These were the: Public Library (Oude Gracht), City Hall (at central station), St. de Moestuin (Maarschalkerwaard), Wilhelminapark (spread among recreationists)
- **E-mail:** the link to the interview has been internally spread within Eneco Warmteproductie Utrecht (14 respondents) and Green Office Utrecht (1 respondent).
- **Mailbox:** the business cards have been spread in mailboxes in Noordwest (Lombok, Kempisplantsoen, Oog in Al).

Neighbourhood	**Shopping Centre**
Noordoost	Winkelcentrum De Gaard
Noordwest	Winkelcentrum Plantage
Oost	AH Burgemeesterreigerstraat
Overvecht	Shoppingcenter Overvecht
West	AH Oog in Al, Handelstraat
Zuid	Winkelcentrum Lunetten, Winkelcentrum Smaragdplein
Zuid – West	Winkelcentrum Kanaleneiland

Table 2-4 Distribution locations

2.7.5.4. Statistical analysis

Five types of questions can be distinguished in Table 2-5. All questions are assessed in their own way, depending on the type of data they have gathered. These are measured on different levels: the nominal and the ordinal level. The ordinal level is in the survey communicated to be equally distanced. It means we can treat the Likert scale data as interval data: the central tendency will therefore be the mean (descriptive).

For the research purpose it is also valuable to account for differences in answering for different groups within the sample (inferential). The questions which are answered in this part are: are the differences or relationships observed in the sample caused by mere random chance? What is the probability that the sample results reflects patterns in the population from which the sample were selected? (Healey, 2014)

Answers complemented questions on the significance questions. Where independency has been rejected, it gives insight to find what kind of relationship there is. So, questions like 'How strong is the relationship between the variables? What is the direction or pattern of the relationship? (Healey, 2014) Dependency proven relationships are researched by using the following tests (Table 2-5). What the inferential and bivariate methods entail is explained in Appendix A. (Appendix: Explanation of tests). The chosen tests are validated by a 'methods and statistics' scholar of Leiden University.

Abbrv.	Descriptive statistics	Inferential statistics	Bivariate statics
LSQ (O)	- Frequency table - Central tendency: *median* comparison - Skewness: to determine the direction of the skew - Kurtiosis: to determine the outliers	If comparing 2+ groups: - ANOVA Kruskal Wallis (Test No. 1) If comparing 2 groups: - ANOVA Mann-Whitney U test (Test No. 2)	If two variables are ordinal/interval: - Lambda If related to nominal: - Phi/Cramer's V
CLSQ (O)	- Central tendency: *median* comparison - Skewness: to determine the direction of the skew - Kurtiosis: to determine the outliers - Comparative one sample median test: to determine distance from the median answered among all aspects/categories	If comparing 2+ groups: - ANOVA Kruskal Wallis (Test No. 1) If comparing 2 groups: - ANOVA Mann-Whitney U test (Test No. 2)	If two variables are ordinal/interval: - Lambda If related to nominal: - Phi/Cramer's V
MCQ (N)	- Frequency table - Central tendency: *mode* comparison	- Crosstable	If one or more variables are nominal: - Phi/Cramer's V
SCQ (N)	- Frequency table - Central tendency: *mode* comparison - Chi Square 'Goodness of Fit' - *When just two choices: binominal test	- Crosstable - Chi-Square of 'Independence' (Test No. 3)	If one or more variables are nominal: - Phi/Cramer's V
CIQ (I)	- Central tendency: *median* comparison - Skewness: to determine the direction of the skew - Kurtiosis: to determine the outliers	If comparing 2+ groups: - ANOVA Kruskal Wallis (Test No. 1) If comparing 2 groups: - ANOVA Mann-Whitney U test (Test No. 2)	If two variables are ordinal/interval: - Lambda If related to nominal: - Phi/Cramer's V

Table 2-5 Table of statistics

3. Conceptualisation of energy justice

In the first chapter, the conceptual framework for this research project is presented. Since energy justice is a rather new and broad concept, the presentation of a conceptual framework gives a clear overview of the basic assumptions and theoretical background throughout this research project. This chapter answers the following sub-question: how is energy justice related to ownership of natural monopoly infrastructures? To answer this question, we will start with a literature review on the definition of energy justice, explaining the concepts of distributive and procedural justice.

3.1. Defining energy justice

Justice in the energy sphere – including heat provision – is defined by the recently developed concept of 'energy justice'. In summary, this concept is dealing with "energy policy, energy production and systems, energy consumption, energy activism, energy security, the energy trilemma, political economy of energy and climate change" (Jenkins et al., 2016). It reflects challenges regarding energy in which "injustices emerge, which affected sections of society are ignored, which processes exist for their remediation in order to reveal and reduce such injustices" (Jenkins et al., 2016). Thereby energy justice is an application of general definitions of justice, which entail 'the quality of being just, impartial, or fair' (Merriam-Webster, 2018). Which reflect the interchangeability of justice and fairness (Hart, Hart, & Green, 2012).

In the normative debate justice is defined in a more complex manner which include notions of equality and the equitable distribution of benefits (CRC, 1998):

- equality definition – 'everyone should get or have the same amount, regardless of how hard they work, or what they put in' (Gross, 2007)
- equity definition – 'people should get benefits in proportion to what they contributed to producing those benefits. In other words, the harder and better you work, the more you should get as a reward for that work' (Gross, 2007).

For this project, normative arguments are not defended. But these justice stances do give an illustration on how people could evaluate the factors important for energy justice. Do people think that the way of sharing costs and benefits should be equal or equitable? Do they think every resident has an equal vote in procedures of implementation? Or may some stakeholders be more important than others in the decision-making process (equitable vote?).

Since the energy application of justice is researched, the defining efforts from Jenkins et al. (2016) are important for this thesis. Their exploration of energy justice distinguishes distributive, procedural and recognition justice (Jenkins et al., 2016). According to Jenkins et al. (2016) these three aspects entail the most aspects to be tackled if energy injustice is perceived: distributive as the identification of the concern, recognition as the identification of the affected people or stakeholders, procedural as the identification of the strategies for remediation. In accordance with Gross (2007) and acknowledged as most important by Jenkins et al. (2016), this research distinct only two levels of justice: procedural justice and distributive justice. In the following paragraph these two types of justice are discussed on their definition.

3.2. Procedural vs. distributive justice

"Distributive justice concerns the ways the distribution of costs, risks, and benefits between different actors is perceived" (Goedkoop & Devine-Wright, 2016). Distributive justice arises from the discourse on fairness in organisation psychology, which started with equity theory, emphasizing the fairness of outcomes, namely distributive fairness (Cohen-Charash & Spector, 2001). Cohen-Charash and Spector (2001) explain the relationship of distributive justice on the individual as follows:

"Due to its focus on outcomes, distributive justice is predicted to be related mainly to cognitive, affective, and behavioural reactions to particular outcomes. Thus, when a particular outcome is perceived to be unfair, it should affect the person's emotions (e.g., experience anger, happiness, pride, or guilt), cognitions (e.g., cognitively distort inputs and outcomes of himself/herself or of the other), and ultimately their behaviour (e.g., performance or withdrawal)."

These individual effects are reflected in the societal effects – especially in terms of the creation of 'winners and losers' – of distributive injustice recognised by Gross (2007):

"justice is accepted as central to the well-functioning of society with fairness being an expectation in day-to-day interactions. Outcomes that are perceived to be unfair can result in protests, damaged relationships and divided communities, particularly when decisions are made which benefit some sections of the community at the perceived expense of others."

Overall definitions of distributive justice vary in what is to considered to be relevant (income, wealth, opportunities, jobs, welfare, utility etc.); who is recipient (individuals, groups, reference classes etc.); and how distribution should be made (equality, maximization, according to individual characteristics, according to free transactions etc.)(Lamont & Christi, 2017).

Procedural justice arises from the inability of equity theory – or distributive justice – to explain and predict all reactions on perceived injustice (Cohen-Charash & Spector, 2001). Procedural justice[13] focusses on the perceived fairness of the process, since findings in organisation theories showed that the outcomes were not always as important as the process by which they were allocated. It is defined as the 'fairness of the process by which outcomes are determined' (Cohen-Charash & Spector, 2001). It is considered to be of influence when procedures entail certain types of normatively accepted principles (e.g. consistency, bias-suppression, accuracy, correctability, representativeness and ethicality (Leventhal & Lane, 1970)).

The distinction between these two types of justice is well supported in literature (Cohen-Charash & Spector, 2001; Goedkoop & Devine-Wright, 2016) and the concepts are therefore used to examine the natural-gas-to-district-heating case study. So how do these two concepts relate to the case study?

3.3. Distributive justice in a natural monopoly

Opposing to the community effects Gross (2007) identified, in the case of natural-gas-to-district-heating transition, issues with distributive justice do currently not occur among neighbours. Whereas Gross (2007) identifies divided communities in wind turbine projects – land owners are 'winners' and the neighbouring community without redistributed wealth are the 'losers'–, there is no community division in the case of district heating. Goedkoop and Devine-Wright (2016) acknowledge that apart from these intra-community tensions, the distribution of benefits between developers and communities should also be concerned in distributive justice.

The perceived distributive injustice in the case of natural-gas-to-district-heating is funded in the transition to a *natural monopoly infrastructure*[14]. Because of the absence of competitiveness *on* the district heating network by different companies, heat provision schemes are based in a natural monopoly due to the infrastructural characteristics (e.g. network benefits, economies of scale, locality of sources etc.). The monopoly is regulated by law to protect customers for monopolistic power, by

[13] A debated extension of procedural justice in organisational theory is the 'interactional justice' coping with concepts like honesty, politeness and respect (Cohen-Charash & Spector, 2001).

[14] It is assumed that competition on the network is unlikely to happen on the short term, due to the high overhead costs and local risks mitigation necessities. Economies of scale are key to keep these costs acceptable.

the current not more than elsewhere principle (NMDA-principle) (R. Haffner et al., 2016). Despite (or some say: because of) these protective measures by the national government of the Netherlands, the district heating company is perceived to charge too high prices to their consumers. This is the reason why there is a notion of perceived distributive injustice in the welfare distribution of district heating: the fairness of the distribution of wealth is perceived to be unfair in the producer-consumer relation. This supported by the fact that, according to three large Dutch consumer organisation, the regulations (1) do not regulate well the high fixed costs, and (2) the reference pricing method (NMDA) does not properly reflect real market conditions (Mulder et al., 2014). Moreover, satisfaction scores (e.g. net promotor scores) for district heating are often in the low ranges due to price dissatisfaction.

One of the solutions for this perceived unfairness is explored in this research: the type of ownership of the monopolist assets (Pitkin, 1981)[15]. In the case of renewable energy technologies, Kunze and Becker (2015) reason that collective or public forms of ownership could "serve as means to achieve wider goals, such as local community control, distributive justice, environmental sustainability and improved participation". Therefore, this research explores whether there is a difference in preference for public, private, cooperative or mixed ownership.

The used definition for researching the natural monopoly is: "the equal distribution of benefits and ills on all members of society, regardless of income, race" (Jenkins et al., 2016). The following aspects are associated to be equal or equitable for distributive justice (Jenkins et al., 2016):

- Equal financial benefits and ills among all members of society, e.g. financial participation
- Equal (perceived) risks among all members of society, e.g. financially, regarding siting, failures,
- Equal access to energy and heat services, e.g. exclusion of members of society
- Equal burden among all members of society, e.g. siting issues
- Equal distribution of responsibilities among all members of society, e.g. time

3.4. Procedural justice in a natural monopoly

Procedural justice is concerned with the processes by which decisions are made. Important elements in procedural justice include rights of participation, access to information, and lack of bias on the part of the decision-maker (Gross, 2007). Jenkins et al. (2016) acknowledges the same three aspects in procedural justice in three mechanisms of inclusion designed to achieve just outcomes: 'mobilizing local knowledge', 'disclosing information' and 'representation in institutes'.

The first has raised in literature as a critical motivating factor for seeking inclusion and engagement of affected public. An example of a strategy using this concept – outside indigenous contexts – is the gathering of local facts on public health and geophysics to resist for the expansion of an energy-from-waste plant (Jenkins et al., 2016). An example of mobilizing local knowledge regarding the heat transition could be to involve local statistics on income levels and 'stories of neighbourhoods'[16].

The second – disclosing information – aims to make as much information as possible available on the justice issue. Regarding distributive justice in the case of energy savings, by means of information disclosure consumers are conferred with 'hints and tips' for energy usage, and producers awarded with

[15] Others include transparency (could change the 'perceived fairness' in 'educated fairness') (Gross, 2007), competitivity (market creation to incentivize producers not to maximize profits, but to 'gain consumers') (R. Haffner et al., 2016) .

[16] An example of resistance arguments to natural gas grid removals can be found in Utrecht Overvecht. Neighbourhood residents refer to their (poor) socioeconomic status compared to others in Utrecht, asking decision makers why they have to be 'the guinea pig' in Utrecht instead of their fellow citizens with higher socioeconomic statuses (Penris, 2018)

'usage data'. Increasing real-time feedback loops between these actors could include households in resolving distributive injustices. An example of this in development of district heating is the rewarding consumers not using district heating inside the collective peak[17]. The financial rewarding justifies this redistribution of energy (distributive justice), but the process of 'request and reward' is voluntary (procedural justice).

The third – representation in institutes – refers to the representation of different actors and 'public backgrounds' in decision making bodies. Jenkins et al. (2016) refer to this in the context of gender imbalance in energy companies, being very 'white and male' in general. "Ensuring better representation in such institutions offers a more proactive approach to achieving justice, rather than 'depending upon the response of affected communities to injustice" (Jenkins et al., 2016). In the case of district heating development, the local decision makers on the heat transition should be perceived to represent the neighbourhood. Therefore, it is key in participatory methods like consultation, to translate 'the voice of the neighbourhood' in the decision-making process.

As where the process of consultation is a complicated process, for the aim of this research the outcome in terms of assigned *community power* over the process has been used to conceptualise the procedural justice. This has been done by defining the overall influence the community will have over the process of the project, including the elements identified by Jenkins et al. (2016). Also, the conceptualisation of the 'overall question' is used, including: no participation, alibi participation[18], informing, consulting, cooperating and financial participation.

3.5. Considered aspects

Expectations on procedural aspects co-determine the choices for owners of natural monopoly infrastructure: some owners are perceived to create better processes of participation – including the methods distinct by Jenkins et al. (2016) – than others. Therefore, *procedural justice* aspects are considered for determining the preferences of ownership for district heating. The concept of *participation* is taking into account the importance of mobilizing local knowledge and disclosing information, *financial information* is important for disclosing information and *trust* relates to Jenkins et al. (2016) by the representation in institutes.

Expectations on distributive aspects co-determine the choices for owners of natural monopoly infrastructure as well: some owners are perceived to create more equal or equitable distribution. Taken this into account the following *distributive justice* aspects are considered for determining the preferences of ownership for district heating. Distribution of *cost and benefit* is considering the equal risk and financial benefits and ills, *responsibility* is considering the perceived equality of burden and distribution of financial responsibility as well. *Access* is not assessed in terms of preferences but is taken into consideration because of equality in access might be different per ownership type.

3.6. Conceptual framework

Figure 6 show the conceptual framework. This framework gives has a visualisation opportunity for combining different concepts used in the rest of the research project. This conceptual framework is

[17] Real time data transfer could spread out this peak, making the demand for 'peak heat' less.

[18] Alibi participation refers to those citizens who want to be involved, but whose participation is ineffectual because their opinions are suppressed in some way (Langer et al., 2017). This operationalises the 'lack of bias of the decision maker' identified by Gross (2007).

proposed to guide the influence of ownership types on perceived energy justice. The following boxes are giving the following information:

A. Box A represents the conceptual connection between the 'outcomes' the 'processes' influencing energy justice.
B. Box B represents the operationalisation of the concepts of procedural and distributive justice on the research topic: ownership of monopoly infrastructures
C. Box C represents the different ownership types. All these types have different natural or strategic ways of to cope – or not – with procedural and distributive justice.

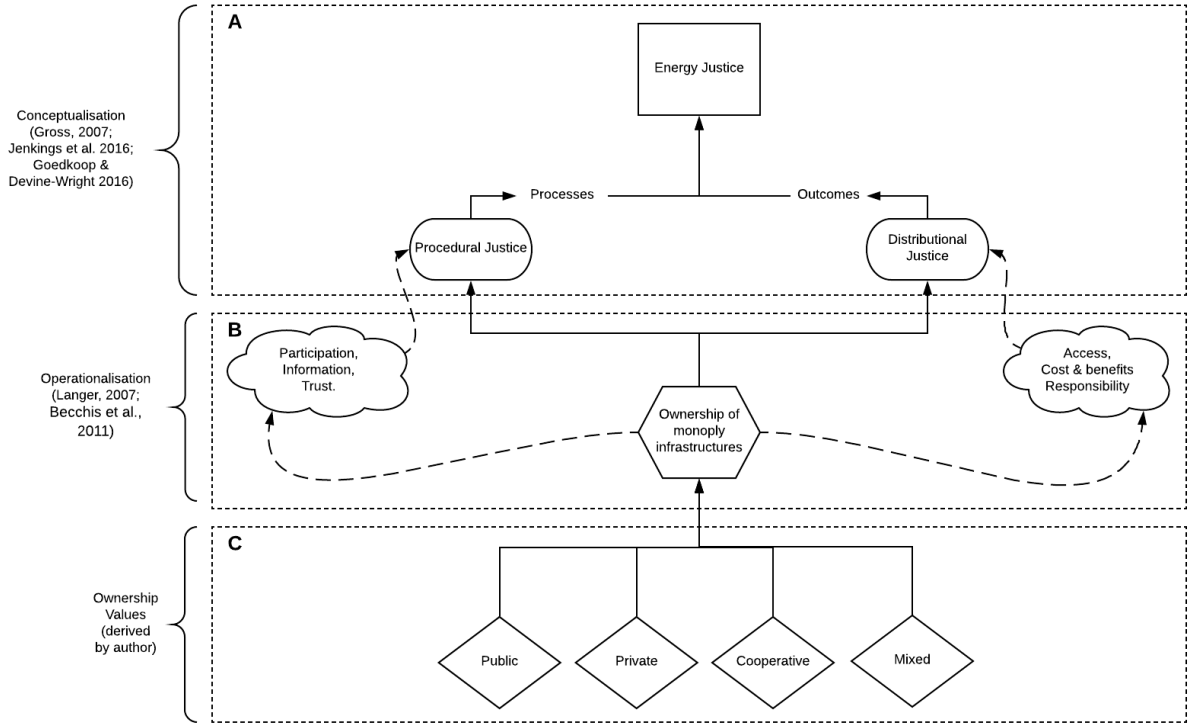

Figure 6 Framework Ownership - Justice

3.7. Validation

Validation of the conceptual framework is done by expert validation. An assistant professor working in this field is requested to discuss the framework overview of combining the different concepts. After introducing the research project and the problem statement, a concept-version of the conceptual framework has been showed to the professor. First, he ascertained that distributive and procedural justice was related to the problem statement and to ownership. He proposed some changes on the conceptual framework. Initiated in this discussion, the six aspects have been formulated to base the preferences of residents on.

3.8. Conclusion

This chapter has given a conceptual framework on the concept of energy justice in the case of district heating. By using the concepts of access, cost & benefit and responsibility the distributive justice has been operationalised. Using the concepts participation, information and trust define the operationalisation of the procedural justice. Accordingly with literature, procedural and distributive justice are used to define energy justice. The question at the basis of this chapter was: how is energy

justice related to ownership of natural monopoly infrastructures? The influence of ownership on energy justice is defined by the operationalisation of procedural and distributive justice.

FOLLOW-UP

As proposed in the research flowchart, the distinguished aspects influencing procedural and distributive justice are used to indicate energy justice in both the expert assessment of ownership types and in the design of the public preferences study. The theory on energy justice is used to reflect upon in the discussion.

4. Sociotechnical system of case-study

The second chapter of this thesis will elaborate on the sociotechnical system of heat provision, on which the transition from natural gas to district heating takes places. To describe a sociotechnical system, it is very common to use three type of elements: (1) technical elements, (2) actor elements, and (3) social elements (Ottens et al., 2006).

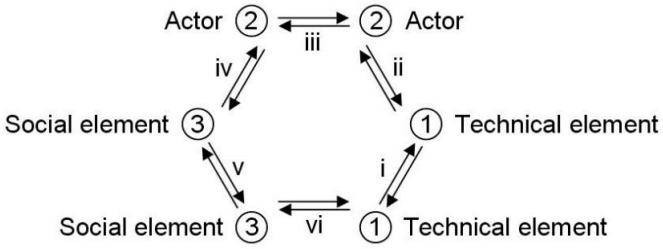

Figure 7 Elements (1-3) and relations (i-vi) in a sociotechnical system (Ottens et al., 2006)

The *technical* elements of the sociotechnical system consist of physical or software elements in the system (Ottens et al., 2006). The *actor* elements consist largely out of human beings, but also organisations can be considered as actors: they can act in the same legal sense as human beings (Geels, 2002; Koppenjan & Groenewegen, 2005; Ottens et al., 2006; Smith, Stirling, & Berkhout, 2005). Actors have personal preferences and/or represent different stakes. They can have influence and generally behave independently. The *social* elements include policies, laws, financial structures, organisational structures etc. (Ottens et al., 2006). These can also be named 'institutions': which influence in terms traditions, norms, judiciary, bureaucracy, contracting and allocation (Williamson, 1998).

The sub question in this part of the thesis is: what are the actors, institutions and technology when the sociotechnical system of heat provision changes from natural gas to district heating in Utrecht? Since we are dealing with a very complex transition perspective, the main aim of this part of the research is to identify the different stakes and goals of stakeholders on the technical and social elements. It is an exploration of the reactivity of the sociotechnical system on ownership structures.

4.1. Technical elements

The relevant technicalities to put into context are the *asset changes* within the heating system, during the heat transition. This is because ownership transfer of existing district heating networks is not under research in this thesis. Development of a new heating provision is the proposed and investigated option to diminish the use of natural gas. To find the technical changes in the heat provision system, we define both the natural gas system and the district heating system. Differences are identified and analysed on perceived changes for users: how do residents notice the new heat provision system?

4.1.1. Heat provision by natural gas

Figure 8 gives an overview of the steps of the natural gas delivery in the Netherlands (Weidenaar, Hoekstra, & Wolters, 2011). The first phase of the heat provision provides natural gas to household:

- Exploiting natural gas (NAM), or – depending on market conditions – imported or fed-in from storage facility (NAM, 2017). This is allocated by natural gas wholesaler 'GasTerra' (Gasterra, 2018)
- Natural gas runs through transmission lines under high pressure (TSO: 'GasUnie'). Both on the 'main transmission lines' and the 'regional transmission line'. Pressure is monitored and controlled in monitoring and regulating station (M&R)
- Natural gas flows into distribution networks, with lower pressure (DSO: 'Stedin')
- Gas is supplied at low pressure to households

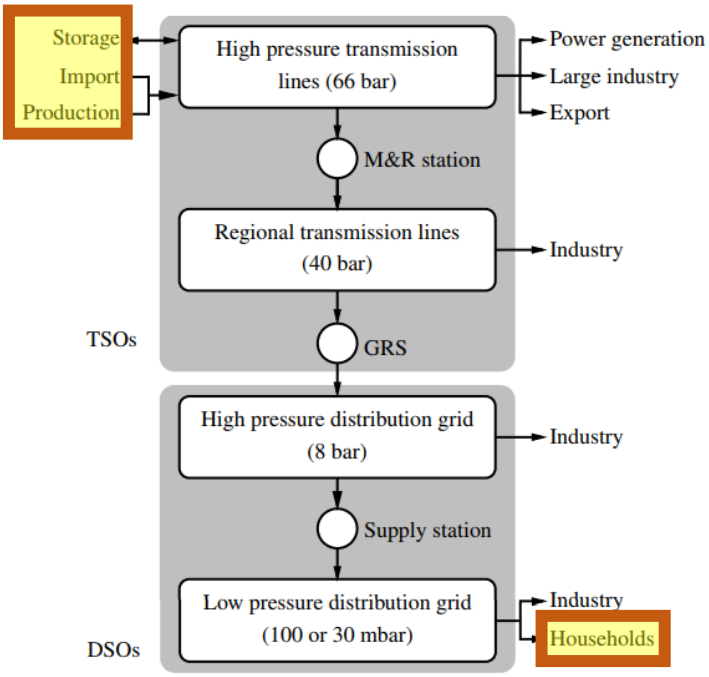

Figure 8 Dutch gas supply system, highlighted the by researcher[19]

The second phase provides heat to the households from the supplied natural gas. Final heat transfer is done by radiators in the house (Stougie, Dijkema, & Chappin, 2018):

- Natural gas is burned in central heating systems to generate water of 80 degrees Celsius
- The pumps in the central heating system force the hot water through the house, and supply the final product 'heat'
- Natural gas flowing into the house is measured in m^3. Billing is executed by commercial energy companies (like Eneco, Nuon, Essent etc.). These are responsible to buy the natural gas used by the customers at NAM or import – through Gasterra.

[19] This image has been derived from (Weidenaar et al., 2011): Abbreviations: TSOs=Transmission service operator/"GasUnie"; DSOs=distribution service operator/"Stedin"; M&R = Metering and regulating; GRS=gas receiving stations

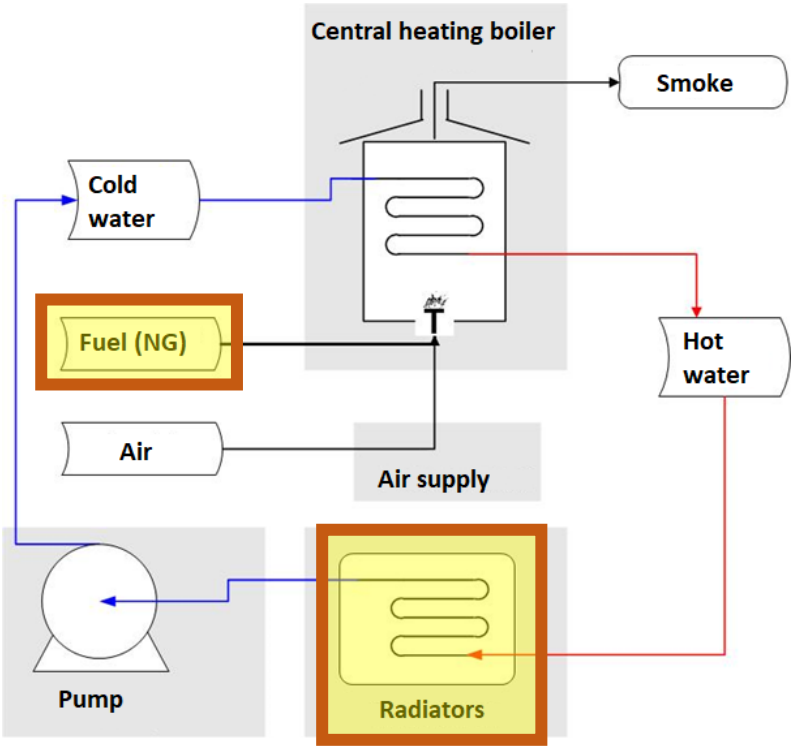

Figure 9 Central heating system: derived and adjusted from (Stougie et al., 2018)

4.1.2. Heat provision by district heating

The new technical situation with district heating is identified in this paragraph. The changes in the physical landscape are widely known, tested and proven in existing situations for many years. The steps with an asterisk are used in large-scale systems only[20]. The following steps will now have to take place for the heat provision to your house (HIERverwarmt, 2018b):

- Waste heat from industries is used or heat is generated centrally[21]
- Heat is captured in water, which is used as the energy carrier
- *High temperature and high-pressure water[22] (more than 70 °C) is transported through transport pipes (first cycle).
- *A heat transmission station (HTO) transmits the heat to the distribution network into the distribution network.
- High temperature water (more than 70 °C) is distributed by the distribution network to households (second cycle)
- Heat is exchanged in the houses with a heat exchanger to the internal water cycle (third cycle)
- Water in the house is recycled until it has the right return temperature
- The temperature difference and water flow are calculated to gigajoule of heat (GJ) used
- The used GJs are billed by the DH-company to the customer

[20] Which is the case with some of the district heating networks in the Netherlands in the large Dutch cities, like Utrecht.
[21] Central generation in district heating is still rather local. Most generation facilities are working within city boundaries.
[22] In some cases, steam is used

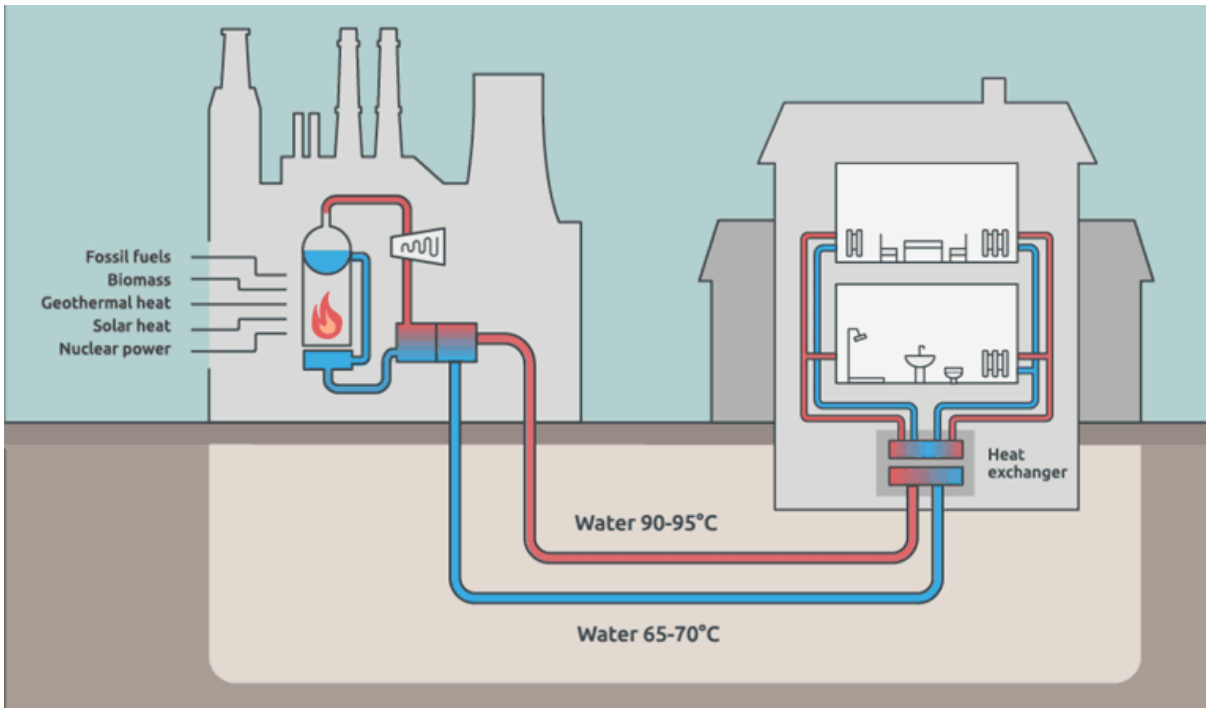

Figure 10 Small-scale district heating system, without HTO[23]

4.1.3. Physical changes

The physical changes for the people at their homes are in italic, these changes are mostly perceived by residents. The other infrastructure is to be developed outside their homes. Despite its minor effects close to their homes, it can still have influence on the life of citizens while developing it: streets might be overhauled, roads closed etc.

Removal of NG-infrastructure	**Installation of DH-infrastructure**
Their central heating boiler is removed	*A heat exchanger is installed*
(Old radiators are removed)	*(New radiators are installed*[24]*)*
The old meter based on gas m3 will be removed	*A new meter based on GJ will be installed*
Removal of the natural gas grid	Install DH-distribution piping (insulated) through neighbourhood, and pumping stations.
	(Install DH-transport piping and pumping stations)
	Connection to waste heat source, including the installation of the heat capture installation at the heat source. If there is no waste heat available: the development of heat generation source like biomass plant, industrial heat pumps, solar heat capture etc.

Table 4-1 Physical changes NG to DH

[23] This image has been created during "DensityDesign Integrated Course Final Synthesis Studio" at Polytechnic University of Milan, organised by Density Design Research Lab in 2016. Image is released under CC-BY-SA licence. Attribution goes to **"Laura Toffetti, DensityDesign Research Lab"**. It has been adapted by the researcher, taking a snapshot of the final stage in de original GIF-image.

[24] Depends on the temperature of the heat flow. When so called 'low-temperature networks' are in place there is no 'one to one' transfer to the old radiators. Instead floor heating or extra radiators need to be installed.

4.2. Actor elements

The relevant actor elements to be researched are the established *relations* during the heat transition. Therefore, it is needed to identify and categorise the stakeholders first. The actor-element in the sociotechnical analysis does focus on the case study. As already mentioned in the methods chapter, this is because citizens perceive actors differently on a case-by-case basis, because actors interact with citizens in their specific manner in their local context. The question in this part is therefore: who relates to (who in) the heat transition in Utrecht? The three-step approach for stakeholder analysis is used: (1) identify stakeholder, (2) categorising stakeholder, (3) researching relationships between stakeholders (Enserink et al., 2010; Reed et al., 2009)

4.2.1. Identify stakeholders

Through desk research and discussion with the Eneco supervisor, four organisations had been successfully selected for conducting an interview. Using a semi-structured interview protocol, these interviewees were asked on stakeholders in the heat transition in Utrecht, proposing a preliminary list and using the 'snowball method' to validate and extent the stakeholders. Finally, four interviews were conducted on the Utrecht heat transition (6Co, 2018; 9Pr, 2018; 13Go, 2018; 14Go, 2018).

4.2.1.1. Interview findings

6Co (2018) indicated the relevance of its own organisation in the first place. They are a not-for-profit institute to enhance the transition towards renewable energy. He validates the stakeholders already defined by the preliminary definition of stakeholders in developing new heat networks: the municipality, current heat network owner, current electricity and gas network owner, energy companies, national government, lobby and consulting groups and citizens. The role of national government is important due to the shaping of regulations and public mind-set (2nd layer institutes (Williamson, 1998)). The role of local governments and citizens is relatively large, because they are directly involved the execution of the heat transition (6Co, 2018). In addition, he indicates that some neighbourhoods are well equipped to attract or distract change. The role of the current electricity and gas network owners is minor in terms of development of heat networks, but might be larger if they – as publicly owned companies – are assigned with the task to manage heat networks (6Co, 2018). They are currently withheld from developing any 'commercial activities'.

13Go (2018) indicated many stakeholders relevant for the heat transition in the Netherlands. He identifies the following stakeholders: the Ministry of Economics and Climate, the parliament, the administration, consumers, energy companies, heat companies, housing corporations, municipalities, sub companies, contractors, consultants and lobbyists (e.g. Enecron, HIER opgewekt). '

14Go (2018) notes the importance of municipalities as they have been assigned to reach the climate goals on a local level. The question he states is whether the municipalities are equipped well enough to administer these local challenges. Other important stakeholder he identifies are the current public network operators (possibly for network), private companies (for heat generation).

4.2.1.2. List of stakeholders

These interviews resulted in the following list of stakeholders (Table 4-2). The description of the organization is provided on the right side of the table. Categorizing has been conducted by the researcher but validated within the multi-actor discussion. The findings of this discussion are posed in 4.2.2.2.

STAKEHOLDER	*DESCRIPTION*
Governments	
Ministry of Economy, Infrastructure and Environment	Ministry in charge of all policy related areas for the heat transition.
Tweede Kamer (Parliament)	National legislative institute
Municipality of Utrecht	Local government on the city level
Utrecht council	Local legislative institute
Authority for consumers and market (ACM)	Independent controlling agency for consumers and companies.
Netherlands Enterprise Agency (NEA)/Rijksdienst voor Ondernemend Nederland (RVO)	Institute led by the Ministry of EIE, to execute policies touching on private companies
Knowledge partners	
Energiecooperatie-U	Local Utrecht non-profit organisation (cooperative) advising residents on renewable energy technologies and reduction in energy use.
Consultants	Consulting companies advising on the 'rational best alternative'. These include 'lobbyists' influencing the government and the parliament on behalf of interest groups like HIER (on climate).
Universities	Research institutes researching on technology of district heating, social acceptation etc.
District Heating	
Eneco	Energy company currently possessing the DH-grid (owned by Dutch municipalities, but not by Utrecht). Eneco defines itself as a private company, because municipal owners act as private owners working with financial return-on-investments in the case of Eneco (e.g. in the case of HVC, they work with 'social return on investment' (8Pu, 2018))
Competing DH-companies (present + newcomers)	Companies who are in charge of DH-activities like heat generation, network management and delivery companies.
Natural gas	
Stedin	Gas- and electricity network owner (public company)
National Oil Company (NAM)	Is responsible for unlocking two of the Netherlands' most important resources: gas and oil. NAM supplies 75% of the natural gas required by Dutch households and businesses. 93% of all Dutch households use natural gas. Natural gas accounts for 45% of all the energy that is used in the Netherlands (NAM, 2018).
Gasunie (and Gasterra)	Gasunie owns the national transport NG-grid (Gasterra trades the gas, exploited by the NAM)
NG-suppliers	Energy companies like Eneco, Essent, and Nuon. They currently sell natural gas on the consumer market.
House owners	
Housing corporations	Non-profit institutes assigned by the government to build (social) rental houses. No to be confused with 'cooperative'. Housing corporations have a social purpose but are not owned by the customers.
Private house owners[25]	Citizen privately owning a house. It can be owned to (1) live in it, or (2) rent out.

[25] Besides being a house owner, private house owners also act as consumers for district heating

Institutional investors	Institutes-for-profit renting-out houses to consumers.
Consumers	
Corporate consumers	Private (profit-making) companies with an office/process heat demand
House owner unions (VVE's)[26]	Unions governing collectively needed investments, especially in apartment buildings.
Renters	People currently renting a house of (1) a housing corporation, or (2) a private house owner
Other	
The building sector	The building sector includes (1) construction companies: companies that built and renovate houses and possibly connects them to district heating. (2) Installers: companies fitting connections to grids and give them 'use' for in-house purposes
Opposition groups	Stadsverarming (e.g.), opposing every new monopoly type of organisation
Financial Institutes	Finance institutes (banks), supplying loans/financial advice

Table 4-2 Identification of stakeholders

4.2.2. Identify relations

For the identification of relations Enserink et al. (2010) proposed a five-step approach to define the 'interest' of a stakeholder. These include the: (1) objectives the stakeholders have in the problem, (2) the gap there is from the problem, (3) the causes of this gap and the (4) solution to overcome the gap. For simplification, the interest has been directly asked to the interviewees, as presented in Appendix C (Appendix: Overview of stakeholder). This is because of time-constraints within the conducted interviews. The level of detail of the relations is therefore limited. To validate the exploration, a multi-actor discussion had been conducted with the major stakeholders involved in the heat transition: the partners in the 'heat transition table'.

4.2.2.1. Formal chart

The formal chart can be found in Appendix D (Appendix: Formal chart). The chart is composed from the perspective of the sectors (dotted 'containers' in the chart). These sectors are currently 'represented' by some of the most direct stakeholders in the heat transitions. These are the partners in the heat transition table of Utrecht (grew boxes). The analysis used for composing the relations is listed below:

- *Consultants*
  - Policy consultants like Berenschot, PwC, CE Delft etc. advise on the policy process on the heat transition.
  - Energy cooperation Utrecht is a local non-profit energy consultant, it influences the policies of the municipality and the Utrecht council to make energy more local and cooperative. It advises house owners on energy issues and acquires funding through this. Their motto: Utrecht citizens who drive, organise and guard sustainable energy in homes
- *Natural gas stakeholders*
  - The NAM and the partners on the supply side of NG, formally lobby on the government to see natural gas as clean natural resource.
  - Stedin is actively involved in the alternatives for natural gas. It is important for Stedin to keep the socialised principle in the heat- and energy provision. This means that the direct

[26] VVE's act as a representative body for private house owners; they are further assessed as being the same as private house owners.

costs of an energy connection should be equally distributed among citizens: making it more affordable for citizens outside of cities. When cost-effective areas like cities are transformed to district heating, only the expensive connections for natural gas in the countryside remain. This endangers the socialisation principle.

- *Government*
    - The parliament is the most important political stakeholder of the heat transition; it assigned the Utrecht council with the task to meet climate goals on the local level. The parliament also influences the ministry through legislation like the 'heat law'.
    - The ministry of EZK (economic affairs & climate) is assigned the most important ministry assigned with the heat transition by the parliament. This is based in the political compromise among governing parties ('Regeerakkoord'). It receives diminished economic benefits from vending of Dutch natural gas to Dutch households. It assigned tasks to the Netherlands Enterprise Agency (NEA) for economic stimulation of companies, including the execution of the SDE+ subsidies for green heat provision projects.
    - The ACM is the independent controlling agency for the heat law. It is controlling the current consumer protection measure ('not more than else', NMDA): it sets the maximum-price for heat per GJ, based on natural gas prices. Furthermore, the minister can request the ACM to interpret and assert in specific ways
    - The council is involved in the political decision and targets to be met. Both the local council and the Ministry of EZK give the municipality the task to come up with a strategy to meet climate goals. The governmental bodies are lobbied on by the NG- and DH-stakeholders. The building sector (e.g. NVB Bouw) also influence the policy process by signing accords on new neighbourhoods to be built without NG, but also in the existing neighbourhoods for renovation. They also actively lobby on the house owners because they have the ownership of the dwellings and therefore have the 'final' contract assigning power.
- *House owners*
    - There are three types of house owners relevant for the consumer market: private house owners, investors who rent their properties and housing corporations. They use the advice from the energy cooperative Utrecht and other consultants to 'green' their properties. Eneco and Stedin are the network companies involved in the alternatives, Eneco – as the established body on DH in Utrecht – and Stedin – as the electricity and NG-grid owners – for 'all electric' solutions. They formally exchange knowledge and/or are assigned with the development of the grid-parts of the heat provision solution.
    - If – which is the reason for the dotted line – there are renters, they are protected by laws: house owners cannot raise their rents limitless. There are specific restrictions on this and renters have the right to consent with rent-raising when needed for building measures to make it the dwellings more sustainable
- *Consumers*
    - There are two type of consumers for DH: corporate and private consumers. Private consumers are reflected in the combination of house ownership and district heating or renting while having district heating. Corporate consumers can help to make a business case on a neighbourhood level feasible, because of the volume of their heat demand, but there is no formal relation.
- *District Heating*
    - The district heating sector is monitored by the ACM through the heat law. It acquires projects through the house owners; moreover, the DH-sector is getting permissions of

the municipality to use the underground for their piping systems. For the (green) heat production, they are partially funded by subsidies from NEA. Other funds come from financial institutes like investors/banks etc.

- There is a DH-opposition group in Utrecht opposing the private monopoly of the DH-system in Utrecht. It has no formal relations but influences the public opinion on DH.

4.2.2.2. Validation: multi-actor discussion

The multi-actor discussion has taken place with the most important organisation in the 'heat transition table' of Utrecht. This table is composed of representatives of stakeholders in the local Utrecht heat transition, including the current DH-company, housing corporation(s), grid operator, local cooperative. The preliminary formal chart, based on desk research, is presented to them during a 45-minute meeting. They were asked to focus on the relations of themselves, resulting in adjustments on the final formal chart regarding:

- Adding the municipal council and institutional investors; add relation between Eneco and the housing corporation.
- Change relations between Eneco and the municipality; relations based on knowledge exchange work in opposite directions
- Revise some of the relations that are on very different levels, like excluding the financial flow from the NAM to the government.
- Central problem has been added as the 'relations in the local heat transition'.

4.3. Social elements

The social elements are defined by the institutional context. The model Williamson (1998) uses to describe the 'economics of institutions', provides a method to define the institutional context in the heat transition. The 'four-layer model' distinct various 'levels of institutions', ranging from (1) institutions that are embedded in society (norms etc.), (2) property rights, (3) alienation of governance structures with transaction to (4) momentary agreements. The basic and theoretical model is visualised in Figure 11. These four 'levels of institutions' are used to describe the institutions influencing the heat transition. The question to be answered in the following paragraphs equals 'what institutions influence the influence the heat transition?'

4.3.1. Embeddedness

The first layer includes informal institutions, customs, traditions, norms and religion. The government finds itself responsible for the availability of heat for its citizens (Kamp, 2017). Due to the availability of natural gas from Groningen, it was the norm to almost everyone in the Netherland (93% of households (NAM, 2018)). It was regulated in the natural gas law(EZK, 2000). The effects of these norms on the development of district heating is that the housing stock has been designed with radiators which need water of 70-90°C to meet of an average 21°C room temperature (Milieucentraal, 2018a). If alternative heat provision is within these boundaries, changes to the housing stock are limited[27]. These building standards represent the norms and traditions on heat provision in society.

[27] Alternatively, 'low temperature heat provision' demands for more severe changes to the housing stock, like the increase of radiator capacity or floor heating. Furthermore, increased insulation is key (Milieucentraal, 2018a).

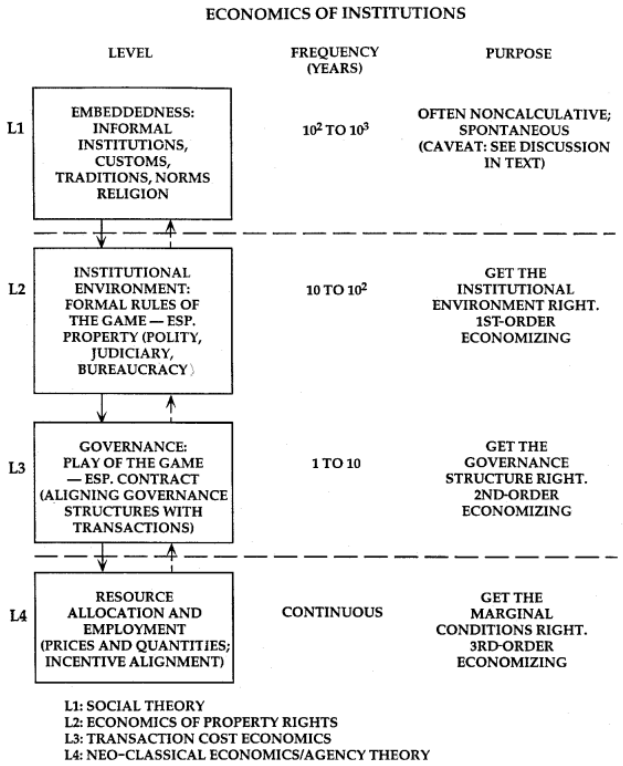

Figure 11 Economics of institutions, derived from (Williamson, 1998)

Also, the governmental aims to reduce climate change reflects the public preferences on sustainability. This is reflected in the Energieakkoord (energy agreement) the Dutch government made with over 40 parties (from the industry, consumers, employers, NGO's) to invest in sustainable growth. The effects of these aims are that new district heating network are not only an 'optimised alternative' to direct natural gas supply, but also an opportunity to reduce the impact on climate. As an informal institution, alternative technologies for carbon intensive services focus on being climate neutral or reduce the climate impact (Kamp, 2015).

Another tradition influencing the heat transition is the 'market tradition'. The Netherlands is a country with liberalised principles (Rutte, 2017), having people accustomed to competing market parties. This competition gives customers market power, namely to have freedom of supplier. This tradition influences how customers will evaluate new formal rules and property rights, which is potentially different from competition and freedom. Thus far, there is no evidence of 'efficient' competition regarding heat networks, mostly because of the lack of scale (R. Haffner et al., 2016).

4.3.2. Institutional environment

The institutional environment includes the 'formal rules of the game'. This is defined to include *"international treaties, national law and constitutions, defining the fiscal structures, elements of market design, the position of the regulator vis à vis the administration and the Court, etc. (Correljé & Groenewegen)"* Special attention is given to property, in the polity, judiciary and bureaucratic sense.

The heat transition in the context of Utrecht is divided into two different institutional environments: the natural gas environment and existing district heating environment[28]. The property rights of the

[28] As where this is the standard in the Netherlands, Utrecht has the alternative intuitional environment of people who are in the existing DH-scheme (+/- 30% of households). These property rights have not been defined by regulations: only customers are protected with the NMDA-principle. Since these property rights are not defined

natural gas market are defined by a regulated market design. Private competition is achieved on a public network (EZK, 2000). By these regulations people can change their gas supplier, based on their preferences (price/quality). People have the notion suppliers compete on price.

Because the infrastructure needs to be replaced, there is an opportunity to change the institutional environment. The property rights and formal rules of the game for the new heat provision by heat networks have not been defined by law or are currently in the revision process. Especially the property rights are the main research gap explored by in this thesis.

4.3.3. Governance

The institutional environment is defined using the following quote: *"These formal laws are operationalised in actual arrangements, often in the form of contracts, rules of conduct, permits and agreements, guidelines, net-codes, rulings, tariffs, etc. These, generally, are more flexible and malleable than the Level 2 institutions. Much of the actual regulatory activities will take place at this level, but also firms trading practices, contracting, price setting, joint ventures and so forth belong to this realm. Fascinating elements at this level, moreover, are those institutions – or mores - that carry the public and private evaluation of risk, profit, price, quality, performance, etc. Typically, these attitudes and preferences are phenomena which may derive from the 'deep' values at Level 1, being partly fixed in laws and procedures at Level 2, getting a real value and meaning at Level 3 (Correljé & Groenewegen, 2006)"*

The governance will be largely changed by changing the heating technology. The current governance of natural gas has influence on the way the governance of heat is evaluated. Most research on market creation for district heating analogises the gas and electricity market regulations towards the district heating market (R. Haffner et al., 2016; Rooijers et al., 2015). The rules and regulations are influenced by the (1) gas law, (2) heat law, (3) energy tax, (4) CO_2 emission trading scheme (ETS), (5) subsidies (Ende, 2014). The effects of these laws on the development of new district heating systems are plentiful. The gas law (e.g.) was until recently affecting DH-development because gas networks were obligatory for new neighbourhoods (Wiebes, 2018). The energy tax on natural gas was raised recently to enable alternatives for gas to be more competitive with direct natural gas supply (Rutte, 2017). ETS influences the costs of pollution by natural gas.

4.3.4. Resource allocation

Eventually all levels determine the actual interaction level of customers and producers: *"At Level 4, the higher-level determinants drive the actual interaction of actors with their specific objectives and inspire concrete strategies and approaches. This gives rise to market strategies, investments (also in lobbying), to cooperation and conflict and to consumer and producer transactions; buying and selling (Correljé & Groenewegen, 2006)"*

People can change their gas supplier every year. Current consumer strategies vary in terms of the type of product they buy (what type of natural gas) and the price they pay for that. In the Netherlands five parts can be distinguished: (1) the price of natural gas itself, (2) the energy tax, (3) the VAT, (4) the contribution to the network management, (5) the contribution to the metering (Ende, 2014).

Of the total price of €0,63 per m^3 (prices 2018), 25 cents are for the actual product, 27 cents are the energy tax and 11 cents are the VAT. The average fixed costs (network and meter) are 185 euro per year. These prices can vary among the energy suppliers active on the Dutch market (Milieucentraal, 2018b). These elements in the price of the current strategy depends the relative attractiveness of one

by law, market forces have developed the integrated company Eneco currently possesses: all infrastructure to service customers with heat is owned by them.

heat provision alternative or the other. People will allocate most rationally to the 'cheapest alternative'.

How district heating will 'compete' to other new heat provisions methods (like heat pumps), depends on local circumstances and local future 'business cases'. Where district heating will be developed, price setting will be subordinate to the heat law. Price equivalence to 1 m^3 natural gas is restricted to 31,7 MJ of heat (0,0317GJ) (R. Haffner, Til, & Schellekens, 2017).

4.4. Conclusion

The sub question in this part of the thesis is: what are the actors, institutions and technology when the sociotechnical system of heat provision changes from natural gas to district heating in Utrecht? The value of this question is twofold. First, the analysis provides us with a contextual framework. For example, it is important to understand the daily influence of district heating in the lives of residents, understanding how people evaluate the influence of energy justice. Second, different elements can help us to design some of the other part of the thesis. The infrastructure modification helps us to define the design space for district heating, for example. The following list of explorative findings justifies the sub-question. Every element can be used in other parts of the thesis:

- **Technical**
  The change of infrastructure to (high temperature) district heating has little effects within households. Contradictory, the development of the infrastructure – especially the network – will ask for significant efforts, also in terms of perceived nuisance for customers. In addition, it is technically needed to have a local source of heat: heat can hardly – if not – be transported of longer distances.
- **Actor**
  There are many actors involved with very different stakes. Some stakeholders have more relations than others. This makes the actor environment of the heat transition complex.
- **Social**
  The institutional context is under transition at the moment. Not only lower order institutions change, the driver of the lower level institutional transitions is currently redefined due to value of *sustainability*. The third and fourth order institutions will be affected: new contracts among parties will set and the customer strategies will change.

FOLLOW-UP

As proposed in the research flowchart, the element of the technical analysis is used for the development of the design space. The actor element is key to understand the influence of ownership changes on current stakeholders. The social context aims to define the survey set-up and adds to the interpretation of it.

5. Structure design space

Herder and Stikkelman (2004) define design space as a list of 'all the alternatives', without assessing them normative. It means in this part, no quantitative or qualitative assessment on what would be 'best' are presented. The product of this chapter is to develop a framework or method to structure discussions on the alternatives for ownership of district heating. Typically, this is used as one the research elements of designing (Herder & Stikkelman, 2004). In this research we aim to define the design space both for the creation of a discussion tool for decision makers, and for the designing and discussing the public preferences survey. In addition to defining design variables, a 'table of possible effects' is composed by combining literature and interview finding (Correljé & De Vries, 2008). The main question to researched in this part of the thesis is: what is the design space for ownership structures for district heating?

5.1. Previous research

The technical elements in the sociotechnical analysis provide us with a preliminary overview of 'what is there to be owned'. This includes the heat generation, the network and the heat exchanger in the house. A distinction between large scale (including a transport and distribution network) and small scale (distribution-only) is identified.

In addition to the technical elements, one of the most complete – internationally empirically backed – is the 'ownership guide' of Zeman and Werner (2004). It has been written during the development of more liberal policies in Europe, where municipally developed and owned district heating systems were privatised, outsourced or set under concession. The current (especially Dutch) urge for the extension or development of new networks is clearly not in sight at the time of writing (Zeman & Werner, 2004). They do not conclude their report with design options, but with empirical ownership data of case studies in Europe. Despite the world has changed in terms of climate policies since publication, the overview of ownership types is rather extensive and accurate.

Zeman and Werner (2004) conclude their ownership guide with the following ownership types in Europe at that time. This is used as the basis of the ownership types which could be used to design an ownership structure.

- *Full public control by the state or the municipality*
  Most district heating networks in Europe were historically developed by municipalities (Zeman & Werner, 2004). Zeman and Werner (2004) do not have clear assessment on the reason to stay a public company, rather than its potential environmental and customer benefits which seem to be more readily achieved when there is a strong involvement of public bodies.
- *Full private control*
  The major advantage of privatization of formerly public assets is the transfer of risk. According to Zeman and Werner (2004) 'the private sector is in the best situation to handle risk. In general, the private sector is better placed to deliver capital-intensive projects'.
- *Mixed ownership and management – public and private*
  Best of both worlds: 'The private sector being best placed to raise capital and deal with risk, while the public sector is best placed to deal with local issues involving a number of different municipal departments' (Zeman & Werner, 2004). So, municipalities with their local know-how have value in ownership structures (S. Hall, Foxon, & Bolton, 2016).Also, collaborations with cooperatives (see community-owned one bullet further) have already sprouted in the energy sector, creating added value in the two organisations (Eneco, 2018a, 2018b).

- *Not-for-profit community-owned cooperatives*
  Defined, but not assessed by Zeman and Werner (2004). Others define the cooperative as a different 'democratic organization mode' (Mori, 2014). Defined as 'an autonomous association of persons united voluntarily to meet their common economic, social, and cultural needs and aspirations through a jointly-owned and democratically-controlled enterprise' (COOP, 2018). Cooperatives have a long history in banking and agriculture (e.g.), and have recently been risen in the Renewable Energy sector because they offer consumers to meet demands that go beyond the lowest price available (Devine-Wright, 2005; Yildiz et al., 2015).

Other authors more or less come up with the same distinction. The first author, Magnusson (2016) from Sweden, concludes that a 'vertical segregation of distribution, production and trade should be introduced'. The second author, McGrath (2006), identifies four forms of public ownership structures for district heating:

- *Municipal ownership structure*
  Where there is governmental financial involvement.
- *Community energy trust*
  Which is the same as municipal but with a reinvestment of the profits through a trust
- *Cooperative ownership structure*
  Financed from both public and private sources, where a percentage will be reinvested through a fund
- *Community corporation*
  Private ownership strategies but local residents are stock owners

Since this is an American review some findings are less relevant in the European context. Also, the differences between some of the ownership structures are fiscal oriented. The implicit core of all research encounters governmental, communal, private and mixed ownership types. The third group of authors, Schreuer and Weismeier-Sammer (2010), distinct several dimensions on which ownership renewable energies is measured. Especially the latter three might be relevant for heat cooperatives, others are quite specific for electricity:

- *The individual vs. collective dimension:*
  The first is hardly possible for the near foreseeable future in district heating. Heat generation has significant benefits from economies of scale (Hoogervorst, 2017). Furthermore, the heat grid – as part of the district heating system – is collective in essence.
- *The locally concentrated vs. geographically dispersed collective dimension (or: community of locality vs. community of interest):*
  This is per definition community of locality, since heat cannot be transported the way electricity can be transported over larger distances.
- *The energy produced for feed-in vs. local consumption dimension:*
  For heat networks it is always local consumption.
- *Control over project lead vs. participation (project or company shares)*
- *Full ownership vs. co-ownership with professional investor*
- *Legal ownership vs. sense of ownership (may be additional to or instead of to legal ownership)*

5.2. Ownership of assets

The theoretical findings give us insight in some of the opportunities present. The only split in the physical change which has been identified by Zeman and Werner (2004) is the decoupling of the heat generation from the heat distribution. Other authors have only looked at community ownership of the whole chain, mostly from the renewable energy perspective. In the Netherlands, comparatively

assessing the different ownership types, the split Zeman and Werner (2004) identify is inaccurate when seeking for 'all options'. For example: the largest network in the Netherland in the Rotterdam region (15Go, 2018; R. Haffner et al., 2016) includes ownership distribution as following:

- Generation is done by a privately-owned waste incinerator (AEB). More private waste heat will be fed in the transport pipes soon (e.g. Shell)
- Only transport pipes[29] are partly owned by a municipal owned 'heat company' (Warmtebedrijf Rotterdam).
- *Distribution* and *delivery* are under concession with private companies (Eneco, Nuon), new ownership structures are sought for neighbourhoods outside the concession areas

Then two more options can be derived from literature. The first is the *delivery-only* activities. This has no example in the Netherlands, but analogised from the electricity sector, this potentially is another 'asset' to be owned (Magnusson, 2016; Schreuer & Weismeier-Sammer, 2010). The physical 'asset' could include the heat exchanger but is defined by the administration of the supply chain. The societal and scientific discussion on 'open heat networks' and third-party-access are in line of this split (Dervis & Nierop, 2015; Hoogervorst, 2017; Ouden et al., 2015; Rooijers et al., 2015).

The second is the ownership of the heat exchange stations. These can be assigned to the tasks of *system operations*: levelling the in- and outflows (11Pr, 2018). This is an analogy with the system operation in the energy market as well, where TenneT is assigned with this task.

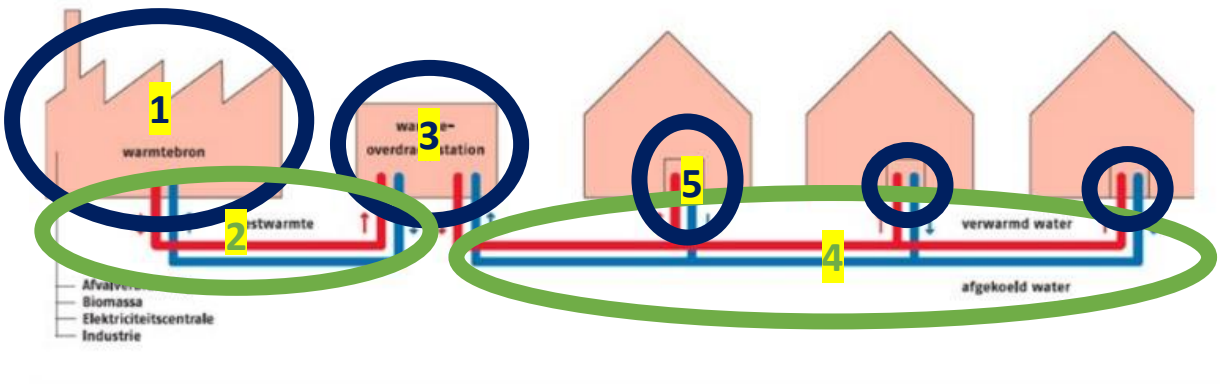

Figure 12 Physical chain of district heating

Thus, within the value chain the following five options can be distinguished in Figure 12:

1. Ownership of the heat source
   Sell the heat to the transport network (2), or when of smaller scale, directly to the distributor (4).
2. **Ownership transport network*
   Transport network owner buys heat from heat source and sells to the owner of the distribution grid(s).
3. **Ownership of the heat exchange*
   This entails the levelling of the system. The heat exchanger has most naturally the responsibility of the system operator[30].

[29] The definition of transport pipes (vs. distribution) is still arbitrary. According to 14Go (2018) *local function* of pipes define what is transport and what is distribution. For regulation by law very clear and general definitions would be needed which is impossible due to local differences.
[30] System operation in small scale networks could be done by the heat source or distributor directly.

4. *Ownership distribution network*
   Network owner buys heat from third party (transport network or, when smaller network direct from the generator). They are responsible for metering at the households.
5. *Ownership of the delivery (load) activities*
   Consumers buy heat from the delivery company. Delivery company is responsible for the administrative process only – when no other assets are owned – but is included in this analysis because of the 'owning of customers', in the sense they have a role in perceived justice.

5.2.1. Identification of variables

A literature review determines three basic categories: public, private and cooperative. These three options can be combined, split among the physical parts of the chain. Transportation and exchange are excluded, when network size is limited. Colouring this in the variables indicates this.

Design concepts for asset ownership (X-axis=Ownership Options, Y-axis=Design concepts, Red=large scale network only)				
1	*Generation*	Public	Private	Cooperative
2	*Transportation*	Public	Private	Cooperative
3	*Exchanger*	Public	Private	Cooperative
3	*Distribution*	Public	Private	Cooperative
4	*Delivery*	Public	Private	Cooperative

Table 5-1 Design variables physical chain

5.3. Combination of ownership

Within the community and mixed types Zeman and Werner (2004) find the following contractual agreements/joint ventures in their international assessment of ownership structures in Europe. For contract type they identify: operations and management contract, leasing, concession, full private ownership with municipal support. For stock division they identify: selected private minority equity partnership, minority private equity invited through the stock market, majority private equity ownership

The contract type category has been identified by the researcher among the options Zeman and Werner (2004) identified. This design concept is important because depending on the contract type among partners ownership is being transferred in a more thorough way than in other contract types. The stock division variable will not assess the selected or stock market variables. We assume there are all kinds of creative ways of private ownership, like crowdfunding, invitation through stock market, selected companies etc. In terms of ownership the only aspect that matters is the minority or majority vote in shareholder meetings.

Another option is to come up with a joint venture. Exemplary is the case of the Westpoortwarmte in Amsterdam where the heat generator and the energy company together form a public private partnership (10Pr, 2018). These collaborative vehicles are possible among all types of ownership: public, private and cooperative (Hoog et al., 2013; Klijn & van Twist, 2007). Within these partnerships stocks can be divided in different ways. A specific party or a specific type of party could be the majority (or at least in terms of voting rights – 'golden vote' or 'preferred shares' (Ligtvoet, 2012)) of shareholders. It is also possible there is a clear equal part per type of stakeholder. Last possibility is of course when there is no collaboration or joint venture, there is no majority, but that is because there is no partnership at all.

5.3.1. Identification of variables

Based on the above stated information from literature and interviews, the design concepts and ownership options are composed (Table 5-2).

Design concepts to combine ownership											
6	*Joint-ventures*	Public private partnership (PPS)			Private cooperative partnership (PrCS)			Public cooperative partnership (PuCS)			No partnership
7	*Stock division*	Public majority		Private majority		Cooperative majority			No majority		No partnership
8	*Preferred shares*	Yes						No			
9	*Level of integration*	No integration	Two parts of value chain		Three parts of value chain			Four parts of value chain			All parts
10	*Contract type*	Concession (ESCO)		Lease		Management			Risk or financial support		No contractual agreement

Table 5-2 Variables to combine ownership

5.4. Variable effects

System effects of the design concepts and ownership types are assessed by means of the semi-structured interviews with experts. An overview is normally used to present the 'consequences' or effects of the variable on the structure design (Correljé & De Vries, 2008). The reason to present them as effects is that it is value-free (Correljé & De Vries, 2008). The general effects of the variables (e.g. generation) on the structure are given below. A brief overview of the effects of the ownership types on the design concepts is given in Appendix E (Appendix: Effects of design concepts).

1. *Generation*
   Could be owned separately, products could be sold to the owners of other parts of the value chain.
2. *Transport*
   Only needed when large quantities of heat need to be transported over 'larger' distances. Probable when there is (planned to develop) an extensive network. Effects of owning this part of the network is the ability and responsibility to control the offered heat to the distribution part of the chain.
3. *Exchanger*
   Having heat exchanging facilities in large scale networks, gives the responsibility and level the transported heat with the distributed heat. It is the physical location of system operation.
4. *Distribution*
   Distributes the heat from the heat source or the transport pipes to the households to offer it to the heat delivery sets in houses. Effects owning this part of the network is the ability and responsibility to control the offered heat to the distribution part of the chain.
5. *Deliver*
   Effects of owning this part of the network is the responsibility to deliver the heat to its customers. They are responsible for contracts and arrangements with other parts of the value chain to fulfil their customers' demands in terms of quantity and quality of supplied heat
6. *Joint-ventures*
   As an effect of a joint venture arrangements need to be made upfront on the rights and duties the partners have.

7. *Stock division*
   A majority of shares gives the entity most influence and the final vote in shareholder meetings.
8. *Preferred shares*
   Preferred shares give an entity an agreed (higher) influence in shareholder meetings which does not correspond with their financial participation in the vehicle. For example, it happens often with privatised public utilities that municipalities have 1% of the shares, but 51% of the influence (Ligtvoet, 2012)
9. *Level of integration*
   As an effect of a joint venture arrangements need to be made upfront on the rights and duties the partners have.
10. *Contract type*
    The type of contract determines the relationship among partners in when partnerships occur.

5.5. Validation

The overview Zeman and Werner (2004) produced in their district heating ownership guide, was based on international empirical data. It means that he only looked at the existing ownership structures (at that time) but did not review what all theoretical opportunities would be. Despite this way of reviewing (Zeman & Werner, 2004) has been particular useful in defining the framework. Whether his options, and more, are theoretically possible in the Netherlands was to be validated due to interviews with experience experts. The following information was particular useful in the validation of these variables.

5.5.1. Validating interviews

Apart from the exploratory interviews to develop the design space and assess the ownership types in this design space, we conducted interviews with three experts to confirm the design space. These interview set-ups were separately designed, including a specific question on the physical and the combinations of ownership. These interviews were finalised with the visualization of the preliminary design space, discussing the confirmation of the product. The three interviewees were selected on diversity of ownership type, including a private, public and cooperative organisation (5Co, 2018; 11Pr, 2018; 14Go, 2018)

5.5.1.1. Cooperative

5Co (2018) discussed the options they had been assessing for ownership. At date, the cooperative was in the developing phase of a citizen initiative to be developed in Amsterdam. They were brought together by a public grid operator, who's goal it is to develop open heat networks (AllianderDGO, 2018). The cooperative assigned the grid operator to be their party of preference for the distribution part of the value chain. Furthermore, the cooperative was offered free waste heat from a (privately owned) data centre and an ice-skating track (also privately owned). They themselves were planning to do the delivery as a cooperative – but to outsource the administrative part to a private company. The grid was small, so local heat exchange would not be the case: there was no distinction between transport and distribution.

The challenge 5Co (2018) states, confirms the composed design concepts (and ownership types) of physical ownership for small scale network (transport and exchange are not used here). He also confirms the management outsourcing as an option for cooperative heat (contract type).

5.5.1.2. Private

11Pr (2018) of a private company specialised in district heating was asked to validate the design space. Her main viewpoint was: everything is possible, but at what cost? She mentions that splitting the value chain to create competition on the network would entail almost 35% more overhead costs (based on a Swedish case study). More important the private point of view in terms of costs and benefits was

helpful. All types of partnerships are possible with public and cooperatives, but what their reason would be to do so is questionable.

With the private vision of 11Pr (2018) we could discussed the physical ownership. She pointed out the importance of the system operator. Furthermore, she also confirms that all types of organisations based on the preferences of the stakeholders could start to exist: in terms of joint ventures, stock division, preferred shares, level of integration and contract type.

5.5.1.3. Public

14Go (2018) of the governmental organisation also was asked to validate the design space, just like 11Pr (2018) he mentions the importance of the system operator. Furthermore, he was assessing the importance of clear concessions and the level of integration.

The public stance of 14Go (2018) also confirms the physical ownership possibilities and the design variables to combine ownership.

5.5.2. Multi-actor discussion

The multi-actor discussion aimed to validate by-use in a workshop. There was a lively discussion at the time of arrival. Therefore, improvisation was needed. Instead of working separately, a joint-discussion method was conducted. The case of an existed neighbourhood using natural gas was presented, without any alternative infrastructure for natural gas nearby. Using the composed design space as a 'conversation starter' the following findings were done:

- According to Stedin it would be quicker to achieve sustainability quicker through public ownership.
- The participants agreed upon the fact that *everything* in the design space was possible.
- Since there are no facts (like: is there an active cooperative organisation in the neighbourhood? Is there a local waste heat source available?) available, it was impossible to assess what was needed and what was logical.
- So, when to use this tool? According to Energie-U there are basically two levels of decision. First is on the *city level*: what should we aim for? It is useful to guide the discussion on this. On the *neighbourhood level* (say 20-100 houses) it could be assessed again when district heating is 'chosen to be the best option'. It depends for example on the neighbourhood, if there is any 'cooperative force', which means a bottom-up approach for this is essential. As a municipality, you cannot force citizens to be community-owners of the district heating network.
- Notes on the relevance of this were also discusses by the actors: some say that other factors might be more important for the influence on *acceptance* than ownership (among others: municipality). These include: freedom of choice (as a society we are very used to market principles), sustainability (we make citizens find that interesting), price ("love comes through the stomach, acceptance through the wallet", mentioned quote of the Minister of Economic Affairs & Climate), service ("what do you get for your contribution/pay?"), and transparency.

5.6. Conclusion

The sub-question guiding this chapter was: what is the design space for ownership structures for district heating? With a literature and report review, we could compose a framework in which ownership choices are defined. The physical ownership variables are (1) generation, (2) transportation, (3) exchanger, (4) distribution, (5) delivery. The ownership variables for the combination of ownership are (5) joint ventures, (6) stock division, (7) preferred shares, (8) level of integration (9) contract type. For the physical ownership the ownership types are public, private and cooperative. For the combinations of ownership, one could find the design concepts in Table 5-3.

Validation of the design space has been done by expert discussion and a multi-actor discussion, proposing the literature-based design space. Discussion emphasised the importance of the system-operator as a responsibility in the network. Likewise, the importance of other aspects *for acceptation* are acknowledged, but allowing for the discussion on energy justice in general. In addition, it is found that the design space functions as a conversation starter on two levels: the city level and the community level.

Design concepts for asset ownership (X-axis=Ownership Options, Y-axis=Design concepts, Red=large scale network only)						
1	*Generation*	Public	Private	Cooperative		
2	*Transportation*	Public	Private	Cooperative		
3	*Exchanger*	Public	Private	Cooperative		
4	*Distribution*	Public	Private	Cooperative		
5	*Delivery*	Public	Private	Cooperative		
Design concepts to combine ownership						
6	*Joint ventures*	Public private partnership (PPS)	Private cooperative partnership (PrCS)	Public cooperative partnership (PuCS)	No partnership	
7	*Stock division*	Public majority	Private majority	Cooperative majority	No partnership	
8	*Preferred shares*	Yes	No			
9	*Level of integration*	No integration	Two parts of value chain	Three parts of value chain	Four parts of value chain	All parts
10	*Contract type*	Concession (ESCO)	Lease	Management	Municipal support	No contractual agreement

Table 5-3 Design space for ownership structures, created by researcher.

The product of this chapter is a model to be used when assessing the ownership possibilities when new district heating systems are developed, or existing systems are extended. The decision maker, which can be the municipality or – on a lower level – a citizen initiative, can use this framework to assess the options in terms of ownership. Also it gives insight when negotiating with parties.

FOLLOW-UP

As proposed in the research flowchart, the design space analysis is deepened with expert insight on the ownership types. What do experts think of different ownership structures? Reviewing the design space is part of the design space analysis. The overall design space functions to design the survey and gives insight in discussion of the results.

6. Review design space

Thus far we explored the sociotechnical system and the design space of ownership structures for district heating networks. We derived four different types of ownership: public, private, cooperative and several ways of mixing this ownership. We know what the effects on the system are, but we did not explore the effects of the different ownership types yet. In this chapter, we have explored these effects. General experts (consultants) and experience experts, experienced with the specific ownership type are interviewed on the *strengths (S)* and *weaknesses (W)*. These strengths and weaknesses have not been solely focussed on justice but have been aimed to explore as much as possible on the application of these ownership structures in the case of district heating. Their focus is internal. Furthermore, the aim in the interviews was to distinguish the *opportunities (O)* and *threats (T)* in the broader context of the heat transition in the Netherlands, because of the explorative purpose for this specific societal urgency. These focus on external aspects.

The chapter is set-up to with assessing the ownership types one-by-one. The ownership types are briefly introduced and contextualised by a literature review. The literature coping with these ownership types is assessing this in general, without explicit application to district heating. The ownership type is finalised with the arguments important for the perceived energy justice. These are marked with an asterisk.

The sub-question to be answered in this chapter is: what are the differences and similarities on strengths, weaknesses, opportunities and threats for ownership types of district heating at present in the Netherlands?

6.1. Cooperative ownership

The first assessed ownership type is the cooperative ownership. As already proposed in the design space, the definition of cooperative district heating is 'to share control over a joint asset, self-delivering heat to the members in control'. For simplification reasons, this does not mean that the legal form 'cooperative' must be chosen by definition. As long as some there is some sort of direct democratic control by the customers, it defines as 'cooperative' (ICA, 2018).

6.1.1. Literature review

The first source of literature for cooperative district heating is the literature on cooperative ownership of renewable energies. Especially in the literature on wind turbine placement, cooperative ownership structures point towards '*high levels of support*' for small-scale, community-based wind power' (McGrath, 2006; Schreuer & Weismeier-Sammer, 2010). Cooperative ownership has also been highlighted as an important aspect of *institutional capacity building* for wind power implementation (Schreuer & Weismeier-Sammer, 2010). This means that institutions can learn how to cope with the implementations of wind power, especially the 'Not In My Backyard (NIMBY)' effects. Other benefits of cooperative energy are found in *distributed generation,* making use of an *additional source of investment capital* – especially when contribution to environmentally friendly energy supply (Schreuer & Weismeier-Sammer, 2010). Also harnessing the *knowledge* of additional stakeholders, *political leverage effects* (local citizen support conducive to political support), operational advantages (locals reporting unusual events), *strengthening and diversifying local economies* – local use of profits, or not-for-profit (McGrath, 2006; Verschuur, 2010) – and enhancing the *democratic legitimacy*" (Schreuer & Weismeier-Sammer, 2010).

Weaknesses are also pinpointed in in Schreuer and Weismeier-Sammer (2010). These include: reduced *economies of scale*, *higher transaction costs* due to the large number of people involved and the limited possibility of making use of *risk mitigating* effects by distributing investment across several projects.

Furthermore it is identified that *legislation* is a very important threat or opportunity for the cooperatives. Schreuer and Weismeier-Sammer (2010) identify that in Denmark larger projects are typically owned by utility companies, while smaller projects typically are owned by cooperatives or farmers. According to some authors this link is a direct relation, but according to Schreuer and Weismeier-Sammer (2010) it has to do with the historical legislative restrictions in Denmark. Another opportunities identified by McGrath (2006) is the particular potential of cooperatives especially where large investors-owned utilities find it economically undesirable.

6.1.2. Experts review

Table 6-1 gives the overview of the cooperative SWOT. Table F-1 in Appendix F (Appendix: Extensive SWOT analyses) gives a more extensive summary on the expert judgments, including references, on cooperatives in a SWOT. When – assessed by the researcher – in accordance with the literature review, the beginning of the argument shows a hashtag. When of importance for the energy justice debate, the end of the argument shows an asterisk, just as in 6.1.1.

Most arguments are based on the cooperative specialists (3Co, 2018; 4Co, 2018; 5Co, 2018; 6Co, 2018). Some others include more general assessments on ownership structures (1Cn, 2018; 2Cn, 2018; 13Go, 2018; 14Go, 2018; 15Go, 2018).

STRENGHTS	**WEAKNESSES**
- #Minimizes 'walk-away' risk - Satisfies desire of influence* - #Satisfies perceived fairness* - #Democratic legitimacy* - #Voluntarism - #Local job creation - Price optimization incentive: direct gains - #Long-term satisfaction - Accessible*	- Need for voluntary common ground* - Vulnerable organisations - Exclusion possibility* - #Less economies of scale - Necessity of financial participation - #Inefficiency risk, because of participation - Risk of lack of expertise - Outsourcing risk
OPPORTUNITIES	**THREATS**
- Small scale developments - Neighbourhood cohesion - Network development - Starting point 'sustainable life' - Group pressure* - House value increase - Collective problem - Development of expertise centre - 'not-for-profit' weakens perceived negativities of monopoly* - Higher NG-prices - Pioneering	- Adaptive capacity - #Legislation - Status-quo, market tradition - Geographical community necessity - Inefficiency - Lack of neighbourhood cohesion - Competition with private/public - Municipal dependence - Tragedy of the commons* - Collective problem - Differences in willingness to pay/spend time*

Table 6-1 Cooperative Overview SWOT

6.2. Private ownership

The second ownership type under assessment is the private ownership. Just as the simplification of the cooperative ownership, private ownership is defined as 'a private company looking for profits'. This does not mean that these companies have no other company values (e.g. being sustainable or concerned to society) other than rent-seeking. It means that companies have no financial governmental back-up and are therefore more conscious on future business continuation.

6.2.1. Literature review

The literature review of the arguments for private ownership are largely derived from the privatisation literature. From the 1980s there has been significant policy reforms to overhaul existing energy markets to make them more efficient. According to D. Hall, Lobina, and Motte (2005) the strengths of private ownership were expected to '*inject investment and efficiency* into these sectors, replacing public-sector systems (in developing countries) suffering from under-investment and inefficiency due to excessive political interference'. In developing countries gains were also *expanded coverage*, *improved quality, competitive tariffs* (D. Hall et al., 2005)'.

Key disadvantage named by Sheshinski and López-Calva (2003) is the needs *for regulation* to solve the market failure – because of the possibility of exploiting market power by private owners. Public resistance during these privatization reforms also occurred, mostly with arguments stating it is '*fundamentally unfair*, both in conception and execution' (D. Hall et al., 2005). It is perceived to make 'prices higher than they would otherwise be and profits – and senior management pay – higher than justified' (D. Hall et al., 2005). Also, they are poorly 'subjected to local decision making', leaving them to 'global, commercial operators and market forces'(D. Hall et al., 2005)

6.2.2. Experts review

Table 6-2 gives the overview of the private SWOT. Table F-2 in Appendix F (Appendix: Extensive SWOT analyses) summarizes the expert judgments, including references, on private in a SWOT. When – assessed by the researcher – in accordance with the literature review, the beginning of the argument shows a hashtag. When of importance for the energy justice debate, the end of the argument shows an asterisk, just as in 6.1.1.

Most arguments are based on the private specialists (9Pr, 2018; 10Pr, 2018; 12Pr, 2018) Some arguments have been stated as 'opposition arguments', derived from cooperative and public interviewees (7Pu, 2018; 8Pu, 2018). Some others include more general assessments on ownership structures (2Cn, 2018; 15Go, 2018).

6.3. Public ownership

6.3.1. Literature review

Public ownership in infrastructure has long been common, it was a justified and social way to cope with the market failure that more than one infrastructure is impossible on efficiency grounds (Sheshinski & López-Calva, 2003). As already mentioned in 6.2 liberalisation and privatization has changed the public-owned infrastructure landscape. In the assessments of pros and cons on privatization, the old situation had been assessed as well. According to van Dijk (2008), one of the main advantage of public ownership is that *social goals* can be more easily fulfilled. To achieve social goals in private ownership, a lot of regulating and monitoring would be needed from the government. To achieve certain goals, profit maximization is seen as counterproductive (Westin & Lagergren, 2002). Furthermore, there is *no conflict between owners and supervisors,* while this is unavoidable in natural monopolies private owners want monopoly prices, while public supervision wants social wealth maximization

STRENGHTS	WEAKNESSES
- #Executive and financial power - #Financial optimization incentive - Integral risk distribution - #High quality - #Healthy financial analysis - Profits not only driver*	- #Need for regulation - Possible bankruptcy - Relatively high financial pay-back needs - #Public attitude on private monopolies* - No local jobs
OPPORTUNITIES	**THREATS**
- Ownership has little influence on imago* - Higher NG-prices - Liberal municipalities - No national strategic interest - All hands-on deck in heat transition - Economies of scale - Housing corporations	- Competitive disadvantage - New approach for existing neighbourhoods - Dependence on business case game changers

Table 6-2 Private Overview SWOT

Key disadvantage named by Sheshinski and López-Calva (2003) is that 'monitoring is poorer in publicly owned firms – and therefore the incentives for efficiency – are low powered'. Disadvantages van Dijk (2008) names are the *lack of pressure from the capital market:* public companies are less naturally controlled on their financial performance than private companies. A second disadvantage is the so-called *soft budget constraint*: there is less budget discipline than in private companies, because the company 'can't go bankrupt'. The political interference also potentially affects the 'purpose and goals' of the company for political reasons: therefore there is less long term 'investment incentive' within the public company's purpose (McGrath, 2006; Sheshinski & López-Calva, 2003; van Dijk, 2008). This political interference also gives a risk of corruption (McGrath, 2006)

One of the opportunities McGrath (2006) distinguishes is the potential for local economic development.

6.3.2. Experts review

Table 6-3 gives the overview of the public SWOT. Table F-3 in Appendix F. (Appendix: Extensive SWOT analyses) gives a more extensive summary on the expert judgments, including references, of the public ownership type in a SWOT. When – assessed by the researcher – in accordance with the literature review, the beginning of the argument shows a hashtag. When of importance for the energy justice debate, the end of the argument shows an asterisk, just as in 6.1.1.

Most arguments are based on the public specialists (7Pu, 2018; 8Pu, 2018). Some others include more general assessments on ownership structures (2Cn, 2018; 15Go, 2018).

STRENGHTS	WEAKNESSES
- Carry high and more volatile risks - #Regulatory simplicity - Public accountability* - Localness (municipal-ownership) - Professionality potential	- #Inefficiency/Bureaucracy - Public resource allocation - Political profit spending* - Incoherence
OPPORTUNITIES	**THREATS**
- #Social Return-on-Investment - Socialization* - Higher NG-prices - Public knowledge development - Faster transition potential	- Market tradition - Political interference* - Dependency (on waste heat partner)

Table 6-3 Public Overview SWOT

6.4. Mixed ownership

Mixed ownership is defined as a cooperation between different types of actors. Classic types of mixed ownership are public-private partnerships (e.g. for infrastructure development). But more types of partnerships can be formed, both vertically – managing a part of the value chain – or horizontally – joint ownership of the complete district heating system. It therefore includes argument opposing and in favour of splitting networks.

6.4.1. Literature review

The main topic in mixed ownership is the division of responsibilities and tasks: and how this is determined (e.g. by contracts). Regarding the strengths of mixed ownership Ligtvoet (2012) has found that when contracts are well set, the *best of both* types of organisations could be extracted in the partnership. This is also the case on the employee-level: mutual awareness among *employees* to make profit (commercial), combined with awareness on stability and security (public) (Ligtvoet, 2012). And the *regulatory level* as well: diversified partners give opportunities to use all strengths and regulatory benefits (Ligtvoet, 2012). Another benefit is that it is highly contingent, in practice there are many opportunities for all kinds of cases, making mixed ownership for in many situations an option (Ligtvoet, 2012).

The main weakness that a mixed form of ownership is in essence more *complicated* in terms of coordination than a single owner is (Ligtvoet, 2012). Poor stakeholder management could leave guidance on responsibility and accountability in the partnership (De Schepper et al., 2014)

Opportunities for partnerships with communities give the option to gain public support, but to minimize time efforts needed for cooperative ownership (Schreuer & Weismeier-Sammer, 2010). Another opportunity lies in the cultural traditions in the Netherlands for partnering: 'The Dutch culture allows for segmenting problems, thus one can be enemies on one issue whereas one could be friends on another issue' (Ligtvoet, 2012)

A threat to the complicated arrangements is (rapidly) *changing environment* (Ligtvoet, 2012). Tasks and responsibilities might seem logical at the time of arranging, but can be very different a view years

later: unforeseen benefits or disappointments are possibly equally distributed among the partners (Ligtvoet, 2012). One of the key aspects in the relation in these type of environments is therefore the trust between the partners: distrust could kill the partnership (Ligtvoet, 2012). In a way, it makes them mutually dependent (Ligtvoet, 2012). This is an even larger risk when one of the partners go bankrupt (Ligtvoet, 2012).

6.4.2. Experts review

Table 6-4 gives the overview of the mixed SWOT. Table F-4 in F. (Appendix: Extensive SWOT analyses) gives a more extensive summary on the expert judgments, including references, of the mixed ownership type in a SWOT. When – assessed by the researcher – in accordance with the literature review, the beginning of the argument shows a hashtag. When of importance for the energy justice debate, the end of the argument shows an asterisk, just as in 6.1.1.

Arguments are based on all specialist types, to get an overview of the consequences from different points of view (4Co, 2018; 9Pr, 2018; 11Pr, 2018; 13Go, 2018; 14Go, 2018; 15Go, 2018).

STRENGHTS	**WEAKNESSES**
- #Potential of win-win	- #Complexity - No business case benefits - Overhead costs
OPPORTUNITIES	**THREATS**
- Risk mitigation - Regulation - Imago improvement* - Level-playing field*	- #Changing environment - Unequal distribution of risk in the heat chain - Diversity of context

Table 6-4 Mixed Overview SWOT

6.5. Comparison

Assessing the different ownership types, it is almost impossible not to compare with other ownership types. During the interviews, often the arguments were comparative mentioning that 'this type of ownership is better than this, because of…'. So, the analysis above is not 'comparison free'. In this part we try to identify some of the patterns within the SWOTs. This means it will focus on similarities and differences.

Through the SWOT-analysis, it has been identified there are both differences and similarities among the ownership types. Some external factors are very important for the *overall feasibility of district heating*, like the increase of the natural gas price. If the natural gas price increases (e.g. by taxes) the feasibility of all ownership types for district heating increase, being a more financially interesting alternative for natural gas. When the financial difference between natural gas and district heating becomes larger, for more ownership types it becomes feasible to offer an alternative for natural gas.

Furthermore, one can identify that the *context* is of importance for the strengths and weaknesses of the different ownership types. How the context relates to the ownership structure depends on the influence it has on the ownership structure. For example, the market/liberal tradition in the Netherlands, nourished by the current political affiliation, make it more likely that regulations will be in favour of the private sector. This means the regulatory and political context is likely to affect the different ownership types.

More often than not context have *contrasted effects* on ownership structures. As where the market tradition in the Netherlands can be seen as an opportunity for private ownership it is a threat to public ownership. This is not only in the external assessment the case, but also in the internal assessment the different ownership types contrast in their aspects. For example, inefficiency/bureaucracy goes along with higher participation or political influence, as where efficiency occurs when there are less actors/factors to take into account. The financial focus in private ownership in essence excludes these types of 'overhead' costs and is therefore 'better' in achieving a good price/quality balance.

In addition to these general patterns, this study offers us knowledge on the differences of the ownership types. These findings can also be put in the perspective of theoretical knowledge on the ownership types in general. For the cooperative type it was found that most benefits according to the interviewees influenced the *perceived justice*. These were mostly found in a more natural way of influencing both the outcomes (distributive) and the process (procedural): cooperative ownership gives more *influence* on the customer than other ownership types, trust in the organization because of the possibility to influence policies. It is assumed by many experts that these aspects influence the overall organizational sustainability. Another aspect influencing this sustainability is the size and the *locality* of the organization, influencing the interpersonal relationships – which are more natural within cooperatives. These findings do not contrast findings from literature, as literature also identified public support and local beneficiation as important aspects of cooperative ownership compared to other types of ownership.

Regarding the private type of ownership, most arguments were *business-oriented*. This means that the interviewees found financial, efficiency and quality most important aspects for the development of district heating networks. They also emphasize that profits are needed to incentivize the acquisition of private money. Particularly in the current heat transition these kinds of money acquiring methods are beneficial for – urgent in the context of climate change – quick action. Compared to other types of ownership, financial motives were most prominent in the private ownership type. The private ownership literature also emphasizes the argument on business executive power. Injecting investment and efficiency are also most important in the case of district heating, but the costs of regulation need to be in justified with the benefits of the private ownership.

Assessing the public type for ownership, most benefits were pointing towards the *social principles* the government can fulfil. This socialization principle – all paying the 'equal' amount, instead of paying the costs per case – is clearly distinctive from the other ownership types. Also, it is possible to 'internalize' social benefits, as social effects for private ownership might be seen as 'external effects'. Also, for public bodies risk mitigation can – in theory – be done within the public budget. Whether this is fair or not can be discussed, but it gives opportunities for quick action in the heat transition. The literature on public ownership also emphasizes these aspects when considering privatization in the past.

Mixed ownership promises to give win-win situations for different partners. In that sense it is promising: when combining the right ownership aspects, in the right place and time, everyone could benefit. But due to the rapidly changing contexts and environment it is hard to arrange contracts (tasks and responsibilities). It distinct therefore by having large potential to combine different ownership

strengths, but it increases complexity and hardens flexibility of the organizations. Literature also distinct another important feature in favour of mixed ownership structures compared to other ownership structures: the consultation culture (the so-called 'poldermodel') in the Netherlands allows for trust and professionalism among partners.

6.6. Conclusion

By comparatively analysing differences among experts, we aimed to answers the question: what are the differences and similarities on strengths, weaknesses, opportunities and threats for ownership types of district heating at present in the Netherlands? The conclusion cannot be stated unambiguously. While different ownership structures distinct a lot, it does not mean that the different ownership types have no refuted answers on the weaknesses and/or threats. For example, private parties can have other incentives than profit. Cooperatives can try to achieve more efficiency by their governance structure and – overall – want to be financially healthy as well. It really depends on the context to achieve the most optimal outcome satisfying all stakeholders.

Within the explorative purpose of the analyses, the 'design space' had been structured and reviewed to identify some larger patterns or distinctions. Further research is needed to prove that patterns, like the contrasting effects and the exact outcome of ownership, are present when comparing particular ownership types in a specific context.

FOLLOW-UP

Regarding the overall ownership question, some clarification on the context has been provided to be able to assess different ownership structures on their justice principles. Despite the ambiguity especially cooperatives have great potential to increase the perceived energy justice by local residents. Thus far, it is unclear how the public values different ownership types and how they place them in the design space for ownership considered in the previous chapter.

The following chapter will explore the public preferences regarding these different ownership types and how people place them in the design space for ownership of district heating. The expert opinion will give insights thereafter on the motivations citizens might have choosing specific ownership types.

7. Public preferences

The last phase in this research is measuring the public preferences on ownership. In this chapter the findings from the design space and the conceptual framework are used to design the survey. We will reflect on the answers using the sociotechnical analysis and the ownership types reviews. The structure which is used for this chapter is:

- Survey design: what are the questions found to be important for the analysis of public preferences?
- Application of energy justice concepts: how is the conceptual framework reflected in the survey questions?
- Cleaning data: what is selected? What is taken out and why?
- Sample: how well does the sample fit the target group?
- System of analysis: how will the data by systemically assessed?
- Findings: what patterns or preliminary findings can be distinguished?

The chapter will conclude with the main question: What choices in ownership of district heating systems reflect the preferences of Utrecht residents?

7.1. Survey questions

The questions summed below are the questions asked to the respondents. The full questionnaire with the proposed answers can be found in Appendix E. (Appendix: Effects of design concepts). We elaborate on the connections with the conceptual framework in paragraph 7.2. Regarding the use of the design space in the survey: this is limited. Due to the lack of familiarity on the topic of participants, and specific effects by the precise context in which they live, most design concepts could not be evaluated directly by the public. Question 24-26 have been devoted to ask direct preferences on some aspects of the design space: it was found that the distinct between generation and distribution was most graspable for participants, and most valuable to derive conclusions upon for the researcher.

Regarding the question formulations: the type of questions is stated between brackets behind the topical questions with abbreviations (abbreviations in Table 2-3). The questions have been validated and checked not being double barrelled, negative, biased by social scientists experts at TU Delft (Babbie, 2010). In addition, the questionnaire has been pretested with three random respondents on the street, before self-administration was allowed.

1. Do you live in Utrecht?
2. What is your gender?
3. What is your age?
4. What is your family situation?
5. What is your education level?
6. What is your family income?
7. What type of house do you live currently?
8. What is the ownership of the house where you currently live?
9. What is the construction year of your house?
10. In what neighbourhood do you currently live in Utrecht?
11. Do you have a natural gas connection in your house? (SCQ)
12. What do you already know on the alternatives for natural gas? (LSQ)
13. When do you expect not to use gas anymore? (CIQ)
14. What do you think is how important in the alternative for heating your house with natural gas? (CLSQ)

15. Rank what do you think is how important in the alternative for heating your house with natural gas (CLSQ)
16. What organisation do you think is responsible for the alternative of your natural gas connection? (MRQ)
17. How trustworthy do you think these organisations are? (CLSQ)
18. How would you like to cover for connection costs? (SCQ)
19. How much influence would you like to have on the decision what alternative for your gas connection will be chosen? (SCQ)
20. Do you already buy energy from an energy cooperative? (SCQ)
21. How likely do you think a heat cooperative will rise in your neighbourhood? (LSQ)
22. How much time are you willing to spend per month on a heat cooperative? (CIQ)
23. How likely is it you would invest in a heat cooperative? (LSQ)
24. What do you think is a good organisation to own a heat network? (MRQ)
25. What do you think is a good organisation to own a heat source? (MRQ)
26. Do you find it desirable that both network and source are owned by the same type of organisation? (SCQ)

7.2. Application of energy justice concepts

Table 7-1 and Table 7-2 give the application of the concepts proposed in the conceptual framework on the survey questions. It specified how the question is influencing energy justice. Question 24 -26 are not related to energy justice, these are directly related to ownership.

Q.	What?	Justice aspect	Explanation
14/15	Aspect *influence* compared to others	Participation	The importance of influence compared to other aspects of the new heat provision system, represents the procedural justice because participation is one of the most important aspects in procedural justice.
14/15	Aspect *trust in supplier* compared to others	Trust	The importance of trust compared to other aspects of the new heat provision system, represents the lack of bias from the decision maker, compared to other aspects.
14/15	Aspect *clear bills* compared to others	Information	The importance of clear bills is representing the information disclosure in the perceived justice between consumer-producer.
17	Transition *trust*	Trust	The importance of the organization trusted with the transition represents the perceived lack of bias from this decision maker.
19	Type of influence	Participation, information	The importance of influence on the heat transition, represents the procedural justice because participation is one of the most important aspects in procedural justice. Disclosing information is one of the (minimal) participatory options.

Table 7-1 Application of procedural justice

Q.	Aspect	Justice aspect	Explanation
14/15	Aspect *self-supportive* compared to others	Cost-Benefit	The importance of self-supportiveness compared to other aspects of the new heat provision system, represents the distributive justice because being self-sustained eliminates the distributive injustice between producer and consumer.
14/15	Aspect *no adjustments* to house	Responsibility	The importance of no adjustments can be derived to the question how to distribute the responsibilities equally. The importance of the adjustments to the house are related to this.
16	Transition *responsibility*	Responsibility	The importance of the organization responsible for the transition represents the on how the equal or equitable distribution of responsibility is perceived by participants.
18	Connection fee	Cost-benefit	The importance of the connection fee represents the distributive justice, because it represents how people are willing to distribute the burden of the heat transition.
19	Aspect of 'ownership rights' in type of influence	Cost-Benefit	The importance of *ownership rights* on the heat transition, represents the distributive justice because being owner not only gives you the opportunity to participate, but also to share in financial distribution of the infrastructure project
22	Willingness to spend *time* on cooperative	Responsibility	The willingness to spend time, relates to distributive justice because it evaluates the distributive activity of neighbourhood actors in relation to others.
23	Willingness to spend *money* on cooperative	Responsibility	The willingness to spend money, relates to distributive justice because it evaluates the distributive financial participation of neighbourhood actors in relation to others. There is a potential notion of winners and losers when unequally distributed.

Table 7-2 Application of distributive justice

7.3. Cleaning data

7.3.1. Filter data

After distributing the survey in the way described in the method paragraph the total of received surveys was $N_{preliminary}$=236. To develop statistical conclusions this is not enough. With a margin of error of 5% and a margin of representability of 95%, a city of Utrecht – with more than 350.000 citizens – needs a minimum of 384 respondents (Healey, 2014). Due to time constraints, this has not been met in this research. Also, because this research as an explorative purpose, statistical validity was no aim. The following filters have been applied to meet the purposes of the research:

- *Completion*
  Progress of the survey was measured in the system of Qualtrics. Not all surveys were finished. A total of N=38 was not 100% completed. In this N=38 there can still be found some valuable information of people who ended in a later stage of the survey. The minimum requirement which was set for including in the total N was the completion of the first question 'on topic'. This means that more than the background questions were answered. Minimum progress was

set on 60%. The number of people who did not complete more than 60% was 31. This means $N_{completed}$=205.

- *Target population*
  Since the purpose to measure the preferences in the agglomeration of Utrecht, people who lived outside there were filtered: people who indicated to live in Westland, Capelle aan de Ijssel, Nijkerk (5 people). Also, people who in the first place indicated to live in Utrecht, but when they needed to state their Utrecht neighbourhood they were indicated to live in Den Haag and Amersfoort (2 people) Some people also answered they did not live in Utrecht. But they did live in Nieuwegein, Soest, or Zeist. Due to the proximity of these municipalities they were accounted for in the sample (4 people). The total $N_{Utrecht}$ = 198.
- *Others?*
  Other filters that were designed to be applied when needed were: currently on district heating of Eneco, currently on 'neighbourhood energy'. These filters were not used, because the insignificance of the strata's (neighbourhood energy) and/or their equally valuable opinion on the topic (district heating consumers)

So, the total sample which was used **N=198**, of which seven respondents did not complete the entire survey.

7.3.2. Revalued data & missing values

The following revaluations have been executed to increase the comparative analysability of the data:

- Data revaluation has been executed for the Likert scale question of the elements which should be adapted (question 14) have been revalued from 2-6, to 1-5. Means and medians are therefore equally interpretable as other Likert scale question.
- Regarding *missing values i*n ordinal questions: 'don't know' or 'different, namely' have been valued as 'missing value'. This way the descriptive statistics in terms of means and medians can be run on input which was valued. This limits the analysable N in some questions.

7.3.3. Categorising 'different, namely'

A lack of category is only problematic for the background questions when running inferential and bivariate statics on split samples, because of their limited strata sizes. Therefore, the following 'different, namely-input' of background questions have been categorised:

- *Housing type (Q7)*
  1. 'Old house in attic': apartment
  2. New category for corner house has been added (6 houses).
  3. '3-under-1-roof': semi-detached house
- *Ownership of house (Q8)*
  1. 'Overvecht vastgoed': rental
  2. 'Bruikleenovereenkomst': 'different', since this respondent has no ownership, but probably has no renting rights either.
- *Gas connection (Q11)*
  1. 'Hybrid heat pump': gas using.
  2. Don't know has been added in the options.
  3. 'Blokverwarming' has been kept in 'different'

7.4. Sample generalisability

To check generalisability of the results, in terms of sample characterises and population characteristics: a sample check is executed. The checks are based in the background questions in the questionnaire and can be compared to the population characteristics. These population characteristics can be found in the database of WistUdata (Onderzoek, 2018) and CBS. The sample has been controlled for gender, age, family composition, education level, housing, house ownership, construction year and heating provision technology. Income level has also been assessed, but not referred to a database with national or municipal statics. A full overview of the sample check can be found in Appendix G (Appendix: Sample generalisability).

In summary, most important characteristics of the sample are the large percentage of apartments (52%), limiting the generalisability to neighbourhoods without or with very little apartment buildings. Furthermore, a large percentage of highly educated people (89%), limits the generalisability of the conclusions for neighbourhoods where large percentages of people are lower educated. Descriptive analysis

7.5. Descriptive analysis

The following questions are descripted. Comparative Likert scale questions are visualised using a 'divergent stacked bar chart'. Separated Likert scale questions are visualised using a normal bar chart, as well as multiple response questions (MRP). Nominal questions are only evaluated using a frequency and/or descriptive statics table.

- Expectations of aspects
  How important are ownership aspects of heat provision for the alternative of natural gas? This includes mainly: influence (procedural); trust, self-supportiveness and clear bills (distributive trust); no adjustment to house, low costs (distributive investment)
- Responsibility and trust
  What organisations are responsible and trusted for the heat transition? (procedural)
  How much trust in neighbourhood to organise heat cooperative? (distributive)
- Investment
  How to cover for connection costs? (distributive)
  How much time to spend on heat cooperative? (distributive)
  How much money willing to spend on heat cooperative? (distributive)
- Influence
  What type of influence is preferred? (procedural) It further evaluates the aspect of ownership rights (distributive)
- Physical ownership:
  Who is suited for generation of heat in the value chain?
  Who is suited for distribution of heat in the value chain?
  Is it preferred that the heat chain would be vertically integrated?

7.5.1. Expectation on aspects of heat provision

Safety, sustainability and comfort are very important. Because of validity, we need to derive conclusion from the median. Therefore, from the aspects the following can be derived: (1) that safety is the only 'very important' aspect in new heat provision, (2) almost all aspects are important, but self-supportiveness which is neutral, (3) the order based on both valuation and ranking methods have a clear 'top 3' of important aspects: safety, sustainability and comfort. These aspects entail the technical functionality of the heat provision. Figure 13 gives a visual overview of these findings.

The ranking question gave more insight in how aspects are compared among each other. Table 7-3 gives the aggregated ranking. In the lower regions 'clear bills' is in comparison to other aspect least important. Aspects more important when compared are 'low costs', 'little construction' and 'self-supportive'.

Rank what is important to you for the alternative of natural gas? (Q15)			
Rank (previous)	***Descriptive Statistics (N=198)***	***Mean (1-9)***	***Std. Deviation***
1	Safety	2,81	2,168
2	100% Sustainable (CO2-Neutral)	3,55	2,556
3	Comfort	3,93	2,098
4 (6)	Low costs	4,56	2,406
5 (8)	Little construction to house	5,23	2,381
6 (4)	Trust in supplier	5,86	1,986
7 (9)	Self-supportive	6,07	2,471
8 (7)	Influence	6,35	2,200
9 (5)	Clear bills	6,75	1,913

Table 7-3 Ranking

Concluding in terms of preferences for ownership, these aspects reveal that heat cooperative aspects like self-supportiveness and influence (Table F-1) are important, but not as important as other aspects of heat provision. The rank of 'trust in supplier' indicates how important ownership preferences finding of question 17 are.

Concluding in terms of procedural justice, influence and clear bills[31] are less important than other aspects. Trust in the supplier or being self-supportive (self-trust) is more important than influence. Distributive aspects regarding responsibility (no adjustments) are more important than other aspects. Low costs also indicate limited responsibility.

7.5.2. Responsibility & trust

All technical and investment aspects being equal for different ownership types organisational trust is more important than influence on the process (Q14). Question 16 and 17 are devoted to compare different organisations on this trust. Apart from the technical aspects of heat provision, trust is rather important for consumers.

[31] Possibly, because of the limited relatedness for current natural gas clients. One of the complaints of the NMDA-principle is the unclearness of the pricing methods, this results in unclear bills. District heating clients might see this as a larger problem than natural gas clients, because they are not familiar with the problem.

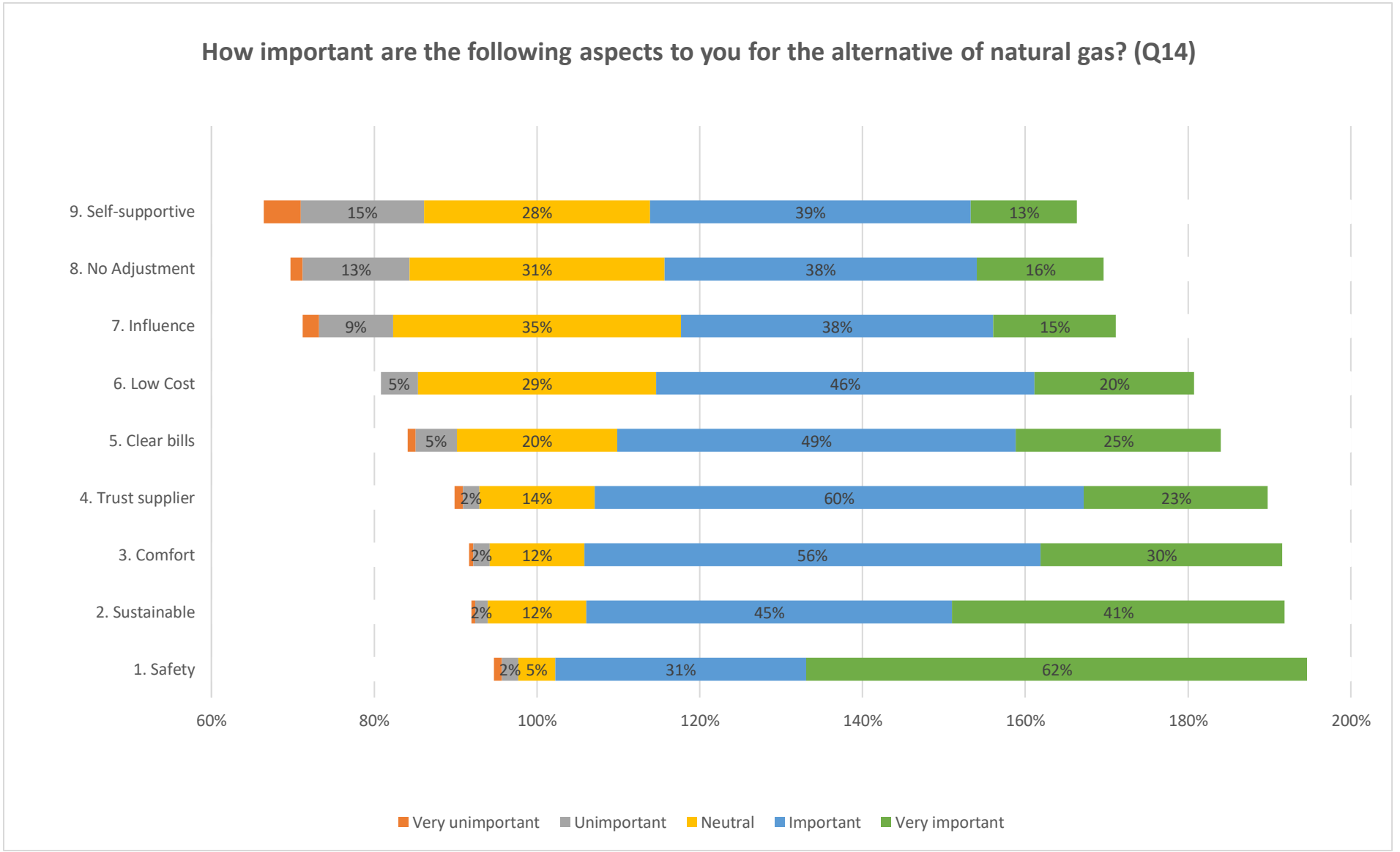

Figure 13 Aspects overview (100% = half the answered 'neutral'. Distributing half of the neutrals on the 'negative side' and half the neutrals on the 'positive' side)

Expectation in terms of responsibility has been measured in question 16: what organisation do you think is responsible for the alternative of your natural gas connection? Table 7-4 gives the frequencies of responsibility question. Since it was an MRP-question the 'percent of cases' is meaningful.

Who is responsible for the alternative for natural gas? (Q16)				
Rank (based on percentage)		***N***	***Percent***	***Percent of cases***
1	The municipality	134	26,60%	*67,70%*
2	You	97	19,30%	*49,00%*
3	Energy companies	95	18,90%	*48,00%*
4	Electricity grid operators	76	15,10%	*38,40%*
5	Housing corporations, house owner (renting), VVE	66	13,10%	*33,30%*
6	Your neighbourhood	20	4,00%	*10,10%*
7	Other	15	3,00%	*7,60%*
	Total	503	100,00%	*254,00%*

Table 7-4 Frequency table responsibility

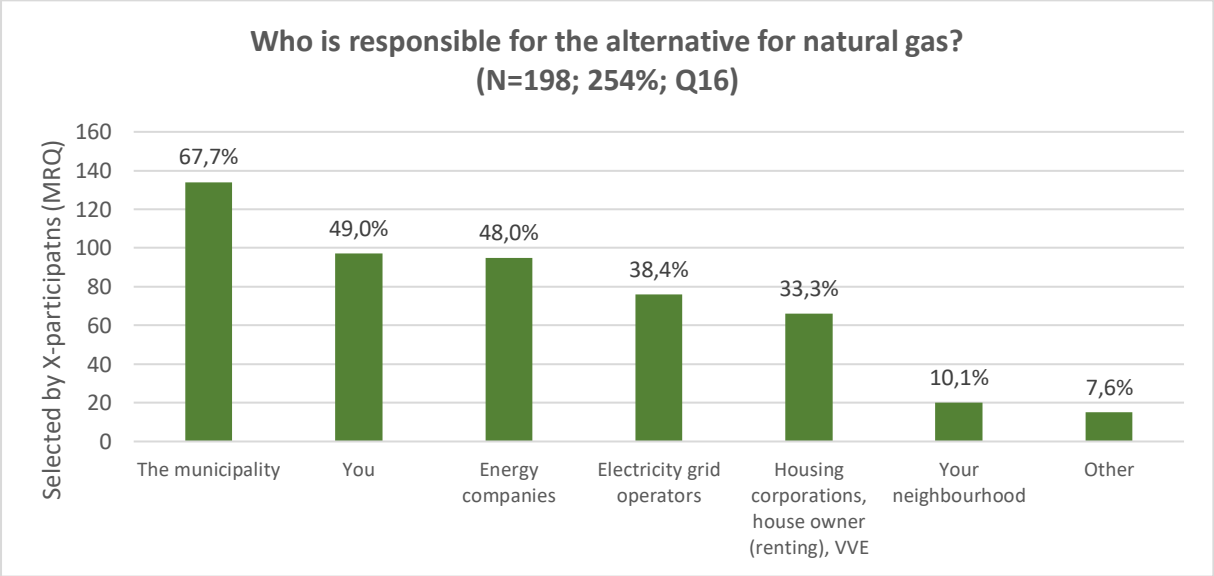

Figure 14 Diagram responsibility

Concluding in in terms of justice, on average 2/3 of the respondents find the municipality responsible for the natural gas alternative. The percent of normalised on the total N of answers is visualised in Figure 14. The municipality accounts for more than 1/4 of total amount of answers. This indicates for procedural justice that the municipality is perceived to be most equal or equitable organisation to be responsibility or to distribute responsibility among citizens.

Question 17 is devoted to the trust people have in these organisations: how trustworthy do you think municipalities, energy companies, grid operators, housing corporations are? People do trust themselves with the transition towards an alternative for natural gas. On average people – or when assuming normal distribution: most people – value themselves as most trustworthy, followed public

organisations (the municipality[32] and the grid operators). Private companies[33] and the neighbourhood[34] are less trusted. Important notice is that all organisations have their own N, since one of the options was to select 'does not apply', which have been categorised as missing values.

It is found that the differences are not very large. People are more divided (much high trust, much low trust) in answering their self-trust and energy companies. People are more consistent in answering municipality and grid operators. Housing corporations have a lower mean and higher standard deviation: this explained by the fact not all people are relating to this, especially home owners not. A graphical representation is given in Figure 15.

How trustworthy do you think these organisations are? (Q17)				
Rank (based on means)		***N***	***Mean***	***Std. Deviation***
1	You	190	**3,96**	1,095
2	Municipality	195	**3,78**	0,939
3	Grid operators	192	**3,490**	0,976
4	Housing corporations/owner, VVE	140	**3,31**	1,151
5	Energy company	196	**3,23**	1,075
6	Neighbourhoods	192	**2,86**	1,089
7	Different, nl.	125	**1,95**	1,224

Table 7-5 Means and st. deviations of trust in organisations

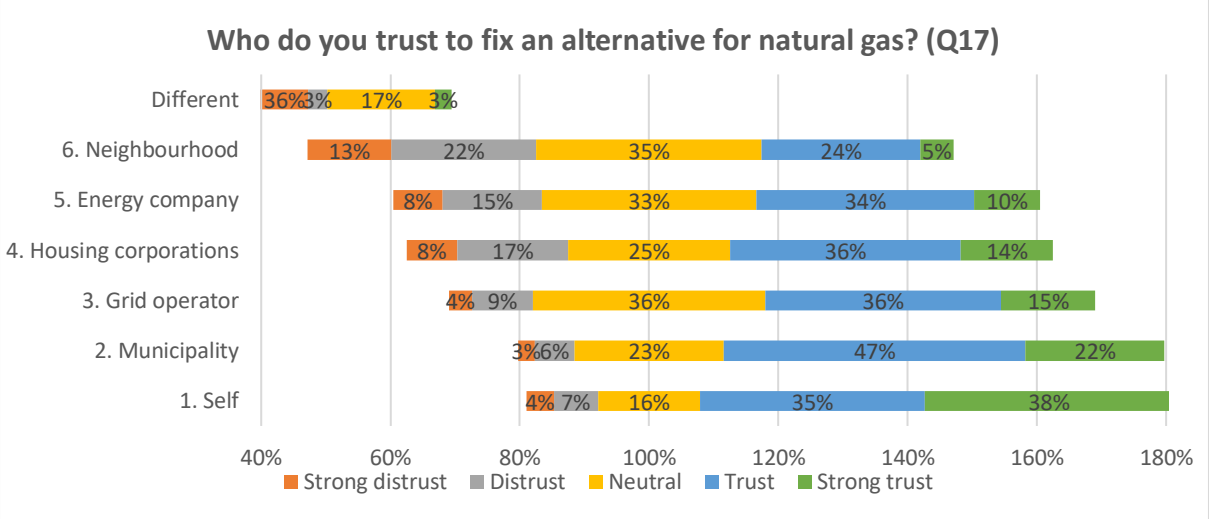

Figure 15 Organisational trust (100% = half the answered 'neutral'. Distributing half of the neutrals on the 'negative side' and half the neutrals on the 'positive' side)

[32] Public: if assessing municipalities on a median base by looking at percentile 50, one can say that the Likert value is *positive*. Compared to the aggregated mean of this question (3,44) – considering the average positivity or negativity of the respondents on the proposed organisations – the difference of municipalities is also significantly more than average (P= <0,001)

[33] Private: if assessing energy companies on a median base by looking at percentile 50, one can say that the Likert value is neutral. Compared to the aggregated mean of this question (3,44) – considering the average positivity or negativity of the respondents on the proposed organisations – the difference is not significantly different (P=0,008).

[34] Cooperative: if assessing on a median base by looking at percentile 50, one can say the Likert value is neutral. Compared to the aggregated mean of this question (3,44) – considering the average positivity or negativity of the respondents on the proposed organisations – the difference is significantly less than averagely answered (P=<0,001).

In terms of heat cooperatives, neighbourhoods are least trusted from all organisations. The reason might be that there is no organisation yet. Therefore the 'likeliness of organizing a heat cooperative' is asked.

Based on the frequencies that can be found in Figure 16, one can say that people are less positive than negative. There are slightly more respondents who think that their neighbourhoods are not capable of setting-up a heat cooperative (51 > 49). If compare *not capable at all* with *totally capable* (22 > 7) this is a larger difference. The mean is 2,84, just under neutral on the negative side. The negative skewness of (-0,077) indicates a slightly negatively skewed distribution. The negative Kurtosis of -,723 indicates not so many outliers.

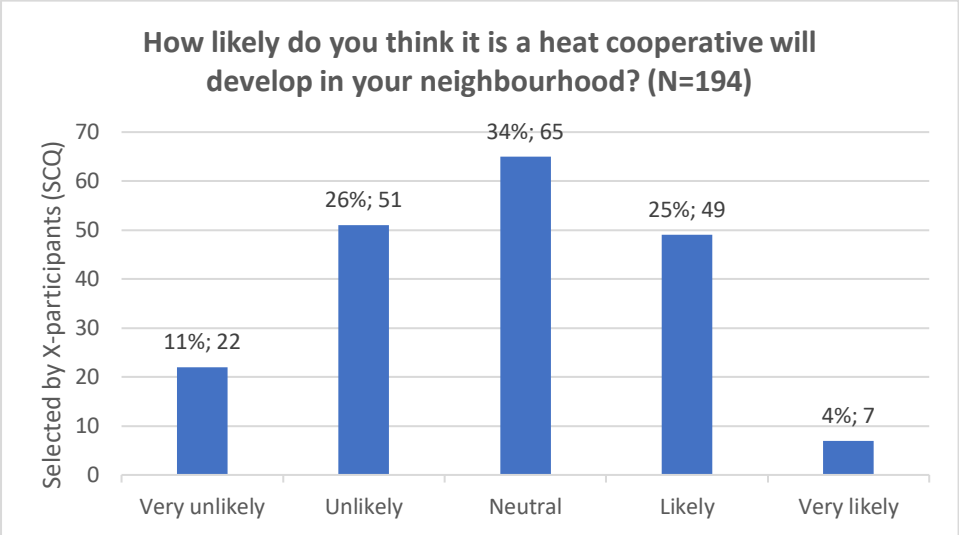

Figure 16 Likeliness of organising a heat cooperative ('trust in neighbourhood')

Concluding in terms of ownership: municipalities mostly trusted compared to other *organisations* in the process of the heat transition. Despite the low valuation on the aspect of 'self-supportiveness'[35], people do have faith in their own capabilities to 'fix an alternative heat provision'. Despite the question emphasize on the process of the heat transition, it is unclear if people selected because of procedural or distributive justice reasons.

7.5.3. Investment

Investment aspects (little adjustments, low costs) are most important aspects after the technical aspects. Question 18 is designed to act as a 'case' for investment potential in general. The investments preferred in a heat cooperative are measured in question 22 and 23.

Based on the frequencies which can be found in Table 7-6, one can say that most participants were in favour of payment in terms. 22,7% is not agreeing with one of the options and has answered 'different'. Within the 'different' category, many argument are given. Most of them relativize the range of 10-30 years or €5k-€30k, e.g. 'willing to pay €5k upfront, maximum of 10 years payback'.

[35] Self-trust: if assessing on a median base by looking at percentile 50, the Likert value is positive. Compared to the aggregated mean of this question (3,44) – considering the average positivity or negativity of the respondents on the proposed organisations – the difference is significantly more than averagely answered (P=<0,001).

How would you like to cover your connection costs? (Q18)	*Frequency*	*Percent*
In terms (10-30 years)	89	44,9%
High connection fee (€5k-€30k)	64	32,3%
Different	45	22,7%
Total	198	100,0%

Table 7-6 Connection costs

The 'time investment' is measured in question 22. In terms of frequencies (Table 7-7) most people are willing to spend some time (1-4 hours per month) on a heat cooperative (48,0%). Another part would not like to spend time on a heat cooperative (44,4%). Very few people would like to spend 5-8 hours (4,0%). Only 3 (1,5%) is willing to do more than 8 hours of voluntary work per month for a heat cooperative. The chi square 'goodness of fit' gives a significant value (<0,001), confirming there is a significant difference among these values.

How much time are you willing to spend per month on a heat cooperative? (Q22)	*Frequency*	*Percent*
0 hours	88	45,4%
1 - 4 hours	95	49,0%
5 - 8 hours	8	4,1%
More than 8 hours	3	1,5%
Total	194	100,0%

Table 7-7 Willingness to Invest time in heat cooperative

The willingness to 'invest money' is measured in question 23. In terms of frequencies (Figure 17) most people indicate it is likely they would invest in a heat cooperative (32%). The mean value of the Likert scale question is 3,04, looking at percentile 50 the median is neutral. On average on can say that people are neutral about willingness to invest in a heat cooperative.

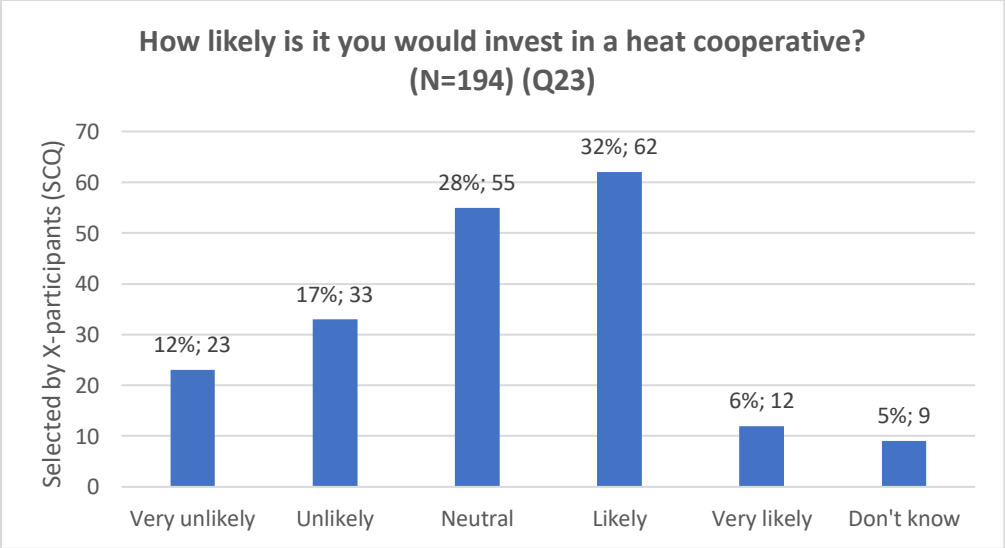

Figure 17 Willingness to invest money in heat cooperative

Concluding in terms of ownership, assuming heat cooperatives demand voluntary work, Q22 limits the preference for heat cooperatives. The findings of Q18 might have minor indications that people are willing to invest in what is needed for them specifically; limiting the need for socialisation (public).

Concluding in terms of justice the 'investment' category resulted in information on distributive justice: only a few people are willing to invest significant amounts of time, indicating possible perceived injustice when 'you are doing more than someone else'. It also potentially indicates the low level of relevance of distributive justice compared to other aspects in the heat provision: if cooperative heat would have been perceived very 'just' compared to other types of ownership, more people would probably be willing to spend time. In terms of financial investment only a minority of people indicate they would probably invest in a heat cooperative: indicating a majority does not perceive financial injustice in other ownership structures.

7.5.4. Influence

Table 7-8 shows that most people would like to have a right to vote on the change (46,0%). Some would like to be consulted (20,7%) or informed (18,7%). Fewer people would like to get ownership rights (9,6%). The chi square 'goodness of fit' gives a significant value (<0,001), confirming there is a significant difference among these values.

How much influence would you like to have on the decision what alternative for your gas connection will be chosen? (Q19)	***N***	***Percent***
Being informed	37	19%
Being consulted	41	21%
Having voting rights (consenting)	91	47%
Having ownership rights	19	10%
Different	6	3%

Table 7-8 Influence preference

Concluding in terms of ownership preference, the limited preference for 'ownership rights' (9,7%) limit the need for heat cooperatives. Most people are devoted to consenting, which is the highest level of 'influence' in terms of procedural justice. These aspects are expected to be well achieved by all ownership structures.

7.5.5. Asset ownership

For the generation part of the heat chain, most people find private energy companies fitted to maintain a heat source (61,9% of respondents). Heat cooperatives and municipalities are also seen as good fitted organisations by a majority of the respondents (respectively 50,8% and 52,4%). Network owners are least popular, only 36,0% of the respondents answered they would be well fitted to own a heat source.

For the distributive part of the heat chain, most people find municipalities best fitted to own a heat network (63,4% of respondents). Electricity distributors are also by a majority valued as possible to own a heat network (57,1%). Only 44,5% think heat cooperatives are good organisations to own the network activities. Which is, despite its minority, still more than how many people think energy companies are well fitted to own a heat network (35,1%).

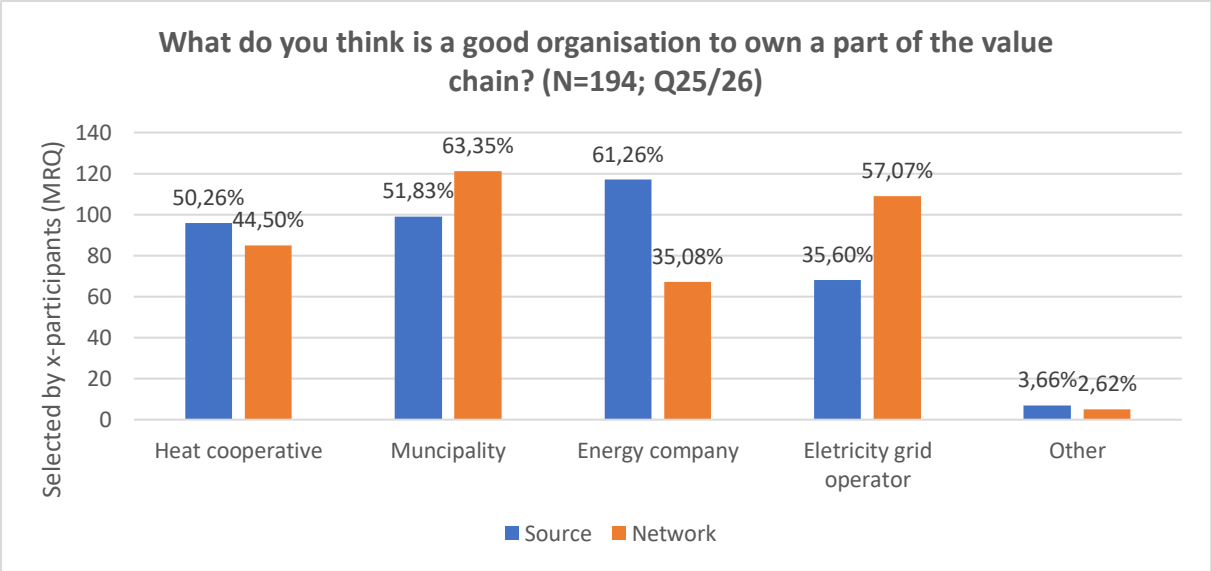

Figure 18 Fitness to supply chain

Whether or not the heat chain should be integrated is unclear. Most people would have no preference (30,3%). Some would like to see it integrated (29,3%), fewer people would like to see it split (20,7%). The chi square 'goodness of fit' gives a non-significant value (0,128), meaning there is no significant difference among these values. That means we cannot derive any integrative conclusions on what people think is best in terms of integration.

Concluding in terms ownership preferences, there is an indication that competition on an open network is preferred by most people (energy company=source, grid operator=network). But differences with municipally integrated – and cooperative integrated – preferences are limited. How combinations between these answers are preferred cannot be taken from this question.

7.6. Inferential statistics

Then, from the direct design questions, there are also other determinants which are interesting to research that could benefit the analysis on the public preferences on the design space. Inferential statics will therefore be performed on the following background information.

- House ownership
- Income
- Current heating technology
- Levels of prior knowledge
- Influence
- Cooperative source/network
- Physical ownership

The null- and alternative hypotheses are systemically stated in Appendix H. (Appendix: Summary of hypotheses). Not all background questions are assessed on the same relations. Assessing all relations among all variables was limited due to time constraints. Therefore, the most expected relations have been chosen in accordance with an expert on district heating in Utrecht.

7.6.1. House ownership

As we want to explore whether there is a difference in preferences due to house ownership using the chi-square, we needed to combine the 'social rent' and the 'rent'[36]. This resulted in 84 respondents who rent and 114 respondents who own. On these, chi-square tests 'on independence' have been conducted, for which the following questions have been stated.

- Do people with different housing ownership types vary in their opinions about *who is responsible* for a gas alternative?
- Do people with different housing ownership types vary in their *opinions about connection fees*?
- Do people with different housing ownership types vary in their *opinions on influence*?

Testing has resulted in the following answers. The percentage of participants that valued specific organisations of ownership did differ by house ownership, $\chi^2(6, N = 188 = 68{,}237, p = <0{,}001)$.

The percentage of participants that valued connection fees did differ by house ownership, $\chi^2(1, N = 153) = 16{,}847$, $p = <0{,}001$). There is a strong relationship (V=0,332). What people prefer on connection fees is strongly dependent on house ownership. House owners rather pay high connection fees, where renters want to pay in terms.

The percentage of participants that valued specific ways of influencing the decision-making process did not differ by house ownership $\chi^2(3, N = 188) = 8{,}836$, $p = 0{,}032$). The null-hypotheses need to be rejected: the preferred type of influence is (strongly) dependent of house ownership. Renters are less interested and are finer with being informed (25,9% of renters instead of 15,0% of buyers), where more house owners would like to have ownership rights on the heating technology (15,0% of buyers instead of 3,7% of renters)

The house ownership category does reveal connections with question on responsibility for alternatives, connection fees preferences and the type of influence.

7.6.2. Income

The income level is assessed by how they value connection fees and how they value investment in heat cooperatives.

- Do people with different income levels vary in their *opinions on connection fees*?
- Do people with different income levels vary in *their willingness to invest in a heat cooperative*?

Testing has resulted in the following answers. The percentage of participants that valued a specific strategy to cover connection fees did not differ by their income level, $\chi^2(5, N = 188) = 7{,}153$, $p = 0{,}210$). The null-hypotheses need to be confirmed: what people prefer on connection fees is not dependent of income level.

Willingness to invest: compared nominal – Due to the large degrees of freedom in the cross tabulation of income with willingness to invest (20), 53,3% of the cells have expected counts less than five. Therefore, the Likert scale of willingness to invest in a heat cooperative is being reduced to 3 levels: willing, unwilling and neutral. The income scale has been reduced to 2 levels: less and average income, more than average income. The percentage of participants that differ by house ownership $\chi^2(4, N =$

[36] Because chi square tests need a minimum of 5 respondents in all outcomes after comparing with the dependent variable, splitting groups of only 13 respondents – who lived in a social renting house (6,6%) – gives insufficient outcomes when having multiple degrees of freedom.

185) = 9,149, *p* =0,057). The null-hypotheses need to be confirmed: what people prefer on connection fees is not dependent of income level.

Willingness to invest: compared ordinal – A Kruskal-Wallis H test showed that there was no statistically significant difference in willingness to invest between the different income levels, χ2(2, N=168) = 7,411, p = 0,060, with a mean rank income score of 75,54 for less than 'modaal', 72,57 for 'modaal', 87,87 for 2x 'modaal', and 97,60 for more than 2x modaal. Since the insignificant but rather low p-value there was also an assessment of the data on a lower level of detail. The income scale has been reduced to 2 levels: less and average income, more than average income. A Mann-Whitney test showed that there *was* a statistically significant difference in willingness to invest between the different income levels, χ2(2, N=168) = 2709,500, p = 0,012, with a mean rank income score of 5410,50 for 'modaal' and less, and 8785,50 for more than 'modaal'. So: what people are willing to invest in heat cooperatives is dependent on whether people earn less or more than 'modaal'

On a nominal and high level of detail, the income levels do not reveal any connection with preference for connection fees and willingness to invest in a heat cooperative. There is a significant difference when data levels of income are reduced on an ordinal level. So: what people are willing to invest in heat cooperatives is dependent on whether people earn less or more than 'modaal'.

7.6.3. Current heating technology

The current heating scheme participants use, is assessed for the following questions:

- Do people with different technologies of heating their house vary on what kind of party is *responsible* to organise an alternative for natural gas?
- Do people with different technologies of heating their house currently vary on their opinion which organisation fits managing the *source*?
- Do people with different technologies of heating their house currently vary on their opinion which organisation fits managing the *network*?
- Do people with different technologies of heating their house currently vary on their preference for an *integrative* company?
- Do people with different technologies of heating their house currently vary on their *willingness to invest time* in a heat cooperative?
- Do people with different technologies of heating their house currently vary on their *willingness to invest money* in a heat cooperative?
- Do people with different technologies of heating their house currently vary on the *trust they have in their neighbourhoods* to organise a heat cooperative?
- Do people with different technologies of heating their house currently vary in their *valuation of important aspects* for heating alternatives?
- Do people with different technologies of heating their house currently *vary on their opinion how trustworthy* they think specific organisations are?

Testing has resulted in the following answers. The latter two analyses are non-chi square, so are separated by indicated paragraph.

7.6.3.1. Chi square analyses

The percentage of participants that answered specific organisations to be responsible for the natural gas alternative differs by currently used heating technology, $\chi^2(6, N = 190)=13,905$, p =0,031. We need to reject the null-hypothesis: who is responsible to organise an alternative for natural gas is dependent on their current heating technologies

The percentage of participants that answered specific organisations to manage the source does not differ by currently used heating technology, χ^2(4, *N* = 159=2,323, *p* =0,677). We need to confirm the null-hypothesis: which organisation people think fits managing the source is not dependent on their current heating technologies.

The percentage of participants that answered specific organisations to manage the network does not differ by currently used heating technology, χ^2(4, *N* = 159=2,152, *p* =0,708). We need to confirm the null-hypothesis: which organisation people think fits managing the network is not dependent on their current heating technologies

The percentage of participants that were in favour of integrated companies does not differ by currently used heating technology, χ^2(2, *N* =155) =0,468 , *p* =0,791. We need to confirm the null-hypothesis: whether people think the whole chain should be integrated is not dependent on their current heating technologies

The percentage of participants that is willing to invest time does not differ by currently used heating technology, χ^2 Independence (3, *N* = 189) =2,156, *p* =0,541). A Mann-Whitney test showed that there was no statistically significant difference in willingness to invest between the different income levels, χ2(2, N=189) = 2358,50, p = 0,714, with a mean rank of heating technology of 95,57 on NG and 92,08 on DH. We need to confirm the null-hypothesis: the willingness to invest time in a heat cooperative is not dependent on their current heating technologies

The percentage of participants that is willing to invest money does not differ by currently used heating technology, χ^2 Independence (4, *N* = 189) =6,166, *p* =0,187. A Mann-Whitney test showed that there was no statistically significant difference in willingness to invest between the different income levels, χ2(2, N=180) = 1945,000, p = 0,323, with a mean rank of heating technology of 92,19 on NG and 82,07 on DH. We need to confirm the null-hypothesis: the willingness to invest money in a heat cooperative is not dependent on their current heating technologies

The percentage of participants that trusted their neighbourhoods in setting up a heat cooperative differs by their currently used heating technology, χ^2 Independence (4, *N* = 189) =14,513 (20,0% of cells less than 5), *p* =0,006. We need to reject the null-hypothesis. A Mann-Whitney test showed that there *was* a statistically significant difference in willingness to invest between the different income levels, χ2(2, N=189) = 1679,50, p = 0,004, with a mean rank of heating technology of 99,87 on NG and 70,18 on DH. So: the trust people have in their neighbourhoods to organise a heat cooperative is dependent on their current heating technologies. When currently using district heating people tend to answer more that their neighbourhood is less capable of organising a heat cooperative than people who need to change.

Who is responsible to organise an alternative for natural gas is dependent on their current heating technologies. Furthermore, people currently using natural gas are more positive towards the capability of their neighbourhoods to organise a heat cooperative than people who are currently using district heating.

7.6.3.2. Non-chi square analyses

Based on this assessment a less than 5% difference is assumed not to be relevant to mention, since we are not dealing with continual data and sample sizes are very limited.

Heat provision aspect	NG (mean)	DH (mean)	%Difference
CO2 Neutral	4,220126	4,382353	3,8%
Comfort	4,144654	4,205882	1,5%
Safe	4,515723	4,441176	-1,7%
No adjustments	3,572327	3,411765	-4,5%
Self-supportive	3,352201	3,676471	9,7%
Influence	3,559748	3,529412	-0,9%
Low Costs	3,792453	3,941176	3,9%
Clear Bills	3,886792	4,147059	6,7%
Trust in company	4,012579	4,117647	2,6%

Table 7-9 Comparative aspects, grouped by heat provision

DH-customers find being self-supportive 9,7% more important than NG-users *on average*. This could be explained by the experience of DH-customers on the relationship with the monopolist district heating company (Eneco). Also, DH-customers find clear bills 6,7% more important than NG-users *on average.* This can be explained by the (negative) experience DH-customers have with their bills: based on the NMDA principle. Since differences of larger than 5% were found, the null-hypothesis is rejected. Hence, what people think is important for heating is dependent on their current heating technologies

Trust in organisation	NG (mean)	DH (mean)	% Difference
Yourself	3,95	4,03	2,0%
Your neighbourhood	2,89	2,66	-8,0%
Municipality	3,73	3,94	5,6%
Energy Company	3,25	3,18	-2,2%
Electricity grid operator	3,45	3,63	5,2%
Housing corporation/VVE	3,24	3,66	13,0%

Table 7-10 Trust in organisation, grouped by heat provision

So, we can conclude that people using natural gas trust their neighbourhoods 9,7% more in finding an alternative for natural gas *on average*. This could be explained by the unnecessity of DH-customers to find an alternative and don't think neighbourhoods should take over from Eneco. Also, DH-customers trust municipalities and electricity grid operators respectively 5,6% and 5,2% more than NG-users *on average.* This could be explained by the experience they have with Eneco and/or could be answered because they answer this 'to make a change'. The largest % difference is the trust district heating people have in their housing corporations (13,0%). This could be explained by the fact there is a relationship determined between households currently in district heating schemes and type of house ownership[37]. Since differences of larger than 5% were found[38], the null-hypothesis is rejected. Hence, what organisation people trust for their heating their homes is dependent on their current heating technologies

What people think is important for heating is dependent on their current heating technologies, since differences are found over 5% for self-supportiveness and clear bills. DH-customers prefer more than natural gas customers to become self-supportive and clear bills. What organisation people trust for

[37] The percentage of participants that answered the specific organisations to be responsible for the natural gas alternative differs by housing ownership (social rent+rent/buy). An alternative hypothesis should be accepted: the heating technology is dependent on the house ownership. Looking at frequencies there is a clear relationship between rent and district heating and buy and natural gas.

[38] Moreover, the median percentiles change over Likert values, which is the actual appropriate level of analysis.

their heating their homes is dependent on their current heating technologies, since differences are found over 5% for all organisations, but energy companies.

7.6.4. Levels of prior knowledge

The following multiple response questions is assessed on their relationship with the levels of prior knowledge:

- Do people with different levels of previous knowledge vary on what kind of party is *responsible* to organise an alternative for natural gas?
- Do people with different levels of previous knowledge vary on the opinion who fits best the managing of the *source*?
- Do people with different levels of previous knowledge vary on the opinion who fits best the managing of the *network*?

Testing has resulted in the following answers. The percentage of participants that answered who is responsible to organise an alternative for natural gas does not differ by levels of prior knowledge, $\chi^2(24, N = 159) = 27{,}214$, $p = 0{,}295$. We need to confirm the null-hypothesis: which organisation people think fits managing the source is not dependent on their current heating technologies.

The percentage of participants that answered specific organisations to manage the source does not differ by levels of prior knowledge, $\chi^2(16, N = 159) = 17{,}425$, $p = 0{,}359$. We need to confirm the null-hypothesis: which organisation people think fits managing the source is not dependent on their current heating technologies.

The percentage of participants that answered specific organisations to manage the network does not differ by levels of prior knowledge, $\chi^2(16, N = 159) = 12{,}230$, $p = 0{,}728$. We need to confirm the null-hypothesis: which organisation people think fits managing the source is not dependent on their current heating technologies.

No dependency on the higher or lower levels of knowledge are distinguished.

7.6.5. Influence

The following questions are assessed on influence:

- Do people with different preferences of influence vary on their *willingness to invest time* in a heat cooperative?
- Do people with different preferences of influence vary on their *willingness to invest money* in a heat cooperative?
- Do people with different preferences of influence vary on the *trust they have in their neighbourhoods* (to organise a heat cooperative)?
- Do people with different preferences of influence vary on the *trust they have in an energy company to* organise an alternative for natural gas?

Testing has resulted in the following answers. The percentage of participants that is willing to invest time does not differ by preferred type of influence, χ^2 Independence ($9, N = 188$) = 12,704 (50% of cells of value less than 5), $p = 0{,}176$. A Kruskal-Wallis H test also showed that there was no statistically significant difference in willingness to invest between the different income levels, $\chi 2(3, N=188) = 6{,}782$, $p = 0{,}079$. We need to confirm the null-hypothesis: whether people think the whole chain should be integrated is not dependent on their current heating technologies

The percentage of participants that is willing to invest money does differ by preferred type of influence, χ^2 Independence ($12, N = 180$) = 21,480 (35% of cells of value less than 5), $p = 0{,}044$. With a lower level

of detail (only negative, neutral and positive) we can reduce the number of cells with less than N=5. Then: χ^2 Independence (6, *N* =180) = 18,297 (0% of cells of value less than 5), *p* =0,006. A Kruskal-Wallis H test also showed that there was a statistically significant difference in willingness to invest between the different income levels, χ2(3, N=180) =11,239, p = 0,011. With a mean rank for being informed of 87,58, being consulted 95,063, having rights to vote 96,45 and having ownership rights 97,45. We can reject the null-hypothesis: the willingness to invest money in a heat cooperative is dependent on their preference of influence. Namely: people who want to become shareholders are relatively more willing to invest. People just want to be informed are relatively unwilling to invest.

The percentage of participants that trusts their neighbourhood to be able organise a heat network does not differ by preferred type of influence, χ^2(12, *N* =188) = 8,989 (45% of cells of value less than 5), *p* =0,0704. The percentage of participants that trusts their neighbourhood in general (trusting different organisation question) organise a heat network does not differ by preferred type of influence, χ^2 Independence (12, *N* =183) = 14,487 (40% of cells of value less than 5), *p* =0,271. With a dummy variable with only 3 levels (positive, neutral, negative) the χ^2 Independence (6, *N* =183) = 6,509 (0% of cells of value less than 5), *p* =0,369. A Kruskal-Wallis H test also showed that there was no statistically significant difference in willingness to invest between the different income levels, χ2(3, N=186) = 0,835, p = 0,841. In all four test p-values are too high: we need to confirm the null-hypothesis. The trust people have in their neighbourhoods to organise a heat cooperative is not dependent on their preference of influence.

The percentage of participants that trusts energy companies do not differ by preferred type of influence, χ^2 Independence (12, *N* =186) = 9,616 (35% of cells of value less than 5), *p* =0,650. With a dummy variable with only 3 levels (positive, neutral, negative) the χ^2 Independence (6, *N* =186) = 5,119 (0% of cells of value less than 5), *p* =0,529. A Kruskal-Wallis H test also showed that there was no statistically significant difference in willingness to invest between the different income levels, χ2(3, N=186) = 2,632, p = 0,452. In all four test p-values are too high: we need to confirm the null-hypothesis. The trust people have in specific organisations to organise a natural gas alternative is not dependent on their preference of influence.

The willingness of people to invest money in a heat cooperative is dependent on the preference of influence on the decision of the alternative for natural gas.

7.6.6. Cooperative source/network

The following questions are assessed on source and network. Since we are dealing with an MRP-question there is no possibility doing the normal non-parametric tests. Therefore, we will perform a split over the MRP-aspect (cooperative source/cooperative network) and compare the means. It is assumed a larger difference than 5% is noticeable as 'significant'.

- Do people with different preferences on cooperative ownership for heat generation vary on the trust they have in *energy companies*?
- Do people with different preferences on cooperative ownership for heat generation vary on the trust they have in *municipalities*?
- Do people with different preferences on cooperative ownership for heat generation vary on the trust they have in *grid operators*?
- Do people with different preferences on cooperative ownership for heat networks vary on the trust they have in *energy companies*?
- Do people with different preferences on cooperative ownership for heat networks vary on the *trust they have in municipalities*?

- Do people with different preferences on cooperative ownership for heat networks vary on the *trust they have in grid operators*?

Testing has resulted in the following answers. From the first question we can derive that the mean of trust in *energy company* is 3,41 for people who did not answered *no* on the first question. The people who answered *yes* had a mean of 3,05. For the trust in a public organisation one can look at both the municipality and the grid operator. For people who were not in favour of the cooperative source, the mean was 3,74 (municipality) and 3,39 (grid operator). The people who were in favour had a mean of 3,83 and 3,60, respectively. From the second question we can derive that the mean of trust in energy company is 3,32 for people who did not *no* on the second question. The people who answered *yes* had a mean of 3,12. For the trust in a public organisation one can look at both the municipality and the grid operator. For people who were not in favour of the cooperative source, the mean was 3,82 (municipality) and 3,50 (grid operator). The people who were in favour had a mean of 3,74 and 3,48, respectively. So:

Cooperative source	Yes (mean)	No (mean)	%Difference
Energy company	3,05	3,41	11,8%
Municipality	3,83	3,74	-2,3%
Grid operator	3,60	3,39	-5,8%

Table 7-11 Distrust organisations for source, by cooperative 'fans' - Means

Cooperative network	Yes (mean)	No (mean)	%Difference
Energy company	3,12	3,32	6,4%
Municipality	3,74	3,82	2,1%
Grid operator	3,48	3,50	0,6%

Table 7-12 Distrust organisations for network, by cooperative 'fans' - Means

One can conclude that participants in favour of cooperative ownership for heat *generation* have slightly higher trust in grid operators and lower trust in energy companies on average, than people not in favour of cooperative ownership for heat generation. Participants in favour of cooperative ownership for heat *networks* have slightly lower trust in energy companies on average, than people not in favour of cooperative ownership for heat networks.

7.6.7. Physical ownership

The following question is assessed on source and network. Since we are dealing with an MRP-question there is no possibility doing the normal non-parametric tests. Therefore, perform a split is performed over the MRP-aspect (cooperative source/cooperative network) and compare the means. It is assumed a larger difference than 5% is noticeable as ‘significant’.

The tables with the outcomes can be found in Appendix I (Appendix: Interrelatedness of physical ownership). All null-hypotheses are rejected, since dependent on every ownership type, the preferred consequences the largest differences are at least 30% (H. Appendix: Summary of hypotheses). This is assumed to be significant. The following information can be derived from the analysis:

- Private:
    - If people prefer a private heat generation (61,3%): most chosen network organisations are public (59,8% municipality, 65,0% grid operator)
    - If people prefer a private heat network (35,1%): most chosen heat generation organisation are private (86,6%)
- Grid operator:
    - If people prefer heat generation from the grid operator (35,6%): most chosen network organisations are public (59,8% municipality, 65,0% grid operator)
    - If people prefer heat network owned by the grid operator (57,1%): most chosen heat generation organisations are private (39,7%).
- Municipality
    - If people prefer a municipal owned heat generation (51,8%): most chosen heat network organisation is the municipality (84,8%). Least chosen network organisation is private (35,4%)
    - If people prefer a municipal owned heat network (63,4%): most chosen heat generation organisation is municipal owned (69,4%). Least chosen heat generation organisation is the grid operator (40,5%)
- Heat cooperative
    - If people prefer a heat generation cooperative (50,3%): most chosen heat network organisation is a heat network cooperative (70,8%). Least chosen network organisation is the energy company (36,5%).
    - If people prefer a heat network cooperative (44,5%): most chosen heat generation organisation is the cooperative (80,0%). Least chosen generation organisation is the energy company (38,8%).

So, when choosing to have a heat cooperative or a municipal-ownership: integrated companies combining generation and network are mostly preferred. When public grid operators are involved, the analogy with the electricity market is clearer, arranging competition on the network among private sources.

7.7. Bivariate statistics

On the variables which were declared not independent we will do further examination using lambda, Cramer's V/Phi. According to Healey (2014) the relationship is weak between 0.00 and 0.10, moderate between 0.11 and 0.30, strong when its greater than 0.30. Lambda is a PRE measure (Healey, 2014). Multiple response question cannot be assessed by bivariate statistics.

7.7.1. House ownership

What people prefer on connection fees is dependent of house ownership. The Phi gives a value of 0.332 (p=<0.001), indicating a strong relationship. Assessing the lambda gives an insignificant value (p=0,231). So, we cannot give any proportional reduction in error.

The preferred type of influence is dependent of house ownership. The Cramer's V gives a value of 0,217 (p=0.032), indicating a moderate relationship. Assessing the lambda gives an insignificant value (p=0,231). So, we cannot give any proportional reduction in error.

7.7.2. DH/NG

The trust people have in their neighbourhoods to organise a heat cooperative is dependent on their current heating technologies. The Cramer's V gives a value of 0,277 (p=0.006), indicating a moderate relationship. A significant lambda indicates a value of 0.088, demonstrating that we would make 8,8%

less errors in predicting the chance that a cooperative would spark existence in their neighbourhoods, based on their current heating technology. a

7.7.3. Influence

The willingness to invest money in a heat cooperative is dependent on their preference of influence. The Cramer's V gives a value of 0,199 (p=0.044) for the 5 scale and 0,319 (p= 0.006) for the 3-scale question. This indicates a moderate to strong relationship among the variables. Assessing the lambda gives an insignificant value (p=0,600). So, we cannot give any proportional reduction in error.

7.7.4. Heat cooperative determinants

To test if people are overall in favour of heat cooperatives, the three Likert scale determinants are assessed on correlation: likeliness of financial investing, willingness to spend time and likeliness of organising heat cooperative. The gamma is used: according to Healey (2014)between 0,00 and 0,30 there is a weak relationship; between 0,31 and 0,60 there is a moderate relationship; more than 0,60 there is a strong relationship.

7.7.4.1. Financial investing likeliness versus willingness to spend time

Table 7-13 give an example of the method of assessing the interrelatedness of the 'heat cooperative determinants.

Invested money vs. time							
			How much time are you willing to spend on a heat cooperative?				***Total***
			0 h	***1-4 h***	***5-8 h***	***8+ h***	
How likely is investing in a heat cooperative for you?	**Not at all**	**Count**	21	2	0	0	23
		%	24,4%	2,3%	0,0%	0,0%	12,4%
	Not	**Count**	21	11	0	1	33
		%	24,4%	12,5%	0,0%	33,3%	17,8%
	Neutral	**Count**	23	31	1	0	55
		%	26,7%	35,2%	12,5%	0,0%	29,7%
	Likely	**Count**	19	38	4	1	62
		%	22,1%	43,2%	50,0%	33,3%	33,5%
	Very Likely	**Count**	2	6	3	1	12
		%	2,3%	6,8%	37,5%	33,3%	6,5%
Total		Count	86	88	8	3	185

Table 7-13 Cross table Investments (Heat/Time) Cooperative

The gamma test has been conducted and gives a significant value of 0,573 (P<=0,001). This means we would make 57,3% less errors by using the willingness to invest to predict willingness to spend time. This is a moderate relationship.

7.7.4.2. Willingness to spend time versus likeliness of organising a heat cooperative

The same table as money vs. time has been conducted. The gamma test has been conducted and gives a significant value of 0,308 (P=0,002). This means we would make 30,8% less errors by using the willingness to spend time to predict how capable people value their neighbourhoods – and the other way around. This is a moderate relationship.

7.7.4.3. Likeliness of organising a heat cooperative versus likeliness of financial investment

The same table as money vs. time has been conducted). The gamma test has been conducted and gives a significant value of 0,369 (P<=0,001). This means we would make 36,9% less errors by using the

willingness to invest to predict how capable people value their neighbourhoods – and the other way around. This is a moderate relationship.

There is a moderate relationship among the three variables to determine how much people are in favour of heat cooperatives in general. The trust people have in their neighbourhoods is less connected than the money and effort people are willing to invest in the heat cooperative.

7.8. Conclusion

The central question in this chapter is: what choices in ownership of district heating systems reflect the preferences of Utrecht residents? Two types of conclusion can be derived from this chapter: (1) the exploration of preferences regarding energy justice, like participation and investment influencing ownership; (2) public preferences on ownership structures, of which the choices influence perceived energy justice.

Generalisability to the Utrecht population (and beyond) of the conclusions is limited. The sample has an overrepresentation of highly educated people. Young couples without kids are also more than in the Utrecht population. Furthermore 51,5% of the people lived in apartments, which potentially influences the way they evaluate 'collective solutions' for heat provision.

7.8.1. Findings on energy justice

Energy justice was integrated as a concept to support and extent the findings on ownership preferences. Assessing the concepts of procedural and distributive justice, more sustained conclusions could be derived from the ownership exploration.

7.8.1.1. Procedural justice

Application of the procedural justice aspects (participation, information and trust) has resulted in the following findings. First, heat cooperatives are known for their relation to *influence* and *self-supportiveness.* It was found that self-supportiveness and influence are less important than other aspects for the heat provision. This puts the importance of *participation* in perspective*,* it was found that participants want to have influence on the development of heat networks. None of the respondents (N=198) did *not* care about participation. Most people wanted to consent (voting rights) and some were okay with being informed or consulted (given *information*). Only a few people wanted to have ownership rights. Despite the consenting preference, having influence is only more important than clear bills (when ranked). It was found *none* of the participants did not want at least want to be informed, contrasting with the ranked importance of 'clear bills', which – in terms of information – is lowest ranked in the aspects of importance (but still valued 'important').

Regarding *trust* it was found that it is rather important compared to other aspects (lower than technical functionality aspects, and – when ranked – costs and effort aspects). Furthermore, it was found participants had a high level of self-trust, to be able to fix an alternative for natural gas. Most trusted organisations were public, which means respectively municipalities and public grid operators.

7.8.1.2. Distributive justice

Application of the distributive justice aspects (cost-benefit, responsibility and access) has resulted in the following findings. Regarding perceived equal division of *cost-benefit* it was found that self-supportiveness was among the least important aspects of heat provision, even as the potential distributive effects of ownership rights. Only 10% of the participants wanted to have ownership rights. It is likely that this 10% has chosen ownership rights, because of distributive reasons. Consenting rights were already accounted for in other values. Regarding the connection fee, it was found that almost 45% of the participants wanted to pay in terms opposing 32% preferring to pay upfront. Following from

these results and the large amount of people who were discussing the options (answering 'different'), it showed that there is no clear consensus on the distribution of costs and benefits over time.

In terms of *responsibility*, the ranking the aspects on heat provision provided the insight that effort – in terms of adjustment to their house – is preferred to be low. Participants prefer not to take too much responsibility. This is confirmed by the responsibility assigned to the municipality. It is mostly perceived to be just when municipalities take responsibility. The case of the heat cooperative also indicates who and how participants perceive (their) responsibility. Most (90%) are willing to spend just a few hours a month or no time at all, hence they don't feel responsible. In terms of investment almost half of the people would be willing to invest, the other half would not.

A bit more insights have been found on the aspects influencing the investments: it is proven that there is moderate relationship between people's *willingness to invest* in heat cooperatives and the type of influence they prefer. People willing to invest are more in favour of ownership rights and consenting, than people who are not willing to invest. Lastly, depending on the type of *house ownership* (rent, owner) reveals how people assess the type of influence (moderate relationship) they prefer, assess the connection fees proposal (strong relationship) and the responsible organisation for their natural gas alternative.

7.8.2. Preferences on ownership structure

In general terms the distributive justice evaluation is not assessed on all parts of the value chain[39]. The ownership type in general had been assessed: so, what do people think of private, public and cooperative ownership for district heating?

7.8.2.1. General evaluation of ownership type

In terms of responsibility, most people find the municipality (public) responsible to offer them an alternative for natural gas. In terms of trust, most people have a high level of self-trust in organising an alternative for natural gas. Almost 2/3th of the respondents also trust the municipality with organising an alternative. Only about 2/5th of the respondents, trust grid operators, housing corporations[40] and energy companies with organising the alternative. Nevertheless, on average these organisations are not distrusted. Neighbourhoods are less trusted, which could be explained by the lack of an organisation 'representing' this neighbourhood or could be a sign of 'scepticism' on the power their neighbourhoods could develop within the stakeholder play[41]. Thus, most people find *public organisations* – mostly represented in the municipality – responsible for the heat transition, and most people trust them as well. High self-trust levels contrast in terms of cooperative organisations with the low trust in neighbourhoods, possibly indicating that people find themselves capable of organising individual solutions.

7.8.2.2. Mixed ownership

The participants who were in favour of cooperatives were explored on their distrust towards public and private organisations: this seems not to be the case. But then again, these groups trust municipalities slightly more than they trust private companies. Hence, when a heat cooperative develops and wants to combine ownership with private or public organisations, there can probably be

[39] Only distribution and generation, because this split is most non-technical to propose people. Other splits were found to be too technical to be assessed by the public.
[40] If applicable to the respondent
[41] But, people currently using natural gas are more positive than people on the trust in their neighbourhoods to organise a heat cooperative. Which makes them a bit more optimistic than people currently using Eneco district heating.

a relation of trust. But, their willingness to cooperate with public organisation seems to be higher than their willingness to cooperate with private parties.

A hypothetical situation on ownership of heat generation (source) and heat distribution (network) is measured. It is found that the municipality scores high on both parts of the heat chain: which could be explained by the measured responsibility and trust people assigned to municipalities. In contrast to the responsibility and trust levels, most people do find private energy companies fitted to generate heat. This might be explained by the fact that people think 'waste heat' can be sold by the companies obtaining that heat. Electricity grid operators are also highly valued as potential owners of the heat grid. This combination of public grid operators and private companies could also analogised from the electricity market: in which this same split has been regulated in the market design. But despite this finding, there is no evidence that people find vertical integration better or worse than no integration.

The deeper assessment of asset ownership gave us the insight that most participants prefer that public companies to own the network, giving space for competition of all types of sources like municipally owned, privately owned and cooperatively owned sources. Another important ownership design option was municipally integrated. Furthermore, despite relatively disfavouring findings on heat cooperative sub-questions, the cooperative integrated ownership structure was also relatively high preferred.

7.8.3. Possible implications of 'three streams'

The ownership preference findings can be conceptualised in the following strategies: the splitting and competition stream, the public ownership stream and the cooperative stream. These streams could affect procedural justice with participation, information and trust. There is not much trust in the development of heat cooperatives, despite the theoretical and expert insights on this. But when established, information could be personal and participation evident. This is inherent to the ownership structure of cooperatives. The competition stream aims to trust on governmental ownership of the network to create a level-playing-field. Probably analogised from the electricity market. Competition and freedom of choice creates the power to residents to participate: competition is trusted not to create unbalance; thus, information is less important. The municipal stream finds the municipalities responsible and are trusted, because of democratic legitimacy and power to influence that way. Participation is assumed, because municipalities are incentivised not to get angry citizens.

These streams effect distributive justice with access, cost-benefit and responsibility. Heat cooperatives are not per se creating equal access. They do align equal costs and benefits between owners and users. They don't create equal responsibility because you might have free riders and non-free riders. Public ownership of network can create equal access. Equal or equitable cost and benefit division between owners and users is most likely only perceived sufficient when competition is achieved. In terms of responsibility, the municipality guarantees equality by owning the network. When the municipality is responsible for the complete value chain, all distributive effects are aligned. Access, cost-benefit (not for profit) and responsibility (indirect joint responsibility).

7.8.4. Reflection on sociotechnical system

The sociotechnical system was defined with technical, institutional and actor aspects. The results of the public preferences have influence on these aspects. In technical terms, it is currently unclear to what extent competition or 'openness' is possible on the network. Especially to what extent it is 'cost-effective' and contributes to public goals (security of supply, affordability an sustainability (Kamp, 2017)).

In terms of the actor context the findings have influence on the current 'formal chart' for the heat transition. When a municipal monopoly or competition would be established, e.g. no discussion with Eneco on the heat transition would be needed anymore. The network – and therewith the upmost transition from natural gas – is established by the municipality. The stakeholder field would be diminished, because a single institution gets more responsibilities.

In terms of institutions the ownership changes will change the property rights: a level two change (Williamson, 1998). The theoretical timeframe of this is 10-100 years, meaning that it would mean major differences in how we institutionalised thus far. The question is whether these changes would be possible and feasible. In theory, policy making can be holistic (and rationally) or incremental (Lindblom, 2018). The latter being the most realistic and common one.

8. Discussion

In the discussion section, we reanalyse and contextualize the results. Therefore, the major findings are interpreted and related to theory. Furthermore, the limitations of the executed research are discussed, surprising results are explained and suggestions for further research are given.

8.1. Interpretation of findings

This thesis has found some useful information on district heating development in the context of the heat transition. Using the sociotechnical analysis of district heating in Utrecht, it was found that *a visualisation of the design space for ownership in the heat value chain can function as a conversation starter on ownership of district heating (16Gs, 2018). Modelling opportunities towards the analogy of the electricity market is limited because of limited network scale and dependency on local contexts (1Cn, 2018; 9Pr, 2018; 11Pr, 2018; 14Go, 2018).* It was found that regulations on district heating systems are currently heavily debated. Therefore, to what extent opportunities of ownership are conceivable depends on your perspective in the debate. Economic narratives emphasize that *transaction costs and changing environments currently limit the potential of mixed ownership (9Pr, 2018; 11Pr, 2018; 14Go, 2018)*, limiting the ownership opportunities. Vertical modelling – combining different ownership types for different parts in the value chain – seems to be limited because financial external risk mitigation is limited (e.g. insuring weather risk when you are delivery-only company). Horizontal modelling – combining different ownership as joint venture for the complete heat value chain – seems to be limited because unforeseen consequences are numerous in a changing environment. Opposing the economic narrative, the equality narrative emphasizes equal access for both consumers and producers – of all ownership types – to an infrastructure replacing natural gas. This viewpoint assumes that economic and technical issues can be overcome, increasing the ownership opportunities in terms of ownership division in the heat value chain.

The second finding relates to the purpose of the influence of energy justice on ownership. By means of expert-interviews, it was found that *public and cooperative ownership include most energy justice related principles.* These include aspects like equal access, public accountability, consultation etc. Despite this finding, it is still unclear whether a public monopoly could solve the perceived injustice in the consumer-producer relation. Justice indications are that *municipalities are most trusted organisation (median='trust', all others are 'neutral') in the heat transition and municipal ownership is mostly preferred for integrated companies (52-63%)*[42]*.* Generalisability is limited, due to the limited sample representativity of the Utrecht population: almost exclusively highly educated people have – voluntarily – participated to the survey. But, assuming energy justice as one of the motives for this preference, it indicates that integrated municipal ownership can be a solution for perceived injustice in the current private ownership situation in Utrecht. These findings indicate the preferability according to most participants, but do not clarify on the motives. Further explanatory research is needed to demonstrate to what extent energy justice is perceived in different ownership structures.

The third finding, again limited in its generalisability, encompassed that *Utrecht residents did not mostly – but still substantially (45-50%) – prefer cooperative ownership*. Cooperative ownership not being mostly preferred was unexpected. According to experts – in line with literature – cooperative ownership is superior to other types of ownership in terms of financial involvement and participation: two important strategies creating energy justice in the case of wind turbine placement (Gross, 2007;

[42] Less preferred, but also distinguished as a good type of ownership for integrated value chains, is the heat cooperative.

Langer et al., 2017; Warren & McFadyen, 2010)[43]. It seems that the ownership rights and financial participation aspects of cooperative ownership – resolving the perceived injustice in the current private monopoly –, do not outweigh the costs of organising a cooperative. Participants were on average *neutral on the expectation that a heat cooperative would be established in their neighbourhood[44]; participants were neutral on investments in heat cooperatives; most participants were not very keen on putting effort in establishing a heat cooperative (45%=0 hours, 49%=1-4 hours per month).* In comparative assessment it could well be that participants did not see how the burden of organising a heat cooperative – in both time and financial risk – could be equitably distributed among members of their community, without using the municipality as their overarching institute. Another explanation could be that people might not perceive the injustice yet or might not perceive the burden of financial injustice (DH) as important as the burden of environmental injustice (NIMBY-effect).

The fourth finding is the *preference of Utrecht residents to involve private energy companies (61%) in heat generation on a public (grid operator) heat network.* This is surprisingly, since energy companies are less trusted and accountable than public organisations for the heat transition. These findings show that the two narratives on the development of the district heating are also present among the Utrecht population: should we (1) aim for justice by freedom of supplier? By establishing an equal level playing field allowing for competition among producers and freedom of choice for consumers? Or should we (2) aim for justice by public ownership? Establishing equal or equitable access to a natural gas alternative?

The fifth finding – the establishment of the three streams – *indicate that all ownership structures of district heating influence energy justice differently.* Based on the considered aspects of energy justice, it was found that the three preferred streams create procedural justice in their own ways. All streams can create their own ways of consenting. Furthermore, trust and information access are created by competition or accountability, of which the latter can be on the municipal and community level. For the distributive justice it was found that some ownership structures in theory create more equal access than others; perceived equal distribution of costs and benefits are achieved by competition, non-profit or equal investment opportunities; clearly assigning the responsibility to the municipality indicates there should be an equal responsibility among all citizens. Heat cooperatives are the exception, creating a possible responsibility injustice between citizens in terms of effort and investments, achieving a common goal.

8.2. Contribution to theory

This thesis is contributing empirical observations regarding energy justice and ownership. The first contribution relates to the concept of energy justice. Energy justice is an increasingly important field of study in the context of the energy transition. The transition towards distributed energy production from renewables challenges established justice relations, based on freedom of choice among competing energy producers. Energy justice aims to consider these new relations, in which burdens and benefits are more equally distributed. One of the most prominent examples in the field of energy justice is the literature on both procedural and distributive strategies to cope with negative impacts of wind turbine placements.

[43] In the environmental justice literature on wind turbines one must deal with the continuous burden of sights and sound within a community

[44] Both in terms of expectation of development of a heat cooperative, as well as the trust in neighbourhood to fix an alternative heat provision.

This thesis aimed to address the energy justice concept in the context of district heating, namely in the perceived distributive injustice of owning a monopoly infrastructure while having the possibility to make profit. It contributes in the enlargement of the energy justice literature. Furthermore, it provides a critique on the acknowledged benefits of cooperative ownership for energy and heat projects. Whereas the distributive injustice of wind turbine placements (namely, the burden of hearing and seeing the wind turbine in your daily life) can be influenced with financial redistribution towards influenced communities, injustice might better be solved with equal, fair and not-for-profit ownership in the case of district heating development (Becchis et al., 2011). As where community ownership (e.g. cooperative) is often appreciated as the best ownership strategy to achieve energy justice for wind turbines, this thesis highlights municipal ownership as the best ownership strategy to achieve energy justice in monopoly infrastructures. Even more because in the case of heat cooperatives, unequal financial distribution in the community can create new distributive injustice among members of the community.

In terms of ownership, this thesis adds an explorative case on the debate on ownership of utility infrastructures. What should be public? What can be private? Most studies are done for electricity in the past, especially describing the privatization 'wave' in the '80s. The privatization was meant to sustain equity, considered a public value – by dividing ownership of the value chain and competition among energy producers. The findings of this thesis that there should be (1) competition or (2) a form of public ownership also confirm the two historical situations in the electricity infrastructure: from integrated public utility, towards created market allowing for competition (Savas & Savas, 2000; Sheshinski & López-Calva, 2003). The findings of this thesis criticize therefore the establishment of regulated privately owned monopoly infrastructures, without competition.

8.3. Limitations

In the way the research was conducted the following limitations can be found. First some general limitations of the framework and the way the quantitative study is undertaken are assessed. Then, the validity of the project is assessed.

Deriving conclusions is limited, for example with the 'three streams': despite the attractiveness of concretising these streams in ownership structures, there should be noticed that the design opportunities are broader than the distinction made of distribution and generation in the survey. As proposed, patterns of ideas can be derived from this, but it does not include a full assessment of the design space. Hence the three identified 'streams' act as guidance, not as solutions. One of the main limitations is that there are more design opportunities possible reflecting equality by public institutes. Examples are the possibility of organising a public-private joint venture, or increasing the public influence in a private energy company (e.g. by preferred shares).

Furthermore, some assumptions have been made in the research. One of the assumptions is that we cannot relate the influence of the ownership structures on the energy justice of district heating: it is assumed that justice motives are among other reasons why people trust and 'fit' specific ownership types, and why not. In addition, what people 'find' just, does not necessarily mean it 'is' just. Clearly, the survey set-up limits taking the latter into the analysis.

8.4. Limitations on validity

Assessing the validity has been done by answering the question: did it measure what it was supposed to measure? And is the information obtained generalisable? The conceptual framework has been validated by discussion with a TU Delft researcher, specialised in energy justice. The perceived injustice of district heating in the Netherlands, was – according to him – clearly related to the concepts of procedural and distributive justice. The concepts to operationalise have been taken from literature,

being aspects linked to justice. It was not aimed to define a set of indicators assessing to what extent procedural or distributive justice is present. Hence, no conclusions regarding 'how and to what extent' specific ownership structures are just, can be stated.

Validation efforts regarding the sociotechnical analysis are split among the three elements. The technical analysis has been validated internally by the knowledge which co-workers have provided during the internship. The formal chart of the stakeholder analysis has been validated using the multi-actor interview of the 'heat table Utrecht'. Furthermore, validating the identification of stakeholders has been snowballed among the interviewees to assess its completeness. The institutional elements, mostly based in literature, have also been validated with the interviews with general experts. Overall, the interviews and expert discussions play an important role on the validation of the sociotechnical analysis. The validity is limited in terms of different empirical sources.

The results of the design space have been validated within three validation interviews (5Co, 2018; 11Pr, 2018; 14Go, 2018). Especially in the cooperative validation – as a small-scale neighbourhood level initiative – the ownership choices which they – at the time of writing – needed to do, aligned with the design space. Whether these choices are generalizable depends largely on the regulations which are currently under revision (14Go, 2018; Kamp, 2014, 2017). Another limitation of the validity is that it has not been tested as a design tool, only as a discussion starter.

The public preferences validation is also limited, the same study has not been used in different cases or different study objects; another empirical tool, like customer interviews or focus groups, has not been executed for the validation of the report. However, this was not aimed for due to its explorative purpose. Within the single method strategy, the survey's representativeness of the sample has been limiting generalisability: the conclusions this thesis had demarcated were not representative for the whole population. Especially lower educated people were underrepresented in the sample.

Despite these limitations, some efforts to maximize validity within the survey have been undertaken. Regarding the internal validity, the survey design had been validated with specialists on survey design and answers on questions were randomized. Regarding the external validity the survey method was chosen to be able to generalise the results for the population of Utrecht. According to Babbie (2010) surveys are particular good for that purpose. Also, it is good for the representativeness of the quantitative results, because exactly the same questions are asked, in that sense it can be named standardised (Babbie, 2010).

8.5. Further research

Based on the finding of the preferred competition on public heat networks, a clear indication for further exploration of competition has been found. Furthermore, the exploration of preferences, among ownership structures in the Utrecht case study, needs further research to get generalisable results for local decision makers and regulators on how ownership structures are perceived in terms of justice. For the first, a comparative study on perceived justice among private, public, cooperative and mixed district heating systems in the Netherlands would clarify the justice from *empirical* perspective rather than from hypothetical perspective. For the second, further research could focus on the question what exact physical part of the value chain is most important for perceiving justices by residents. For example, the identified 'justice by competition' could focus on creating level-playing-fields. Focus of regulators would then probably be on network/transport assets. 'Justice by equality' is mostly perceived through the organisation in contact with the customers, which probably means the delivery part of the value chain. Hence, it is currently unclear on which part of the design space the regulator should focus to increase the perceived justice.

More theoretical research could focus on the development of indicators for energy justice in the heat transition. Literature on environmental justice can initiate this development but needs revision in the context of energy and the context of the heat transition. Suggestions of indicators include distributive justice (e.g. access to financial participation, financial transparency, equal access to NG-alternative, equitable burden (of pilot projects) and procedural justice (presence of local representatives, participation methods, access to information).

A study devoted to clarifying the motives to choose for different ownership structures is recommended, to indicate what would be the benefits of subsidizing or supporting specific ownership types by the government. The main question is: in what context and why would you choose a specific type of ownership? As an example, the drivers and barriers of *heat cooperatives* in the heat transition could contribute to knowledge on cooperative ownership in general. It would be interesting aiming to find under what circumstance heat cooperatives could fit the community and contribute to energy justice. What are indicators in the community for success of heat cooperatives (e.g. small town compared with big city)? But, in comparison with the electricity generating cooperatives, how is cooperative heat different from cooperative electricity? What community characteristics are differing for energy and heat? To what extent does this analogy function?

Furthermore, following-up the exploration on the public preferences could take away some of the weaknesses of the survey – especially the artificiality problem – by discussing *hypothetical* situations in focus groups. By providing (1) background knowledge on the technology and (2) transparency on the costs of different ownership structures, focus groups could give insights in how different structures are perceived. Questions to be answered could be: why does a majority of people think the private bodies should generate the heat and public bodies should do the network? Because people think it should look like the electricity market?

Lastly a more in-depth study on how people assess their *financial choices* would be beneficial for the pace needed in the heat transition for which quickly large investments are needed. For example, the qualitative data revealed people would not be willing to pay 30.000 euro upfront but think 5000 euro is acceptable. This range had been chosen because it is very dependent on the local circumstances what the costs would be. How the financial choices would be made and how people value ownership in specific situations, will most probably be different: what people are willing to pay is dependent on what they would get in their specific situation.

8.6. Recommendations

The recommendations are assessed per targeted audience. The audience can be summed in the following stakeholders: (1) Heat transition table, being the group of stakeholder in the Utrecht situation deciding on who is going to develop the new heat provision in Utrecht and how, (2) Eneco, being the current owner of district heating networks in Utrecht, (3) the municipality (of Utrecht), as the problem owner for the change of the natural gas connections in neighbourhoods, (4) the regulator, what recommendations regarding the 'heat law' can be derived from this study, and (5) heat cooperatives (in development). The part following to these recommendations are exemplary assessments of theoretical – but existing – cases in which the ownership design space can be used to assess the ownership choices.

8.6.1. Heat transition table

Being the cooperation of different stakeholders in the heat transition, the heat transition table was indicated to be able to influence the heat transition. The findings of preferences suggest that regulating private companies might not be enough according to citizens – or should be well explained. When competition is possible, private energy companies have a role as they have in the electricity market.

Furthermore, the three streams indicate that different visions on heat provision by district heating exist. On the level of the city, no clear vision is found on what should be aimed: the amount of people, indicate the amount of opinions. On the short term this research found evidence to have a form of public ownership. The limitations of the survey in terms of full assessment of the design structure considering, it is recommended to increase the perceived municipal influence for new district heating networks to diminish the perceived injustice of private monopolies. For example, this could be done by transparency in arrangements between the Eneco and the municipality.

On the longer term I recommend two strategies to deal with this: (1) minimize the scale, (2) increase the openness. The first strategy aims to find community stances in the debate, e.g. there might be (small) concerned neighbourhoods willing to invest more time and money in being self-sufficient as a community. On the other hand, there might also be communities where price is most important. Thus, reaching out towards (potential) communities on a local level is key to find the preferred ownership structure. The second strategy I propose is to increase the openness of the network – not aiming for competition per se. Creating an 'open playing field' and/or diversified options might fulfil the most divergent opinions on ownership. An open network potentially justifies most consumer demands and allows for most diversified design opportunities. The success of the latter depends on the technical innovations and overall scale of the created networks.

8.6.2. Eneco

Particularly from the study on public preferences, valuable conclusions can be derived for Eneco. It provides insights in the public preferences on desired ownership situations in Utrecht. It is found that heat generation is mostly preferred to be privately owned. Therefore, the company could aim to strengthen its grip to heat generation in particular: especially having the knowledge that the largest source in the district heating network – the heat coupled power plants at Lage Weide and Merwedekanaal – will be phased out in the coming years. If competition on heat generation becomes regulated, frontrunning in heat generation might give a competitive advantage in the future.

In terms of customer relations, the self-trust of participants is high. Therefore, creativity in business models should be aiming to harvest this 'capability'. Contrastingly the cooperative model is not so likely valued by residents, having little trust in their neighbourhoods. Business opportunities might be present in combining these counteractive forces. For example, (1) guide the *organization process* of a cooperative, (2) guide, manage and simplify the *development* of the district heating system for the cooperative, (3) acquire *investments* through the members, (4) acquire a long-term service- and management contract. This business model would enhance (1) the low trust level in neighbourhoods, (2) ease and comfort the time-constraints of expected voluntarism in heat cooperatives, (3) give an investment opportunity to members. This opportunity could be justified by increasing the perceived energy justice, but limitations could entail the 'wrong' economic optimization stimulus for Eneco[45].

Other recommendations are related to the marketing for new heat networks: this should build on this self-interest of people, possibly by offering them more options for payments of grid connection[46]. It has been found that most participants are satisfied with the current post-paid system. But a rather high percentage of the participants – especially house-owners and keeping in mind the sample

[45] In this model, Eneco is stimulated to do as much 'service and management' as possible. Instead of optimize the investment vs. output of the district heating system (12Pr, 2018)

[46] Future technologies (4GDH) on the heat networks could create a level-playing field where people could be more in charge of their own heat generation, like the electricity generation (H. Lund et al., 2014). Based on the results of the 'self-confidence' of people, this is probably highly valued by people. So, when there is technically more possible to share decentralised heat production by the network, this should be aimed for by network owner.

limitation – are interested in paying upfront the connection fee and pay a cost-based price for their obtained heat[47]. The connection to the network could be sold as a value in their property, organising this per house. This would entail there is not only a relation with the customer (for the product), but also with the address. When houses are changing owners, the property contract could include the rights to buy cost-based heat from the network or the duty to pay the terms for connection fees. So, for example: you can (1) pay the whole fee upfront and then only pay for the heat and the maintenance, you can (2) borrow money to pay the connection fee back in 5 years, or (3) pay in terms anyway through your heat tariff. These business opportunities should be further assessed by the company or in scientific research, since the findings of these results are based on exploration.

Since the municipalities are highly preferred, the relationship with the municipality could help to improve energy justice. It is recommended to strengthen the relationship between Eneco and the municipality. Especially regarding procedural justice aspects, the municipality and Eneco should not only inform or consult the people: based on the preferences of the participants they should be able to consent with the development plans.

8.6.3. Municipalities

Based on the public preferences, the trust residents have in municipalities to organise and manage parts of the district heating value chain is high. There is a trend that municipalities should not be entrepreneurs in cases where the market could manage. This is the case with the selling of energy companies to the market (Nuon, Eneco etc.), but also with the older DH-networks, which were privatised not so long ago (like Utrecht and the Amernet). The question is whether the regulated monopolies are satisfying for residents in terms of justice. Based on the results there is a reason for municipalities not to rely too quickly on market parties. As reasoned at the heat transition table, it is therefore recommended to increase perceived influence in the first place.

8.6.4. National regulator

Discussions on and revisions of the heat law are currently taking place. In terms of ownership it is discussed if prescribed ownership situations along the value chain (based on ideas from the electricity market) could achieve more cost-effective solutions. But by regulating it in a law, less local flexibility is possible. Since it was found that regulations need to be very clearly stated, without possible ambiguity (14Go, 2018). It is recommended to keep the decision making as local as possible, due to the highly complex and situational optimums. The instrument of the design structuring has proven effective (16Gs, 2018). It is suggested that more clear tools (flow charts/questionnaires etc.) are developed on a national level, so there is a clear decision-making structure to ‘make the local fit’. It is important to do so, because implementing the technology is one thing: keeping people satisfied and situations justified on the long term, is another thing. This is particularly important since the infrastructure will create path dependency for the coming decades.

Based on the research, no clear encouraging of a specific type of ownership is recommended to be regulated for the entire country. If trust levels for resident initiatives would have been very high, recommendations to target a higher share of cooperatives in the district heating ownership mix, could make sense. Based on the exploration there is no reason to encourage a specific type of ownership: achieving the local best should be the aim but can be very different throughout the Netherlands and beyond.

[47] The specific lump sum should be assessed more, not only by the costs of the network, but also in terms of the willingness to pay of people. Qualitative assessment of the survey offered the insight of people doubting with this question based on the specific amount: some are willing to only pay €5000 and others more.

8.6.5. Cooperative initiative

When citizens are keen on organising their own collective heat provision, they are recommended to use the design space to structure their cooperative ideals with ownership of the infrastructure. Since they are not professionals, they must be empowered with tools and ideas to be able to make the right choices for their local situation. On the other hand it is likely the initiative has to acquire external knowledge as well, possibly from private or public companies aiming to own a part of the cooperative ownership structure (5Co, 2018). Using the design space, they are offered a tool for discussion and negotiation with these parties.

Furthermore, because of the more thorough analysis of public preferences for the cooperative initiatives (community-based heat cooperatives) some more recommendations can be made. The first aspect is the cautioning that initiatives must go through a though process. Explored by the survey people do not have a natural trust in their neighbourhoods to develop these complicated infrastructures. In terms of the developed of social capital, organising a cooperative could make the neighbourhood come together more and become a 'community' (5Co, 2018). This is very positive, but time consuming as well. On the other hand – if there are some game changers in the neighbourhood – the sample is willing to invest money and (some) time if needed.

9. Conclusion

The aim of this thesis was to explore what ownership structures for district heating systems would be preferred by residents as an alternative for current gas-based heat provision, taking Utrecht residents as a case-study. This was relevant to increase the perceived justice of district heating, which is important since it is one of the collective alternatives to natural gas heat provision, which is being phased-out at the time of writing in the Netherlands. Therefore, the main research question was:

What ownership structures for new district heating systems would Utrecht residents prefer?

In order to answer this question five additional questions were defined:

1. How is energy justice related to ownership of natural monopoly infrastructures?
2. What are the actors, institutions and technology when the sociotechnical system of heat provision changes from natural gas to district heating in Utrecht?
3. What is the design space for structuring ownership of district heating?
4. What are the differences and similarities on strengths, weaknesses, opportunities and threats for ownership types of district heating at present in the Netherlands?
5. What choices in ownership of district heating systems reflect the preferences of Utrecht residents?

The first sub-question was answered by a proposed conceptual model on energy justice, based on the main two types of energy justice: procedural and distributive. These have been operationalised for assessment. It was found that justice is related to ownership of natural monopoly infrastructures by means of the concepts for procedural justice: participation, information and trust; distributive justice is explored with the concepts of cost and benefit, access, and responsibility.

Design concepts for asset ownership (X-axis=Ownership Options, Y-axis=Design concepts, Red=large scale network only)						
1	*Generation*	Public	Private	Cooperative		
2	*Transportation*	Public	Private	Cooperative		
3	*Exchanger*	Public	Private	Cooperative		
4	*Distribution*	Public	Private	Cooperative		
5	*Delivery*	Public	Private	Cooperative		
Design concepts to combine ownership						
6	*Joint ventures*	Public private partnership (PPS)	Private cooperative partnership (PrCS)	Public cooperative partnership (PuCS)	No partnership	
7	*Stock division*	Public majority	Private majority	Cooperative majority	No partnership	
8	*Preferred shares*	Yes	No			
9	*Level of integration*	No integration	Two parts of value chain	Three parts of value chain	Four parts of value chain	All parts
10	*Contract type*	Concession (ESCO)	Lease	Management	Municipal support	No contractual agreement

Table 9-1 Design Space

The second sub-question was answered by researching the stakeholder field and relations and describing the technical and institutional changes during the heat transition. It was found that changing from natural gas to district heating has little effects within households. Contradictory, the development of the infrastructure would demand significant efforts. This is one of the reasons why the actor environment is complex, involving a large number of actors with very different stakes and relationships. Lastly it was found that institutions of higher order will be affected: new contracts among parties will set and the customer strategies will change.

The third sub-question was answered by proposing a design space to describe ownership structures. It was found that the design space can be, and is often, analogised with the design space for electricity infrastructure. The extent in which analogizing is feasible, depends on technical and institutional aspects. The identified ownership types (public, private and cooperative) were assessed on their strengths, weaknesses, opportunities and threats influencing their success in for the heat transition. This answered the fourth sub-question. It was found that (1) there are external factors influencing all ownership types equally (like tax increase), (2) the institutional context often influences ownership structures contrastingly (e.g. market tradition). Also, it was found that arguments in favour of private ownership often included business-oriented reasons. In favour of cooperative ownership arguments often included influence reasons. In favour of public ownership arguments often included social reasons. Mixed ownership arguments often argue that – possibly – win-win situations occur.

The fifth sub-question was answered by measuring the preferences by a designed online survey to explore ownership preferences within residents (N=198). The sample's representativeness for the Utrecht municipality was limited, since respondents had higher education level than the average Utrecht population and a lower percentage of respondents living in social housing (-32%). Generalisability was limited, since many respondents lived in apartments (51%). We found indication that most respondents appreciated the role of public organisations (e.g. public electricity grid operators and municipalities). Findings also suggested that network activities are the most suited for public ownership. Energy companies were most selected (61%) for the ownership of the generation activities. While community-owned heat cooperatives offer opportunities to enhance justice, this structure was selected fewer times (45-50%) Further analysis of these results offered us three preferred 'streams' of ownership structures: integrated municipal, integrated cooperative or disintegrated private/grid operator. It is expected that the latter was preferred assuming competition, but this has not been demonstrated. In contrast to the preferences on the heat cooperative, it was found that participants did not found it 'likely' that heat cooperatives will rise in their neighbourhoods.

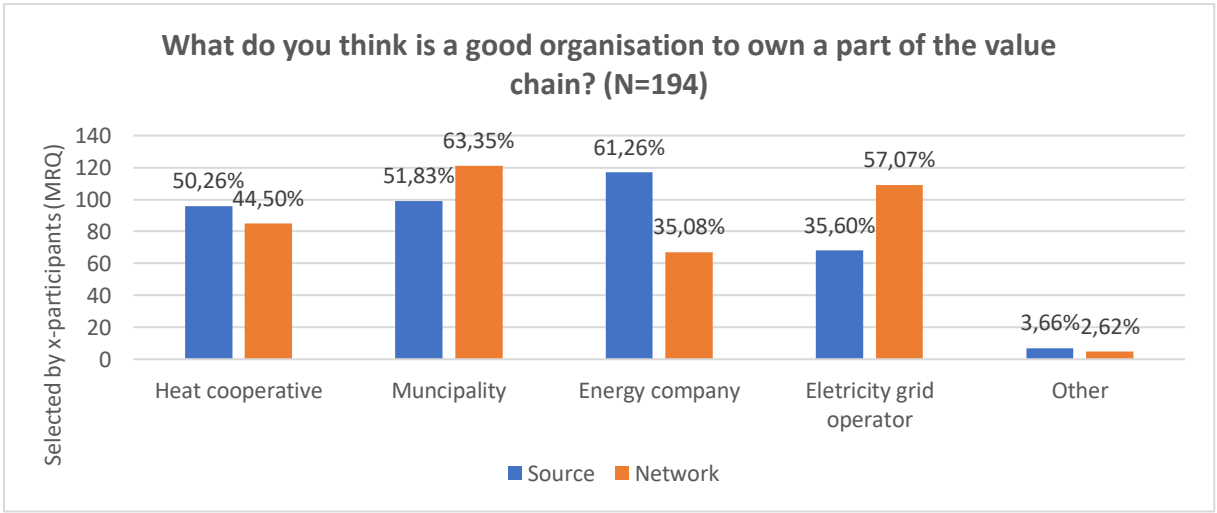

Figure 19 Ownership preferences

In terms of procedural justice, the majority of respondents wanted to have the right to consent (47%). A moderate relation was also found with house ownership: being a house owner increased the level of participation. Financial participation by becoming owner, was preferred by a minority of respondents (10%). This seems to be unrelated to the willingness to invest, as more than 30% was willing to invest upfront in connection fees or heat cooperatives. Municipalities and grid operators were often indicated as trusted organizations, with smaller numbers for energy companies and neighbourhood organizations. Answers revealed a slightly higher trust for public bodies owning parts of the district heating value chain and a preference to be able to consent to the deployment of technology.

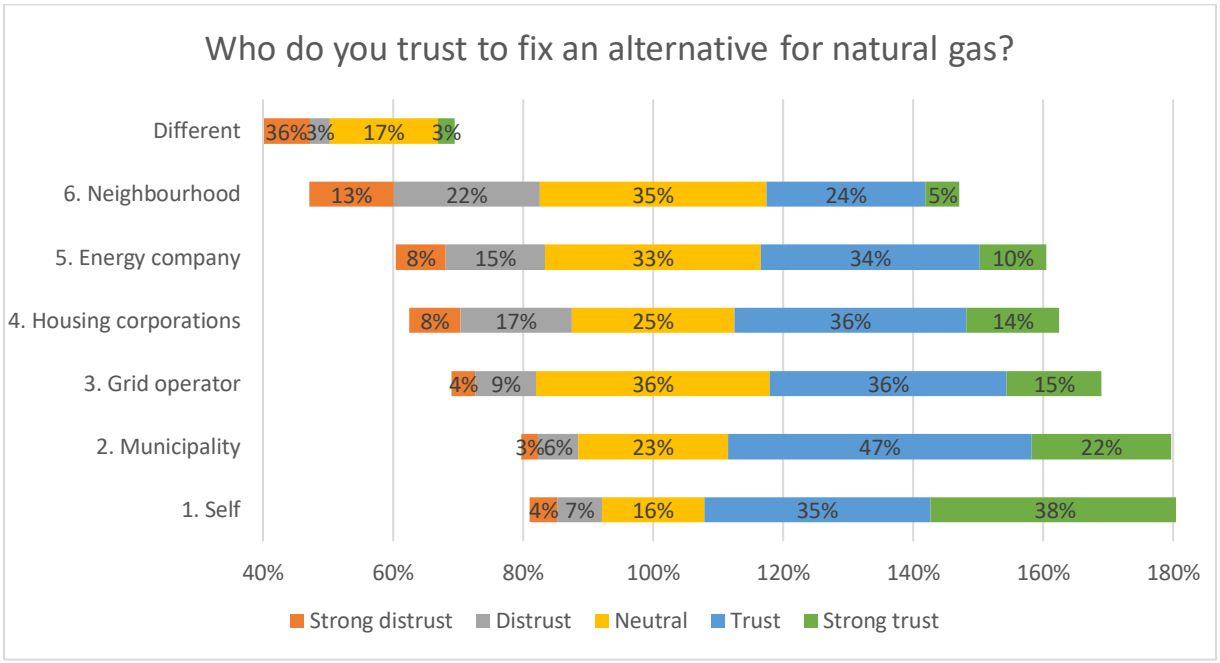

Figure 20 Organizational Trust

Hence, we can answer the main question: what ownership structures for new district heating systems would Utrecht residents prefer? Considering the limitations on the structuring of district heating by Utrecht residents – the design space was not fully assessed – this thesis has derived three 'streams' of ownership preferences: competition, integrated municipally owned or integrated cooperative. Despite its admirability, competition is currently limited according to experts. Furthermore, integrated cooperatives are considered to be preferred owners, nonetheless the lack of preferred self-responsibility, willingness to invest and trust in their neighbourhoods, indicated justice-related limitations in the development of heat cooperatives. Accounting for the limited validity of the explorative research, we cannot conclude that municipalities should be owners of new district heating systems. However, indications were found that public ownership of a natural monopoly is perceived to be more just – especially in terms of trust and responsibility – than private monopolies. It is therefore – and because of the complexity of the sociotechnical system – recommended to increase the perceived influence of municipalities on new district heating systems, extending the current influence they have on established district heating systems. Further research is recommended on further exploring the establishment of competition on heat networks.

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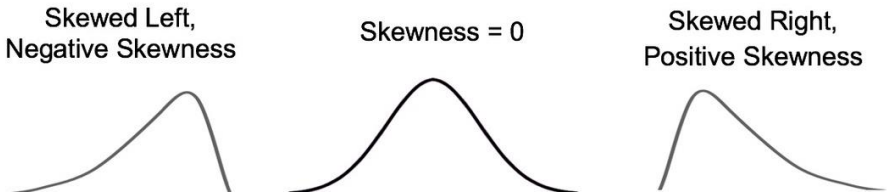
A. Appendix: Explanation of tests

Test	Interpretation
Comparative one sample median test	Tests the significance of the distance from an expected value. The expected value is an average from the compared aspects.
Skewness	Since the data is discrete and not continuous the skewness cannot be used to prove normal distribution. It can only be used to assess where the skew is. A negative value means the skew is to the right of the median, this means most people value an aspect high. A positive value means the skew is to the left of the median, this means most people value an aspect low. 
Kurtosis	To measure outliers: a high value means there are just a few extreme values. A value close to zero is an indicator for a more equal distribution.
Chi Square 'Goodness of Fit'.	The chi square 'goodness of fit' can be computed to see if the value measured is significantly different from the expected value.
Binominal Test	Same as chi square, whereas the expected outcomes of the two categories equal 50%.
Frequency Table	The frequency tables unravel the exact number of respondents which answered a specific value to a question.
Cross table	The cross tables unravel the exact number of respondents which answered a specific value to a question. This is two dimensional related to another nominal question, showing how many respondents answered both specific values in two questions.
Chi-Square of 'Independence'	To compare two or more groups within the sample on their independence. If alpha <= 0,05 the null hypothesis of 'independency of variables' needs to be rejected.
ANOVA Kruskal Wallis	To compare two+ groups within the sample on their independence. If alpha <= 0,05 the null hypothesis of 'independency of variables' needs to be rejected.
ANOVA Mann-Whitney U test	To compare two groups within the sample on their independence. If alpha <= 0,05 the null hypothesis of 'independency of variables' needs to be rejected.
Lambda	This is a PRE (proportional reduction in error) – test. A significant (alpha = 0,05) p-value of the lambda gives the lambda the meaning that the percentage would reduce errors in predicting the related variable (e.g. Lambda of 0,5 = you would make 50% less errors in predicting Y with X).
Phi/Cramer's V	According to Healey (2014) the relationship is weak between 0.00 and 0.10, moderate between 0.11 and 0.30, strong when its greater than 0.30

B. Appendix: Survey design

INTRO

Dit onderzoek gaat over de alternatieven voor de aansluiting op het gasnetwerk dat momenteel – in combinatie met de cv – zorgt voor een warm huis en uw warme douche. In Utrecht zijn meerdere oplossingen mogelijk die dit in de toekomst kunnen voorzien. Het onderzoek bestaat uit 32 vragen en duurt ongeveer 10 minuten. Door mee te doen gaat u akkoord met het verwerken van de gegevens op geanonimiseerde wijze.

ACHTERGRONDVRAGEN

DEEL 1/6

1. Woont u momenteel in de gemeente Utrecht?
   Ja/Nee (Als nee, dan geen verdere vragen beantwoorden)

2. Wat is uw geslacht?
   M/V/Zeg niet

3. Wat is uw leeftijd?
   18-, 18-25, 26-35, 36-65, 65+

4. Wat is uw gezinssamenstelling?
   Samenwonend met inwonende kinderen,
   Samenwonend zonder inwonende kinderen,
   Alleenstaand met inwonende kinderen,
   Alleenstaand zonder inwonende kinderen

5. Wat is uw hoogst genoten opleiding?
   Basisonderwijs/lagere school,
   LBO/VBO/VMBO (kader/beroeps),
   MAVO/VMBO (theoretisch),
   MBO, HAVO/VWO/WO-Propedeuse,
   HBO/WO-bachelor of kandidaats,
   WO-doctoraal of master

6. Wat is het totale bruto jaarinkomen van uw huishouden?
   - Minder dan modaal
   - Modaal (37.000 euro)
   - 2x Modaal
   - Meer dan 2x Modaal
   - Wil ik niet zeggen
   - Weet ik niet

DEEL 2/6

Dit deel van het onderzoek gaat over uw woning

7. A. In wat voor type woning woont u momenteel?
   Hoogbouw appartement,
   Boven- benedenwoning,
   2-onder-1-Kap,
   (Studenten)Kamer,
   Eengezinswoning,
   Vrijstaand huis
   Anders, nl. …….

   B. In wat voor woning woont u momenteel?
   Koopwoning
   Sociale Huurwoning
   Huurwoning
   Anders, nl. …..

8. Wanneer is uw woning gebouwd?
   <1930,
   1930-1979,
   1979-1992,
   1992-2000,
   2000-nu,
   Weet niet

9. In welke wijk woont u momenteel?
   West,
   Noordwest,
   Overvecht,
   Noordoost,
   Oost,
   Binnenstad,
   Zuid,
   Zuidwest,
   Leidsche Rijn,
   Vleuten-De Meern,
   Anders, nl. …..

10. Heeft u een gasaansluiting in huis voor uw CV-ketel, gashaard of gasboiler?
    Ja
    Nee, ik heb stadsverwarming
    Nee, ik heb een warmtepomp
    Nee, anders …..

DEEL 3/6

Momenteel gebruikt bijna iedereen in Nederland aardgas uit Groningen. Aardgas wordt door buizen naar uw huis gebracht, voor het verwarmen van uw huis en om warm te douchen. De regering vindt het belangrijk een alternatief voor gas te vinden. Daarom mogen nieuwbouwwijken nu niet meer op gas worden aangesloten én worden er plannen gemaakt zoveel mogelijk bestaande huizen van het gas af te sluiten. Alternatieve technieken om huizen te verwarmen en warm te douchen zullen steeds gangbaarder worden in uw omgeving.

Dit deel van het onderzoek zal gaan over het *probleem* van het gebruik van aardgas

11. Hoe *veel weet u al* over de alternatieven voor de gasaanslutiing?
    - Helemaal niet– Niet– Neutraal – Wel – Helemaal wel

12. Wanneer verwacht u geen gas meer te kunnen gebruiken? Kies één:
    - U gebruikt nu al geen gas
    - Tussen 0 en 5 jaar
    - Tussen 5 en 10 jaar
    - Tussen 10 en 15 jaar
    - Tussen 15 en 20 jaar
    - Later dan 20 jaar
    - U verwacht altijd gas te blijven gebruiken

Dit deel van het onderzoek (4/6) zal gaan over het *proces* om wonen zonder gas mogelijk te maken:

13. Wat vindt u belangrijk voor het alternatief van uw gasaansluiting? Geef bij iedere punt aan of u het heel onbelangrijk (0) tot heel belangrijk (5) vindt:
    - 100% duurzaam (CO_2-neutraal): Helemaal niet– Niet– Neutraal – Wel – Helemaal wel
    - Comfort: Helemaal niet– Niet– Neutraal – Wel – Helemaal wel
    - Geen storingen: Helemaal niet– Niet– Neutraal – Wel – Helemaal wel
    - Weinig aanpassingen huis: Helemaal niet– Niet– Neutraal – Wel – Helemaal wel
    - Zelfvoorzienend: Helemaal niet– Niet– Neutraal – Wel – Helemaal wel
    - Inspraak: Helemaal niet– Niet– Neutraal – Wel – Helemaal wel
    - Goedkoop: Helemaal niet– Niet– Neutraal – Wel – Helemaal wel
    - Heldere rekeningen: Helemaal niet– Niet– Neutraal – Wel – Helemaal wel
    - Veiligheid: Helemaal niet– Niet– Neutraal – Wel – Helemaal wel
    - Eerlijkheid: Helemaal niet– Niet– Neutraal – Wel – Helemaal wel
    - Lokaal: Helemaal niet– Niet– Neutraal – Wel – Helemaal wel
    - Anders, nl. ……

14. Wat vindt u belangrijk voor het alternatief van uw gasaansluiting? Rank voorgaande aspecten
    Zie vraag 13

15. Welke partij vindt u verantwoordelijk om het alternatief voor aardgas (voor u) te regelen? Let op: u kunt méérdere antwoorden kiezen
    - Uzelf (evt. met uw buurt):
    - De gemeente:
    - De Rijksoverheid:
    - Een energiebedrijf (Nuon, Eneco):
    - Netbeheerder (Stedin):
    - Woningcorporatie, Verhuurder of VVE :
    - Olie- en gasbedrijven (NAM, Shell, Exxon Mobil):
    - Anders, nl. ……..

16. In hoeverre vertrouwt u onderstaande partijen uw woning aan te passen om te kunnen wonen zonder aardgas? Geef bij iedere partij aan of u hen helemaal niet vertrouwt (0) tot helemaal wel vertrouwt (5):

- Uzelf (evt. met uw buurt): Helemaal niet– Niet– Neutraal – Wel – Helemaal wel – Weet niet
- De gemeente: Helemaal niet– Niet– Neutraal – Wel – Helemaal wel - Weet niet
- De Rijksoverheid: Helemaal niet– Niet– Neutraal – Wel – Helemaal wel - Weet niet
- Een energiebedrijf (Nuon, Eneco): Helemaal niet– Niet– Neutraal – Wel – Helemaal wel - Weet niet
- Netbeheerder (Stedin): Helemaal niet– Niet– Neutraal – Wel – Helemaal wel
- Woningcorporatie, Verhuurder of VVE : Helemaal niet– Niet– Neutraal – Wel – Helemaal wel – Niet van toepassing – Weet niet
- Olie- en gasbedrijven (NAM, Shell, Exxon Mobil): Helemaal niet– Niet– Neutraal – Wel – Helemaal wel – weet niet
- Anders, nl. …….

DEEL 5/6

De gemeente wil u graag meenemen in de besluitvorming over het alternatief voor de gasaansluiting in uw buurt. De volgende vragen gaan over hoeveel invloed u wilt hebben op de besluitvorming over uw buurt:

Stel u de volgende situatie voor: de gemeente Utrecht geeft aan dat u vijf jaar heeft tot de gasleidingen weggehaald worden in uw buurt. Naast individuele oplossingen (elektrische warmtepomp) geeft de gemeente aan dat uw buurt geschikt is voor het aanleggen van een warmtenet. De gemeente geeft aan dat dit in uw geval waarschijnlijk de goedkoopste oplossing.

Het aanleggen van een warmtenet betekent dat door uw straat of flat een buizenstelsel aangelegd wordt dat heet water verspreid naar uw woning. Dit buizenstelsel (netwerk) is aangesloten op een warmtebron. Wanneer een groot deel van uw buurt meedoet is dit het goedkoopste alternatief voor gas, ondanks de aansluitkosten.

17. Hoe zou u de aansluitkosten het liefst willen betalen?
    - In termijnen via uw energierekening (minimaal 15 jaar).
      U krijgt een relatief hoge energierekening en u niet wisselen van aanbieder (gelijk aan een mobiele telefoonabonnement met een telefoon op afbetaling)
    - Hoge aansluitbijdrage van tevoren (tussen de 5000 euro en 30.000 euro).
      U krijgt een relatief lage maandelijkse energierekening en u bent flexibel in de nabije toekomst uw huis op andere wijze te verwarmen (gelijk aan prepaid met een los toestel)
    - Anders nl. …..

18. Hoeveel invloed wilt u hebben op de besluitvorming als u *moet betalen* voor de aanpassingen aan uw woning?
    - U heeft geen behoefte invloed uit te oefenen,
    - U wilt graag geïnformeerd worden,
    - U wilt graag geraadpleegd worden,
    - U wilt graag instemmingsrecht hebben,
    - U wilt graag eigendomsrecht hebben (u wordt aandeelhouder),

19. Hoeveel groot acht u de kans dat in uw buurt dat een warmtecoöperatie van de grond komt?
    Helemaal niet – Niet – Neutraal – Wel – Helemaal wel

20. Hoeveel tijd bent u bereid per maand te bezig te zijn met een warmtecoöperatie?
    0 uur, 1-5 uur, 6-10 uur, 11-15 uur, 15-20 uur, meer dan 20 uur

Zoals eerder aangegeven bestaat het systeem uit een (1) buizenstelsel dat heet water door uw buurt of flat pompt (netwerk). Dit warmtenetwerk is aangesloten op een (2) bron, dat warmte maakt om het water te verwarmen dat naar uw huis wordt gepompt.

Beide delen van het warmtenet hebben een eigenaar. De eigenaar van het netwerk zal de gemaakte kosten in 30 jaar moeten terugverdienen. De eigenaar van de bron zal de gemaakte kosten moeten terugverdienen in 15 jaar. Er zou ook één eigenaar kunnen zijn voor beide delen van het warmtenet.

21. Wie vindt u van onderstaande partijen geschikt een *netwerk* voor u aan te leggen? Kies maximaal 3 en zet in volgorde:
    - Warmtecoöperatie:
    - De gemeente:
    - De Rijksoverheid:
    - Een energiebedrijf (Nuon, etc.):
    - De woningcorporatie/Verhuurder/VVE:
    - Een huidige warmteaanbieder (Eneco):
    - Netbeheerder (Stedin):
    - Olie- en gasbedrijven (NAM, Shell, Exxon Mobil)
    - Anders, nl. ……..
    - Weet niet

22. In hoeverre vindt u onderstaande partijen geschikt een *bron* voor u aan te leggen? Kies maximaal 3 en zet in volgorde:
    - Warmtecoöperatie:
    - De gemeente:
    - De Rijksoverheid:
    - Een energiebedrijf (Nuon, etc.):
    - De woningcorporatie/Verhuurder/VVE:
    - Een huidige warmteaanbieder (Eneco):
    - Netbeheerder (Stedin):
    - Olie- en gasbedrijven (NAM, Shell, Exxon Mobil)
    - Anders, nl. ……..

21. Vindt u het wenselijk dat beide onderdelen door één partij worden beheerd?
- Ja, Nee, Geen voorkeur, Weet Niet

C. Appendix: Overview of stakeholder

STAKEHOLDER	*DESCRIPTION*	
Governments		
Ministry of Economy, Infrastructure and Environment	Ministry in charge of all policy related areas for the heat transition.	Problem owner of the national goals for reducing the CO2 and the impact of climate change
Tweede Kamer (Parliament)	National legislative institute	Determines the 'heat law' and political competitivity of NG (taxes)
Municipality of Utrecht	Local government on the city level	Delegated problem owner: have the delegated obligation to meet climate goals on a local level.
Utrecht council	Local legislative institute	
Authority for consumers and market (ACM)	Independent controlling agency for consumers and companies.	Controlling the current regulations of DH-networks (Not more than elsewhere – NMDA)
Netherlands Enterprise Agency (NEA)/Rijksdienst voor Ondernemend Nederland (RVO)	Institute led by the Ministry of EIE, to execute policies touching on private companies	In charge of SDE+ subsidies, which would most likely play an important role in the foreseeable future for to speed up the transition pace.
Knowledge partners		
Energiecooperatie-U	Local Utrecht non-profit organisation (cooperative) advising residents on renewable energy technologies and reduction in energy use.	Possible project maker (in that sense it is also a competitor) for small scale DH-solution in Utrecht.
Consultants	Consulting companies advising on the 'rational best alternative'. These include 'lobbyists' influencing the government and the parliament on behalf of interest groups like HIER (on climate).	Companies supplying rational, calculated advise on technical opportunities. In principle these advises should be objective.
Universities	Research institutes researching on technology of district heating, social acceptation etc.	Universities supplying rational, calculated advise on technical opportunities. These advises are objective.
District Heating		
Eneco	Energy company currently possessing the DH-grid (owned by Dutch municipalities, but not by Utrecht). Eneco defines itself as a private company, because municipal owners act as private owners working with financial return-on-investments in the case of Eneco (e.g. in the case of HVC, they work with 'social return on investment' (8Pu, 2018))	Extension of the current DH-grid for positioning in the Utrecht heat market, but also to not lose total heat demand in the future (due to better insulation); network effects give some environmental benefits; maximize the output of the (current) infrastructure.
Competing DH-companies	Companies who oversee DH-activities like heat generation, network	Local (high temperature) heat network solutions might be

(present + newcomers)	management and delivery companies.	developed by other companies than Eneco. These could be existing companies, but could also be newly formatted
Natural gas		
Stedin	Gas- and electricity network owner (public company)	In charge of the enforcement of the electricity grid when 'all electric' would be chosen. Also wants to own the DH-grid infrastructure to create a level-playing-field and an integral assessment of the optimal local alternatives for NG.
National Oil Company (NAM)	Is responsible for unlocking two of the Netherlands' most important resources: gas and oil. NAM supplies 75% of the natural gas required by Dutch households and businesses. 93% of all Dutch households use natural gas. Natural gas accounts for 45% of all the energy that is used in the Netherlands (NAM, 2018).	Recently announced to stop with NG-production from 2030 onward, with substantial cuts in the coming years. Will lose current market position on in the residential heating market.
Gasunie (and Gasterra)	Gasunie owns the national transport NG-grid (Gasterra trades the gas, exploited by the NAM)	Will lose current market position on in the residential heating market.
NG-suppliers	Energy companies like Eneco, Essent, Nuon etc. They currently sell natural gas on the consumer market.	Natural gas suppliers loose market position when their heat supply will be substituted by other methods (if owned by other companies)
House owners		
Housing corporations	Non-profit institutes assigned by the government to build (social) rental houses.	Have stake in the heat transition as the owners of large quantities of (cost effectively modernizable) houses. Have arrangements with municipality on their environmental performance.
Private house owners[48]	Citizen privately owning a house. It can be owned to (1) live in it, or (2) rent out.	Could be willing to voluntarily green their heat supply, more likely waiting until they must deal with the dismantling of the NG-grid.
Institutional investors	Institutes-for-profit renting-out houses to consumers.	Could be willing to green their heat supply from market perspective, more likely waiting until they must deal with the dismantling of the NG-grid.
Consumers		
Corporate consumers	Private (profit-making) companies with an office/process heat demand	Corporates might be game changers in the minimum scale (profitability) of the network.

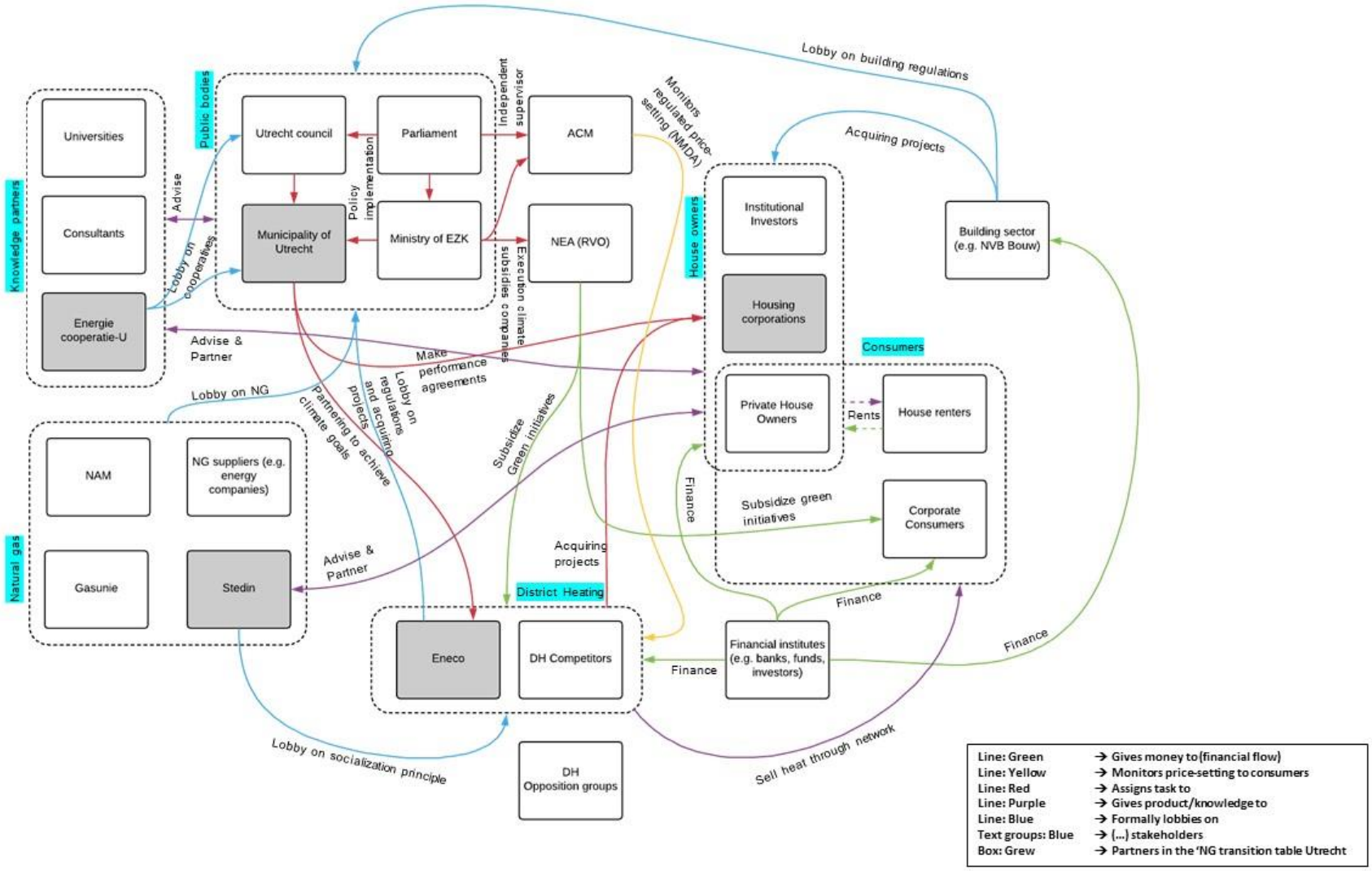
[48] Besides being a house owner, private house owners also act as consumers for district heating

House owner unions (VVE's)[49]	Unions governing collectively needed investments, especially in apartment buildings.	Could play a role in governing local solutions among private house owners. Natural collocutor for collective heat solutions.
Renters	People currently renting a house of (1) a housing corporation, or (2) a private house owner	If a raise of the rent is needed for the heat network, by law 70% of the residents need to agree. If lower, the corporation need ask court whether the raise is 'reasonable or not'. Renters are also worried on the consequences for their households, like electrical stoves etc.
Other		
The building sector	The building sector includes (1) construction companies: companies which built and renovate houses and possibly connects them to district heating. (2) Installers: companies fitting connections to grids and give them 'use' for in-house purposes	Have a stake especially in new neighbourhoods, but also in renovation projects. Other companies – installers – install the DH-equipment per house and deinstall current CV's. They are economically interested.
Opposition groups	Stadsverarming (e.g.), opposing every new monopoly type of organisation	Influencing public opinion on DH-solutions. Might deteriorate public perception on DH, despite potential rational best alternative
Financial Institutes	Finance institutes (banks), supplying loans/financial advice	The financial prospective of the projects are assessed by banks on their 'good financial governance'. They can supply loans or deny them.

[49] VVE's act as a representative body for private house owners; they are further assessed as being the same as private house owners.

D. Appendix: Formal chart

What are the formal relations among stakeholders in the forward-thinking process of integrating district heating as an alternative for natural gas?



E. Appendix: Effects of design concepts

Variable 1: Generation		
What is the effect of generation on an ownership structures for district heating? One part of the value chain. Could be owned separately, products could be sold to the owners of other parts of the value chain.		
Public	**Private**	**Cooperative**
Possible to take more risk to achieve more socially accepted heat generation (e.g. risk of geothermal) (4Co, 2018; 6Co, 2018)	Just like electricity, the market can fulfil the need for generation of heat (10Pr, 2018)	Possibly feeding-in a private/public network, achieving citizens participation in the same model (legal framework) as energy cooperatives (6Co, 2018)

Table E-1 Effects of generation

Variable 2: Transport		
One part of the value chain. Only needed when large quantities of heat need to be transported over 'larger' distances[50]. Probable when there is (planned to develop) an extensive network. Effects of owning this part of the network is the ability and responsibility to control the offered heat to the distribution part of the chain.		
Public	**Private**	**Cooperative**
It is highly risky to develop and possess the transport pipes, especially when there is no long-term securitization of the build capacity. When publicly owned, this risk might be taken when social/environmental benefits are met (e.g. waste heat transportation to areas where no/less waste heat is available)	Private transportation could occur when long-term secured of enough capacity (e.g. Eneco 'Leiding over Noord'). The private party will ask a fee to distribution companies (possibly the same company) for the reserved capacity of distribution. Clear contracts are needed to prevent overdependent relationships.	Cooperative transportation would imply there is a reason for a cooperative to develop and control transportation. This will probably only occur when community is keen on having a specific type of (waste)heat from a source far away, most likely it only would occur when the distribution and delivery is also part of the cooperative.

Table E-2 Effects of Transport

Variable 3: Heat exchange		
Having heat exchanging facilities in large scale networks, gives the responsibility and level the transported heat with the distributed heat. It is the physical location of system operation.		
Public	**Private**	**Cooperative**

[50] The largest distance currently under study in the Netherlands is the transport pipe from Rotterdam to Leiden (43 km) which would connect the city of Leiden with the waste heat available in the Rotterdam harbor (Warmopweg, 2018).

The effect of public heat exchanging is the impartiality of market rules.	The effect of private heat exchanging is that when exchanging based on markets, it is necessary to make clear arrangements for that.	The effect of cooperative heat exchanging is the responsibility for a fair market is done by its customers.

Table E-3 Effects of heat exchange

Variable 4: Distribution

One part of the value chain. Distributes the heat from the heat source or the transport pipes to the households to offer it to the heat delivery sets in houses. Effects owning this part of the network is the ability and responsibility to control the offered heat to the distribution part of the chain.

Public	**Private**	**Cooperative**
The effect of public distribution is the potential to take larger risks. Analogised from the electricity market, it could create a level-playing field to compete for delivery and generation.	In existing networks possible to achieve citizen participation when regulation makes this possible (third-party access) (4Co, 2018)	The effect of cooperative network ownership is the cooperative control of members on the distribution. Together they could choose what to do with the network activities

Table E-4 Effects of distribution

Variable 5: Delivery

One part of the value chain. Effects of owning this part of the network is the responsibility to deliver the heat to its customers. They are responsible for contracts and arrangements with other parts of the value chain to fulfil their customers' demands in terms of quantity and quality of supplied heat.

Public	**Private**	**Cooperative**
Effects of public ownership of the delivery part is the strong societal/political ty with its customers.	Private ownership of the delivery activities gives the shareholders possibility to optimize arrangements in terms of risk and profits to maximize their profits – influenced by regulation and/or competition.	Cooperative ownership of the delivery activities gives members of the cooperative control about the arrangements they make with other parts of the value chain on their requirements.

Table E-5 Effects of delivery

Variable 6: Joint ventures

As an effect of a joint venture arrangements need to be made upfront on the rights and duties the partners have.

Public private partnership (PPS)	**Private cooperative partnership (PrCS)**	**Public cooperative partnership (PuCS)**	**No partnership**
When contracts are unclear, the public partner usually needs to solve (in terms of money).	Cooperatives have a different level of professionalism (5Co, 2018)	Cooperatives have a different level of professionalism (5Co, 2018)	

Table E-6 Effects of joint ventures

Variable 7: Share division			
A majority of shares gives the entity most influence and the final vote in shareholder meetings.			
Public majority	**Private majority**	**Cooperative majority**	**No stock division**
A public majority of shares gives the public entity (politics) most influence and the final vote in shareholder meetings.	A private majority of shares gives the private entity (shareholders) most influence and the final vote in shareholder meetings.	A cooperative majority of shares gives the cooperative (members) most influence and the final vote in shareholder meetings.	This would imply that there is no relationship or an equal relationship among partners.

Table E-7 Effects of share division

Variable 8: Preferred shares	
Preferred shares give an entity an agreed (higher) influence in shareholder meetings which does not correspond with their financial participation in the vehicle. For example, it happens often with privatised public utilities that municipalities have 1% of the shares, but 51% of the influence (Ligtvoet, 2012).	
Yes	**No**
Preferred shares give on party more influence than financially they would have.	Financial share division is key in how much influence partners have to say in mixed companies.

Table E-8 Effects of preferred shares

Variable 9: Level of integration					
As an effect of a joint venture arrangements need to be made upfront on the rights and duties the partners have.					
Fully integrated	**Generation - Delivery**	**Generation – Transport**	**Distribution - Delivery**	**Transportation - Distribution - Load**	**No integration**
Integral approach of energy problems and optimization (9Pr, 2018; 12Pr, 2018; Verschuur, 2010) It means there is full-chain responsibility: one company to blame for (possible) disfunction of end-product (12Pr, 2018). It also means there is lower total risk to be covered, because risks (weather risk, follow-up risk, price regulation risk (7Pu, 2018) can be spread on different parts of the chain.	This type of integration can be found in the electricity market. The network activities are separated from the product which is transported by the network.	The (waste heat) source takes responsibility to bring the heat to the location where it needs to be distributed. This means distributors can see the end of the transport as 'their local source'.	The distribution company takes all responsibility from the generation/transport point. In its integration it can combine network with delivery risks.	Same as distribution and delivery, but in large networks and/or networks which are located for away from the source.	The essence of cuts in the chain is to financially optimize the core business (specialisation), but the chain is core business in heat networks. There is a lot of risk involved: wherever there are cuts, there is risk (like weather risk, follow-up risk, gas price risk. Wherever there is risk: there is a risk premium (7Pu, 2018)

Table E-9 Effects of level of integration

Variable 10: Type of contract				
The type of contract determines the relationship among partners in when partnerships occur.				
Concession (ESCO)	**Lease**	**Management**	**Municipal support**	**No contractual agreement**
Especially functional when specific assets need to be developed under specific desires of the party which has the interest (e.g. municipalities or cooperatives). Regulation is normally needed (Dyrelund, 2016). In principle the ownership (and risk) will be at the concessionaire, or so called 'Energy Service Company' (ESCO). (Westin & Lagergren, 2002; Zeman & Werner, 2004) (Dyrelund, 2016)	After development of an asset, the assets can be leased to a 'lessee' operating, maintaining and investing in the network. To get these rights to do so it pays a rental fee (Zeman & Werner, 2004). Ownership of the assets stay at the party which developed the network (Zeman & Werner, 2004). Lease a specific part of the DH-chain is also possible. Rights to develop geothermal heat on specific (e.g.) (Thorsteinsson & Tester, 2010)	Only operation and management will be 'outsourced' to a private company based on a contract. The developer keeps the responsibility and risk of ownership (Zeman & Werner, 2004). The owner basically buys the service of in the market.	The risk for DH could be too high for a private company. Municipal support in terms of 'back-up' could ease market valuation of the risks (Zeman & Werner, 2004).	Without a contract, no arrangement (but the market) between partners are in place or no partnership is in place and the whole chain is vertically integrated, owned and operated by the same company.

Table E-10 Effects of contract type

F. Appendix: Extensive SWOT analyses

1. Cooperative ownership

	Cooperative ownership for DH
S	• When owning the asset, the risk that people want to use another way of heat provision is being limited (3Co, 2018) • Because the customer is in-charge, there is a motivation to keep the costs as low as possible (3Co, 2018) • The influence on the company gives customers the feeling they have more freedom of choice (3Co, 2018) • More positive sentiment when 'doing it together', possibly more sustainable in terms of long term satisfaction (3Co, 2018) • Small scale perceived to be easily reachable. No perceived bureaucracy because of personal interconnections (4Co, 2018) • Cooperative ownership gives people satisfaction on how 'fair' it is perceived (4Co, 2018) • Fulfils a desire to have influence (4Co, 2018), which is about +/- 5% of the residents (5Co, 2018) • Intrinsic motivation for voluntary work (5Co, 2018). In the future extrinsic motivation by salary might be less important: sport clubs are run in a professional way as well on a voluntary basis (5Co, 2018) • Locality (4Co, 2018), local employment (15Go, 2018) • Environmental targets could remain on top. When the example of increased insulation of houses decreases heat demand (and therefore profitability of the heat provision), people are in control of their choices. Thus no new tensions between producer and consumer (e.g. unwanted or unjust perceived price increase) can come up (5Co, 2018)
W	• Harder and more time-consuming to make decisions collective, especially when size of the group increases (3Co, 2018; 4Co, 2018; 5Co, 2018) • Not always a shared 'cooperative mindset', like self-help, self-responsibility, democracy, equality, equity and solidarity (4Co, 2018). Or have different interests in sustainability (e.g. not interested, financially interested, intrinsically interested). It is sometimes difficult to define common ground within a group of individuals (3Co, 2018) • Most likely to be small of size because of organisation type, which makes them vulnerable (3Co, 2018) • Residents have less capital strength for large projects, if distinct to other types of ownership (4Co, 2018) • Maybe less economies of scale than other larger, private/public-owned networks (4Co, 2018) • Time consuming for some volunteers: you need some game changing individuals (5Co, 2018) • Willingness to pay is different for everyone, especially when there are different potential outcomes (more/less beautiful/more green) (6Co, 2018)

	• Cooperatives could, in theory, exclude people they don't like (14Go, 2018) • Doing business in this field requires a minimum of 30% private equity, thus there is a need of financial participation. External funding cannot fully account for cooperatives (Verschuur, 2010) • Risk of 'over participation' culminating in economic inefficient outcomes (e.g. wind turbines which cannot function at night, because of community objections) (1Cn, 2018) • There could be a lack of expertise which could establish the need to outsource. Outsourcing has bad influence on the efficient functioning and perceived functioning of the network (7Pu, 2018)
O	• Relative small-scale development of waste heat sources. Less potential to exclude of potential waste heat sources because they do not fit in larger networks. In essence: save more natural gas (5Co, 2018) • Neighbourhood cohesion (5Co, 2018) • Personal network building among people, which could have positive influence in someone's personal live or for the economy in general (5Co, 2018) • When people start with 'being green' it often functions as a head start to become more ambitious in terms of sustainability. Cooperative heat has potential to 'awaken' people and make them more sustainable for different aspects on their house/in their lives as well (3Co, 2018) • Group pressure: if developing a network and the majority participates, it is most plausible that some hesitant people will be influenced by the majority. Especially in the case of cooperatives this effect could strengthen the development (3Co, 2018) • A good functioning cooperative can give value on your house (3Co, 2018) • When there is a collective problem (like block heating/old collective VR-boilers[51]), collective action is possible (6Co, 2018) • Development of 'cooperative heat expertise centre': copying best practices, funding and organisation. This could ease challenges facing cooperatives (13Go, 2018) • Weaken negativities of monopolism, when no-profit clause is in place (15Go, 2018) • Higher NG-prices (by taxes) (2Cn, 2018) • Aspects in organisation or technology will go wrong when starting to develop the cooperative heat model, so there is a need for 'pioneering neighbourhoods'. They should not think it is a problem heat provision does not work perfect at moments (sometimes). When risk has been explored better in terms of experiences, more neighbourhoods will follow (6Co, 2018)
T	• If heat sources on the long-term change – some envision this to change 'continuously' – adaption power of cooperatives to reorganise a different source for the network is probably lower than adaption power of other types of ownership (3Co, 2018)

[51] These are specific boilers in some apartment building in the Netherlands at their end-of-life. This type of boilers does not exist anymore. So, there is no easy replacement option. This means larger investments to get more modern boilers are needed anyway, which could be a starting point to look to future and invest sustainably (6Co, 2018).

	• Legislation: at the moment it is easier for large companies to develop heat networks than for smaller organisations like cooperatives. This is based in the heat law (4Co, 2018) • Long term agreements (concessions) with private parties could block the development of cooperative heat (15Go, 2018) • For heat cooperatives it is key to find interested people who live close together: this is difficult when participation is on a voluntary/cooperative basis. That makes it much harder than energy cooperatives (6Co, 2018) • It depends on the existence or the establishment of cohesion in the neighbourhood. If there is no organisation whatsoever, it is hard to 'bind people' (4Co, 2018) • Established situations with private/public owners could block cooperatives from developing (12Pr, 2018) • The tradition of liberal markets in the Netherlands (12Pr, 2018) • Municipalities tend to act very nicely on cooperative initiatives, but if you need them they might brake initiatives by its bureaucracy (5Co, 2018) • Municipalities need to be willing to cooperate, and as a cooperative you need to 'fit in their institutional structure' (e.g. for alignment of construction activities with other underground infrastructure like sewer) (5Co, 2018). • Tragedy of the commons: potential conflict of interest among financial participants and consumers-only within the cooperative: threat of 'becoming a normal supplier' impossible (6Co, 2018; 8Pu, 2018) • To achieve collective action a collective problem needs to be in place, when there is no collective problem, cooperative action is hardly impossible (6Co, 2018)

Table F-1 Cooperative SWOT

2. Private ownership

	Private ownership for DH
S	• Powerful investment force: private companies are experts in acquiring and allocating money to profitable projects (10Pr, 2018) • Profit-driven optimization incentive, optimization in terms of savings benefits the environment naturally (12Pr, 2018) • Optimization efforts can be achieved along the complete chain of district heating (9Pr, 2018) • Assumes to have better/more innovative workers. Because they receive better payments, companies can acquire good expertise to more efficient and higher quality products (10Pr, 2018) • Healthy cost-benefit analyses in project-development, because of this there is less risk of bankruptcy (9Pr, 2018; 10Pr, 2018; 11Pr, 2018) • Less political influence, focus on delivering the product and not on political gain (11Pr, 2018) • Can be just as driven to meet climate goals as public organisations (9Pr, 2018; 11Pr, 2018)
W	• Need of extensive regulations, need for control body (15Go, 2018) • Despite better financial considerations, private companies have the potential risk of bankruptcy. Public institutions/companies always have public back-up (15Go, 2018)

	• Higher demands for interest rates, making less projects feasible for development (10Pr, 2018; 15Go, 2018) • Public attitude harms private monopolies: they are not beloved due to their profit incentive (10Pr, 2018; 15Go, 2018) • Sometimes there is customer dissatisfaction when operating a private natural monopoly, like is the case in district heating (9Pr, 2018) • No local jobs: sometimes headquarters are not even in the Netherlands (7Pu, 2018)
O	• According to 11Pr (2018) it is not so much important who is the owner, it is about doing it right. Changing ownership is not important, but a 'fresh start'. The public award (new) private companies in the first place just as much as other ownership types (11Pr, 2018) • Higher NG-prices could make more business cases viable for private parties (2Cn, 2018) • There are still new neighbourhoods for which district heating is a good alternative, but more new opportunities unfold in old neighbourhoods. Especially in 'liberal municipalities' there are business opportunities for private heat networks (11Pr, 2018) • There is no global strategic reason not to develop heat networks by private companies. Heat networks are very local so there is no risk that a foreign company could paralyze the country – as could be the case with the electricity grid (11Pr, 2018) • In the heat transition we need 'every penny' to keep up with climate goals. So we should not exclude private money (10Pr, 2018) • Coupling networks, as in Amsterdam with east and west, could optimize (also environmentally) the total burden of residential heating (10Pr, 2018) • Housing corporations act as powerful initiators for neighbourhoods. They act as a 'basic and secure volume' to be able to take the risk (10Pr, 2018) • The 'negative imago' of private ownership is not based in ownership, but in price. For most of the people the ownership would not matter, the costs do. So if private parties could compete better in terms of costs than others, this will probably be more important for most people than influence/ownership (4Co, 2018)
T	• Full private companies have a competitive disadvantage, because municipalities partially owning a (heat) utility (like HVC/Eneco) will tend to award them with projects in their municipality (11Pr, 2018) • The transition of the private house owners is very different (and in a way more complicated) from housing corporations: a new approach needs to be developed (10Pr, 2018) • If more housing corporation will 'vote' against district heating or choose for other options, lots of opportunities for district heating will be threatened (10Pr, 2018)

Table F-2 Private SWOT

3. Public ownership

	Public ownership
S	• Possible to carry high(er) risk (15Go, 2018) • No/Less regulation needed, since the owner/shareholder is the regulator (8Pu, 2018) • A public company is more suited to deal with (short-term) fluctuations (8Pu, 2018) • Public accountability: customer-relation has more political load, which increases the incentive to have good customer service (2Cn, 2018) • The monopoly is a monopoly of the public: 'our monopoly' (7Pu, 2018) • Public company could function as good as a private company with the right set-up (7Pu, 2018) • Problem-owner is the problem-solver: municipalities are in charge of their own social and climate objectives, and in charge to create local jobs (7Pu, 2018) • Local jobs create a local 'face' for the company (e.g. by means of their mechanics) (7Pu, 2018)
W	• Risk of inefficiency/lazy civil servants (8Pu, 2018) • Public money can be 'spent just once', so it is questionable if money should be used for district heating or for other societal purposes (7Pu, 2018) • Potential to use profits from district heating network for other societal purposes, instead of trying to keep prices for heat low (7Pu, 2018) • Potential of over-outsourcing, creating incoherence and inefficiency (7Pu, 2018)
O	• Possible to use societal return-on-investments (8Pu, 2018; 15Go, 2018) • Possible to 'socialize the heat transition', this means equitable sharing the costs of the infrastructure development among citizens (8Pu, 2018) • Higher NG-prices (by taxes) (2Cn, 2018) • Creation of public expertise on *energy* transition: potentially broader public impact than only heat supply (7Pu, 2018) • Possible to take big leaps in the transition now: a political decision could fasten the network development. It could incentivize residents by saying: if you take a connection *now* it is free, if you want it later the infrastructure will be there but you will need to pay for it (6Co, 2018)
T	• Liberal and privatised tradition could threaten the potential of public participation in heat networks (12Pr, 2018) • Political ideas can change towards public ownership, threatening sustained organisations (8Pu, 2018) • When waste-heat dependent: you are doing business with someone who's core business is not producing heat. This creates dependency: when they are going bankrupt/make their processes more efficient without waste-heat, this influences the 'free heat' (5Co, 2018)

Table F-3 Public SWOT

4. Mixed ownership

Mixed ownership of DH	
S	• Potential of win-win situations for joint ventures from energy cooperatives (public support) and energy companies (expertise) (13Go, 2018) • Potential win-win situation for joint ventures from municipalities (equity) and energy company (private money) (13Go, 2018)
W	• Complicated contracts (as was the case with an example of the municipality of Hengelo)(11Pr, 2018) • For the business case of district heating there is no point of mixing ownership, only when municipalities would offer lending money for 0% interest (11Pr, 2018) • Because of the small scale of district heating, it should not be too complex (11Pr, 2018)
O	• Risk for developing district heating is very high. Therefore no one will enter this niche market 'on its own' (9Pr, 2018) • Only small benefits in the imago of district heating (11Pr, 2018) • The heat law which is constructed in the coming years, could fulfil a split in the chain of district heating: most likely in the transport part. Distribution and delivery could then be done by private parties. This is because in 'transport' public goals like security of supply, affordability and sustainability could come together (13Go, 2018; 14Go, 2018) • A public heat network gives the opportunity to both private and cooperative parties to generate and deliver heat in a level-playing-field, analogised from the energy market (4Co, 2018; 15Go, 2018) •
T	• Complexity could grow during the relationship, under influence of the changing environment. This could potentially increase overhead costs (11Pr, 2018) • Make good lasting contracts in an environment which is currently highly evolving is hardly impossible (15Go, 2018) • Delivery of heat is the part of the chain with most of the risks/consequences: this is the part in which most of the contact with the residents are taken place. De-integrating the district heating chain make delivery-only very risky and uninteresting for commercial parties. Companies in other parts of the chain can contract the (smaller) risks easier (14Go, 2018). E.g. 'network companies can ask 6% interest, without risk' (14Go, 2018) • As stated in opportunities: 'transport' part in the chain can fulfil public goals. Threatening this is the definition of 'transport'. Since the locality and scale of district heating are very diverse, it is hard to come up with guidelines of 'transport'. So it is unclear this potential 'split' needs to be defined because of the diversity of cases (14Go, 2018)

Table F-4 Mixed SWOT

G. Appendix: Sample generalisability

Gender	**WistUdata (2018**	**Sample**	**Difference**
Man	170.078 (48,9%)	100 (50,8%)	+1,9%
Women	177.496 (51,1%)	97 (49,2%)	-1,9%
Age (% of pop.)[52]	**WistUdata (2018)**	**Sample**	**Difference**
18-24	16,0%	14,7% (29)	-1,3%
25-34	26,7%	40,6% (80)	+13,9%
35-64	44,4%	36,5% (72)	-7,9%
65+	12,9%	8,1% (16)	-4,8%
Family composition	**WistUdata (2018)**[53]	**Sample**	**Difference**
Couple with kids	36.852 (20,8%)	47 (23,7%)	+2,9%
Couple without kids	36.197 (20,4%)	90 (45,5%)	+25,1%
Single with kids	10.239 (5,8%)	5 (2,5%)	-3,3%
Single without kids	94.156 (53,1%)	56 (28,3%)	-24,8%
Highest education level	**CBS Stat. (2018, ref. NL)**	**Sample**	**Difference**
Primary school	1478 (10,6%)	1 (0,5%)	-10,1%
VMBO/MAVO	2985 (21,3%)	4 (2,0%)	-19,3%
HAVO/VWO/MBO	5421 (38,8%)	17 (8,6%)[54]	-30,2%
HBO/WO-bachelor	2610 (18,7%)	70 (35,4%)	+16,7%
WO-master	1490 (10,7%)	106 (53,5%)	+42,8%
Housing	**wistUdata (2018)**	**Sample**	**Difference**
Apartment (flat)	84317 (55,9%)	102 (51,5%)[55]	-4,4%
Semi-detached	2561 (1,7%)	12 (6,1%)	+4,4%
Terraced house	50144 (33,2%)	76 (38,4%)	+5,2%
Detached house	2431 (1,6%)	2 (1,0%)	-0,6%
Semi-detached terrace	11412 (7,6%)	6 (3,0%)	-4,6%
House ownership (% of pop.)	**wistUdata (2018)**	**Sample**	**Difference**
Private property	48,3%	114 (57,9%)	+9,6%
Social rent	38,6%	13 (6,6%)	-32,0%
Rental	13,0%	70 (35,6%)	+ 22,6%
Construction year (% of pop.)	**wistUdata (2018)**	**Sample**[56]	**Difference**
<1930/1945[57]	28,4%	51 (28,8%)	+0,4%
1930/1945-1979	30,3%	65 (36,7%)	+6,4%
1980-now	41,2%	61[58] (34,5%)	-6,8%
Heat provision	**CBS Stat. (2018, ref. Utrecht)**	**Sample**[59]	**Difference**
District Heating	28,4%	17,6% (34)	-10,8%
Natural Gas	71,6%[60]	82,4% (159)	+10,8%

Table G-1 Sample check with database wistUdata and CBS Statline

[52] The percentages were given at wistUdata for all categories. 19,9% of the population in Utrecht is younger than 18 so this was considered be recalculating the percentages per category.

[53] From WistUdata the 'other' category has been filtered: the questionnaire did not take this into account.

[54] In sample: 3% HAVO/VWO; 5,6% MBO → 8,6% to be comparable to Statline

[55] 20,2% apartment flats; 21,2% two floors; 10,1% student rooms → 51,5% to be comparable to wistUdata

[56] 21 of respondents did not know what age their house has.

[57] wistUdata categorises until 1945, the sample until 1930. There is a difference of 15 years.

[58] 1980-now has not been split by the wistUdata, where the sample has 3 categories: 1980-1991 (17), 1992-2000 (13), 2001-now (31). These categories had been defined because of insulation opportunities of the housing types but cannot be related to databases.

[59] 21 of respondents did not know what age their house has.

[60] It is assumed that all people not on District Heating use natural gas as their primary source of heating, but there might be people using heat pumps or other solutions for heating their house.

Income level	**Sample**
Less than average	40 (22,3%)
Average	36 (20,1%)
Double average	54 (50,3%)
More than double average	49 (27,4%)

Table G-2 Income level in sample

H. Appendix: Summary of hypotheses

The bold hypotheses are confirmed.

No.	Question	H0	H1
House owners			
3	Do people with different housing ownership types vary in their opinions about who is responsible for a gas alternative?	Who people think is responsible for a gas alternative is not dependent of house ownership	**Who people think is responsible for a gas alternative is dependent of house ownership**
3	Do people with different housing ownership types vary in their opinions about connection fees?	What people prefer on connection fees is not dependent of house ownership	**What people prefer on connection fees is dependent of house ownership**
3	Do people with different housing ownership types vary in their opinions on influence?	The preferred type of influence is not dependent of house ownership	**The preferred type of influence is dependent of house ownership**
Salary			
3	Do people with different income levels vary in their opinions on connection fees?	**What people prefer on connection fees is not dependent of income level**	What people prefer on connection fees is dependent of income level
1	Do people with different income levels vary in their willingness to invest in a heat cooperative?	What people are willing to invest in heat cooperatives is not dependent of income level	**What people are willing to invest in heat cooperatives is dependent of income level**
DH/NG			
2	Do people with different levels of previous knowledge vary on what kind of party is responsible to organise an alternative for natural gas?	Who is responsible to organise an alternative for natural gas is not dependent on their current heating technologies	**Who is responsible to organise an alternative for natural gas is dependent on their current heating technologies**
2	Do people with different technologies of heating their house currently vary on their opinion which organisation fits managing the source?	**Which organisation people think fits managing the source is not dependent on their current heating technologies**	Which organisation people think fits managing the source is dependent on their current heating technologies
3*	Do people with different technologies of heating their house currently vary on their opinion which organisation fits managing the network?	**Which organisation people think fits managing the network is not dependent on their current heating technologies**	Which organisation people think fits managing the network is dependent on their current heating technologies
3*	Do people with different technologies of heating their house currently vary on their preference for an integrative company?	**Whether people think the whole chain should be integrated is not dependent on their**	Whether people think the whole chain should be integrated is dependent on their

		current heating technologies	current heating technologies
3	Do people with different technologies of heating their house currently vary on their willingness to invest time in a heat cooperative?	**The willingness to invest time in a heat cooperative is not dependent on their current heating technologies**	The willingness to invest time in a heat cooperative is dependent on their current heating technologies
2	Do people with different technologies of heating their house currently vary on their willingness to invest money in a heat cooperative?	**The willingness to invest money in a heat cooperative is not dependent on their current heating technologies**	The willingness to invest money in a heat cooperative is dependent on their current heating technologies
2	Do people with different technologies of heating their house currently vary on the trust they have in their neighbourhoods to organise a heat cooperative?	The trust people have in their neighbourhoods to organise a heat cooperative is not dependent on their current heating technologies	**The trust people have in their neighbourhoods to organise a heat cooperative is dependent on their current heating technologies**
2	Do people with different technologies of heating their house currently vary in their valuation of important aspects for heating alternatives?	What people think is important for heating is not dependent on their current heating technologies	**What people think is important for heating is dependent on their current heating technologies**
N	Do people with different technologies of heating their house currently vary on their opinion how trustworthy they think specific organisations are?	What organisation people trust for their heating their homes is not dependent on their current heating technologies	**What organisation people trust for their heating their homes is dependent on their current heating technologies**
N	Do people with different levels of previous knowledge vary on what kind of party is responsible to organise an alternative for natural gas?	Who is responsible to organise an alternative for natural gas is not dependent on their current heating technologies	**Who is responsible to organise an alternative for natural gas is dependent on their current heating technologies**
Level of previous knowledge			
3*	Do people with different levels of previous knowledge vary on what kind of party is responsible to organise an alternative for natural gas?	**Who is responsible to organise an alternative for natural gas is not dependent on their level of previous knowledge**	Who is responsible to organise an alternative for natural gas is dependent on their level of previous knowledge
3*	Do people with different levels of previous knowledge vary on the opinion who fits best the managing of the source?	**Which organisation fits to manage the source is not dependent on their level of previous knowledge**	Which organisation fits to manage the source is dependent on their level of previous knowledge

3*	Do people with different levels of previous knowledge vary on the opinion who fits best the managing of the network?	**Which organisation fits to manage the network is not dependent on their level of previous knowledge**	Which organisation fits to manage the network is dependent on their level of previous knowledge
Influence			
1	Do people with different preferences of influence vary on their willingness to invest time in a heat cooperative?	**The willingness of people to invest time in a heat cooperative is not dependent on their preference of influence**	The willingness to invest time in a heat cooperative is dependent on their preference of influence
1	Do people with different preferences of influence vary on their willingness to invest money in a heat cooperative?	The willingness to invest money in a heat cooperative is not dependent on their preference of influence	**The willingness of people to invest money in a heat cooperative is dependent on their preference of influence**
1	Do people with different preferences of influence vary on the trust they have in their neighbourhoods (to organise a heat cooperative)?	**The trust people have in their neighbourhoods to organise a heat cooperative is not dependent on their preference of influence**	The trust people have in their neighbourhoods to organise a heat cooperative is dependent on their preference of influence
1	Do people with different preferences of influence vary on the trust they have in an energy company to organise an alternative for natural gas?	**The trust people have in specific organisations to organise a natural gas alternative is not dependent on their preference of influence**	The trust people have in specific organisations to organise a natural gas alternative is dependent on their preference of influence
Cooperative ownership			
N	Do people with different preferences on cooperative ownership for heat generation vary on the trust they have in energy companies?	The trust in energy companies is not dependent on the preference for cooperative ownership of heat generation	**The trust in energy companies is dependent on the preference for cooperative ownership of heat generation**
N	Do people with different preferences on cooperative ownership for heat generation vary on the trust they have in municipalities?	**The trust in municipality is not dependent on the preference for cooperative ownership of heat generation**	The trust in municipality is dependent on the preference for cooperative ownership of heat generation
N	Do people with different preferences on cooperative ownership for heat	The trust in grid operators is not	**The trust in grid operators is**

	generation vary on the trust they have in grid operators?	dependent on the preference for cooperative ownership of heat generation	**dependent on the preference for cooperative ownership of heat generation**
N	Do people with different preferences on cooperative ownership for heat networks vary on the trust they have in energy companies?	The trust in energy companies is not dependent on the preference for cooperative ownership of heat networks	**The trust in energy companies is dependent on the preference for cooperative ownership of heat networks**
N	Do people with different preferences on cooperative ownership for heat networks vary on the trust they have in municipalities?	**The trust in municipality is not dependent on the preference for cooperative ownership of heat networks**	The trust in municipality is dependent on the preference for cooperative ownership of heat networks
N	Do people with different preferences on cooperative ownership for heat networks vary on the trust they have in grid operators?	**The trust in grid operators is not dependent on the preference for cooperative ownership of heat networks**	The trust in grid operators is dependent on the preference for cooperative ownership of heat networks
Physical ownership			
N	Do people with different preferences on cooperative ownership for heat generation vary on the preference for ownership of heat networks?	The preferred network owner is not dependent on the preference for cooperative ownership of heat generation	**The preferred network owner is dependent on the preference for cooperative ownership of heat generation**
N	Do people with different preferences on private ownership for heat generation vary on the preference for ownership of heat networks?	The preferred network owner is not dependent on the preference for private ownership of heat generation	**The preferred network owner is dependent on the preference for private ownership of heat generation**
N	Do people with different preferences on municipal ownership for heat generation vary on the preference for ownership of heat networks?	The preferred network owner is not dependent on the preference for municipal ownership of heat generation	**The preferred network owner is dependent on the preference for municipal ownership of heat generation**
N	Do people with different preferences on grid-operator ownership for heat generation vary on the preference for ownership of heat networks?	The preferred network owner is not dependent on the preference for grid-operator ownership of heat generation	**The preferred network owner is dependent on the preference for grid-operator ownership of heat generation**
N	Do people with different preferences on cooperative ownership for heat networks vary on the preference for ownership of heat generation?	The preferred heat generation owner is not dependent on the preference for	**The preferred heat generation owner is dependent on the preference for**

		cooperative ownership of heat networks	**cooperative ownership of heat networks**
N	Do people with different preferences on municipal ownership for heat networks vary on the preference for ownership of heat generation?	The preferred heat generation owner is not dependent on the preference for municipal ownership of heat networks	**The preferred heat generation owner is dependent on the preference for municipal ownership of heat networks**
N	Do people with different preferences on private ownership for heat networks vary on the preference for ownership of heat generation?	The preferred heat generation owner is not dependent on the preference for private ownership of heat networks	**The preferred heat generation owner is dependent on the preference for private ownership of heat networks**
N	Do people with different preferences on grid-operator ownership for heat networks vary on the preference for ownership of heat generation?	The preferred heat generation owner is not dependent on the preference for grid-operator ownership of heat networks	**The preferred heat generation owner is dependent on the preference for grid-operator ownership of heat networks**

I. Appendix: Interrelatedness of physical ownership

If source energy company	No (N, %)		Yes (N, %)	
Cooperative	36	48,6%	49	41,9%
Municipality	51	68,9%	70	59,8%
Energy Company	9	12,2%	58	49,6%
Grid Operator	33	44,6%	76	65,0%
Total	74		117	61,3%

If source grid operator	No (N, %)		Yes (N, %)	
Cooperative	52	42,3%	33	48,5%
Municipality	72	58,5%	49	72,1%
Energy Company	34	27,6%	33	48,5%
Grid Operator	56	45,5%	53	77,9%
Total	123		68	35,6%

If source municipality	No (N, %)		Yes (N, %)	
Cooperative	41	44,6%	44	44,4%
Municipality	37	40,2%	84	84,8%
Energy Company	32	34,8%	35	35,4%
Grid Operator	53	57,6%	56	56,6%
Total	92		99	51,8%

If source cooperative	No (N, %)		Yes (N, %)	
Cooperative	17	17,9%	68	70,8%
Municipality	57	60,0%	64	66,7%
Energy Company	32	33,7%	35	36,5%
Grid Operator	49	51,6%	60	62,5%
Total	95		96	50,3%

If network energy company	No (N, %)		Yes (N, %)	
Cooperative	61	49,2%	35	52,2%
Municipality	64	51,6%	35	52,2%
Energy Company	59	47,6%	58	86,6%
Grid Operator	35	28,2%	33	49,3%
Total	124		67	35,1%

If network grid operator	No (N, %)		Yes (N, %)	
Cooperative	36	43,9%	60	55,0%
Municipality	43	52,4%	56	51,4%
Energy Company	41	50,0%	76	69,7%
Grid Operator	15	18,3%	53	48,6%
Total	82		109	57,1%

If network municipality	No (N, %)		Yes (N, %)	
Cooperative	32	45,7%	64	52,9%
Municipality	15	21,4%	84	69,4%
Energy Company	47	67,1%	70	57,9%
Grid Operator	19	27,1%	49	40,5%
Total	70		121	63,4%

If network cooperative	No (N, %)		Yes (N, %)	
Cooperative	28	26,4%	68	80,0%
Municipality	55	51,9%	44	51,8%
Energy Company	68	64,2%	49	57,6%
Grid Operator	35	33,0%	33	38,8%
Total	106		85	44,5%