European Commission

OVERVIEW OF HEATING AND COOLING

PERCEPTIONS, MARKETS AND REGULATORY FRAMEWORKS FOR DECARBONISATION

Deliverable 2: Perception and image of H&C technologies by current district heating and heat pump users and non-users from industrial, residential and public sector (Task 2)

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Project coordination

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Notes:

Content

1 Executive Summary

This study assessed the perception of renewable and energy-efficient heating and cooling (H&C) technologies, with a focus on district heating (DH) and heat pumps (HP). The study covered the residential sector as well as industry and the public sector. Moreover, the study highlights the differences and similarities in perception between the sectors.

For the **residential sector** (Task 2.1), an online survey was conducted. The survey ran from June to August 2022, i.e. during the Russian-Ukrainian war. In total, 7857 respondents from 11 different countries participated, which is a representative sample. Key results for the residential sector are:

- Fossil fuels were perceived as the least climate-friendly and the most costly heating option, and connected with a high risk of dependency on fossil fuel suppliers. This assessment reflects the impacts of the Russian-Ukrainian war on the global energy market. In contrast, solar thermal was perceived as the cheapest solution and connected with the lowest price risk.
- Regarding the two focus technologies, DH and HP, the perceived features and characteristics differed across countries, but the overall perception of DH and HP in the surveyed countries was positive. In Lithuania, Spain, the Netherlands and the Czech Republic, there was a below average perception of some features of DH, while in Sweden and Denmark, the general perception was above average. Concerning HP, the overall image was in the lower range in the Netherlands and in the upper range in Poland.
- Regarding the drivers of the perception of DH and HP, attitudes and beliefs such as affinity to technology and environmental awareness were better able to explain the perception of heat pumps (than socio-demographic variables). In addition, features like the perceived climate-friendliness of the technology, its cost, and reliability seem to be essential drivers of the image of DH and HP.
- Our results highlight that information and financial regulations can help to enhance the diffusion and improve the perception of DH and HP in the residential sector.

For **industry and** the **public sector** (Task 2.2), a mixed methods approach was applied, including a short online survey, interviews, and a case study analysis. The analysis was conducted between January 2021 and February 2022, i.e. before the Russian-Ukrainian war. The resulting sample included about 140 respondents and is thus not representative. Key findings for the industrial and public sectors are:

- Fossil fuels were perceived as the least climate-friendly heating option, however, they were seen as very reliable and easy to adopt by the industrial and public sectors. Further, the industrial and public sectors considered the costs of the different heating options as similarly high. Regarding price risks, solar thermal showed the lowest price risks, and fossil fuels the highest.
- The perception of the two focus technologies was generally positive. HP were perceived as more climate-friendly, while DH was connected with a higher dependency on one energy supplier.
- Drivers of decisions in the industrial and public sectors are different from those in the residential sector. The primary focus of the industrial and public sectors is on economic issues or costs. However, energy-related regulations and norms as well as factors at the company level can drive the use of sustainable energy supply and usage (e.g. public pressure for green products or green standards).

Finally, for all the sectors, regulations and financial support can promote the use of renewables and energy efficiency in H&C. The analysis shows that information is a key element that could push sustainable energy use at different levels and in different sectors (e.g. information campaigns focusing on environmental awareness, advice of energy experts).

2 Introduction and Background

This report is part of a study focusing on perceptions, frameworks and markets in heating and cooling (H&C) (project N° ENER/C3/2019-487). The overarching goal of the study is to contribute to the decarbonisation of H&C in buildings. This means fostering the expansion of **renewable and energy-efficient H&C technologies** (RE and EE H&C) with a focus on heat pumps (HP) and district heating (DH) at the system, technology and instrument levels.

This report outlines the objective, approach and results of the study on the perception of HP and DH (Task 2). The focus is on households and representatives of the public and industrial sectors.

Figure 1: Word cloud of elements

Prior to this analysis, **a literature review was conducted on factors affecting decisions regarding H&C technologies** (Task 1, Breitschopf and Billerbeck 2021). This review revealed that many studies investigate drivers and barriers to the application of RE and EE H&C technologies in the residential sector, but only a few studies have focused on industrial sectors or the public sector. Furthermore, according to the review, the perceived challenges and concerns regarding the further deployment of DH are more complex than for HP and include issues such as exposure to the market power of DH suppliers, switching supplier, appropriate and transparent pricing schemes and billing services. In contrast, no study could be found that links the use of HP to dependency on energy suppliers or pricing issues. Instead, understanding how HP technology works seems to be more of an issue.

The **main messages from the literature review** (Task 1) across all sectors are:

- Long-term commitment and planning security are key when deciding to implement DH, but not as important for the adoption of HP systems.
- Institutional frameworks ensuring clarity of and compliance with pricing rules, access to information, restriction of market power and transparency of markets are preconditions for DH, but are less important for HP adoption.
- Social and ecological (energy) values, attitudes, trust in institutions, culture and practices of peers, citizens, community members, and customers are major and undisputed factors affecting energy decisions in all sectors and across all technologies.
- Local environment and conditions, such as the availability of local natural resources, building stock, financial capacities, and socio-demographic aspects, are preconditions for using certain H&C technologies.
- Energy literacy and technical and managerial expertise are considered important drivers, especially for HP and RE-H&C technologies.
- Coordination of actions, policies across all actors, institutions and levels as well as a willingness to cooperate are mandatory for the successful expansion of DH.

These results of the literature review form a key input to this study. They are used to better understand the factors that drive consumer decisions concerning energy services. These factors include, for example, institutional aspects such as monopolistic structures, market power and dependency, individual characteristics of heating systems, and autonomy, cost efficiency and sustainability aspects (see, for example, Bouw 2017[1]).

The objective of this study is to provide an overview of how users and non-users of HP and DH in the residential, industrial and public sectors perceive these H&C technologies, i.e. which attributes of HP and DH are perceived. Second, it aims at understanding how these perceived attributes influence **decisions on energy investments and services** (EIS), and which factors influence these perceptions. A third aim is to understand whether, and if so, why there are gaps between the perceived image of certain H&C technologies and actual applications and energy decisions. Finally, through the interviews conducted as part of this study, we aim at gaining insights into the decision process in industry or the public sector regarding decisions about using H&C technologies.

The report is divided in two parts based on the different methods and target groups:

i) residential sector (Task 2.1; see section 3)

ii) industry and the public sector (Task 2.2; see section 4)

For the first part (Task 2.1), a representative online survey was conducted in the residential sector. For the second part, a mixed methods approach was used, combining a short (non-representative) online survey, interviews and a case study. Both surveys included one common block of questions regarding the perceived features of conventional and low-carbon H&C options (see methodology in section 3.1 and section 4.1).

1 https://research.hanze.nl/ws/portalfiles/portal/16162028/Research_note_Attractiveness_of_DHC_to_consumers.pdf

3 Perception of HP and DH in the Residential Sector (Task 2.1)

3.1 Methodology

This section presents a representative assessment of the perception and image of H&C among users and non-users of HP and DH in the residential sector. Based on the key results of the literature review (Task 1), an online survey was designed with questions concerning the attitudes towards, image of, satisfaction with and the factors driving different heating and cooling systems, e.g. the relevance of trust in monopolistic structures, knowledge, consumer choices and autonomy, economic and sustainability concerns, among others.

The online survey contained around 30 questions (duration: 5-15 minutes) and was structured along the following topics:

- Socio-demographic characteristics
- Current heating system and factors influencing decisions on H&C
- Perception of DH and HP
- Values and trust in promoters.

The survey was divided into two different questionnaires: i) DH and ii) HP, each including slightly different questions. The survey questions are attached to this report in Annex A.1. The two questionnaires covered nine countries, and each questionnaire included a set of countries that differed by two countries (compare Table 1).

Table 1: Countries in the two questionnaires (residential sector)

<table>
<tr><th>DH</th><th>HP</th></tr>
<tr><td colspan="2">Lithuania</td></tr>
<tr><td colspan="2">Poland</td></tr>
<tr><td colspan="2">Denmark</td></tr>
<tr><td colspan="2">The Netherlands</td></tr>
<tr><td colspan="2">Slovakia</td></tr>
<tr><td colspan="2">Italy</td></tr>
<tr><td colspan="2">Germany</td></tr>
<tr><td>France</td><td>Czech Republic</td></tr>
<tr><td>Sweden</td><td>Spain</td></tr>
</table>

The selection of countries was mainly based on the results of Task 1 and considered the representativeness at country level: geographical location and climate, share of RES-H&C, share of DH and HP, economic strength as well as the representativeness of households: size and education. A hierarchical cluster analysis was also used to select these countries.[2] A professional market research institute was subcontracted to collect the data, which has vast experience in data collection at the European level and in the field of energy consumption and consumer attitudes.

[2] Cluster analysis based on the single linkage clustering that relies on a similarity between two groups as the similarity of the closest pair of observations between the two groups (Ward's linkage). It uses an analysis of variance approach to evaluate the distances between clusters, which are based on minimizing the Sum of Squares (SS) of clusters. This method is regarded as very efficient but tends to create clusters of small sizes. Variables were standardised between 0 and 1 and comprise per capita income, share of DH, HP, household size, age, heating degree-days, education and house ownership.

To ensure high data quality, we implemented two control items and excluded respondents from the analyses based on the following criteria:

- Respondent is not responsible for energy decisions within the household;
- Data quality is low, i.e. both control items were answered incorrectly;
- No answer to the country question;
- Age below 18;
- Excluded due to the set quotas;
- Speeders who completed the survey in less than 90 seconds.

This resulted in a final sample size across both questionnaires of **7,857 participants**. Table 2 briefly describes the two final samples of the online survey. To obtain representative samples, we applied the following quota: education (low to high), household size (1 person to more than 6 persons), share of tenants and owners, share of DH and HP users. An overview of how far the recruited sample met these quotas in each country is presented in Annex A.4 (country fact sheets).

Table 2: Overview sample (residential sector)

Category	Sample HP	Sample DH
n	3898	3959
User	348	1019
Non-user	3550	2940
Share female	52%	53%
Average age	48.65	48.67
Share tertiary education	57%	59%
Average household size	2.44	2.36

3.2 Results in the Residential Sector

3.2.1 Overview of perceived features of different heating options among households

This section describes how citizens perceived the different heating options in **both samples** – questionnaires on DH and HP. It focuses on five attributes of heating options, and all respondents were asked to indicate their agreement or disagreement with the statements on a 5-point Likert scale[3]. The attributes or features were based on the following statements:

- Climate friendliness: The following technologies can be used for **climate-friendly** heat
- Low cost: The following technologies can provide heat at **low costs** (i.e. levelised cost of heat)
- Low price risk: The following technologies entail **low price risks** (regarding long-term price development)
- High reliability: The following technologies are **highly reliable** (in terms of supply, heat quality, temperature level, technical issues etc.)
- High dependency: The following technologies entail a **high dependency** on one energy supplier (regarding pricing, metering, billing, etc.)

[3] A Likert scale is a psychometric scale commonly involved in research that employs questionnaires. When responding to a Likert item, respondents specify their level of agreement or disagreement for a series of statements.

- High efforts: The following technologies require extensive **information and efforts** to adopt (regarding technical and administrative issues).

Regression analyses[4] revealed that these attributes contributed and explained about 28% to 31% of the general perception and image of DH and HP (see section 3.2.3.4 for HP).

In the following section, we present all the results of the two samples (section 3.2.1.1), followed by differentiated analyses by country (section 3.2.1.2) and then by selected socio-demographic characteristics of the respondents (section 3.2.1.3).

The overall results are illustrated graphically. The statements are displayed in the heading of the respective figure. The respondents could only select one option; multiple selections were not possible. We visualised the Likert-scale using an intuitive colour scheme, where "a positive perception" is associated with shades of green and "a negative perception" with shades of red. As illustrated in Figure 2, the scale, which runs from red to green for agreement with positively connoted statements (climate friendly, low cost, low risk, high reliability), is inverted for agreement with the statements implying a negative connotation (high dependency, large effort) and runs from green to red.

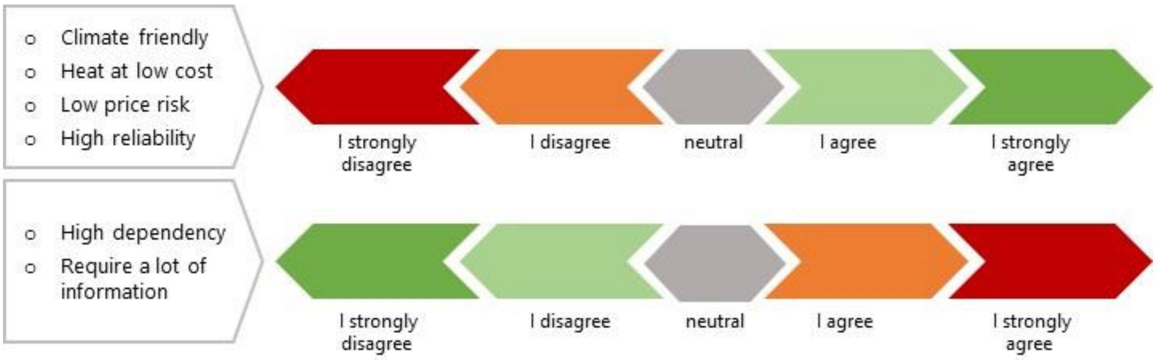

Figure 2: Colour aligned to the level of agreement (households)

As a few respondents did not provide assessments for all statements, the number of respondents for each technology is indicated next to the heating technology option (see n = x).

3.2.1.1 Overall comparison of heating options

The respondents had to rate five heating options: DHC, HP, solar thermal plants (small installations on roof tops), fossil fuel boiler, pellet boiler; the survey of the industry and public sector included a sixth heating option: combined heat and power generation (CHP). The first statement focuses on **climate friendliness** and the responses are presented in Figure 3. Fossil fuel boilers were not perceived by the majority as climate-friendly. In contrast, the majority of respondents agreed very strongly with the climate friendliness of small solar thermal installations. In addition, HP were also perceived as very climate-friendly. Overall, the respondents' answers showed they understood that fossil-fuel-based boilers are the least climate-friendly heating option.

[4] Linear regression analysis (N:3002 and 2924,, Prob <: 0.00, R-square adjusted 0.312 and 0.283 for DH and HP, respectively).

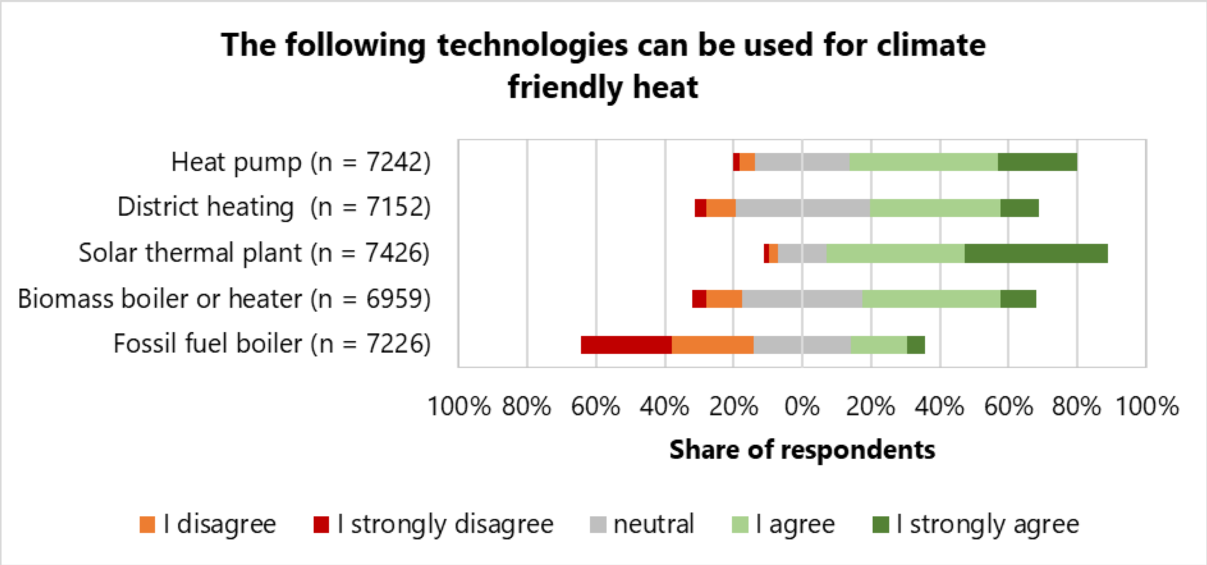

Figure 3: **Perception of households regarding the climate friendliness of heating options**

The second statement addressed economic aspects and asked which technology option can provide **heat at low cost.** The responses are presented in Figure 4. The answers showed a relatively homogeneous perception across heating options, although biomass seemed to be the most costly and solar thermal heating the least costly heating option.

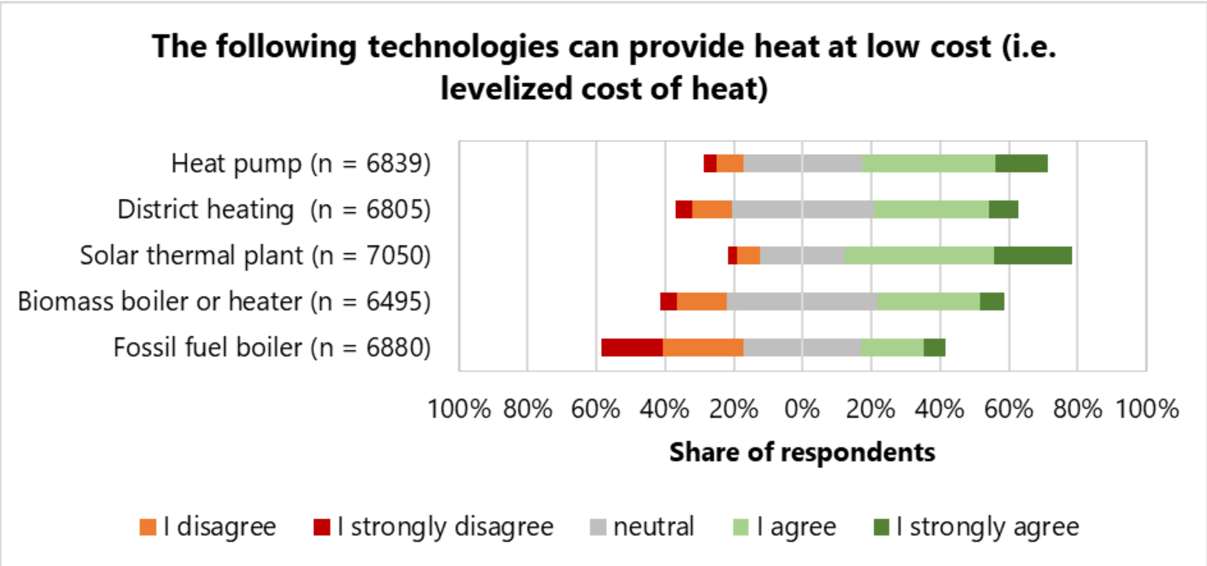

Figure 4: **Perception of households regarding low-cost heating options**

The third statement focused on **price risks to** reveal which heating option was associated with the highest uncertainty regarding future price and cost developments. The answers are presented in Figure 5. Fossil fuel boilers were connected with the highest price risks, which is most likely due to the current energy crisis caused by the Russian-Ukrainian war. The survey was conducted during the war and might reflect the media coverage at that time of natural gas shortages and rising prices. In contrast, solar thermal heating was connected with the lowest price risk, closely followed by HP.

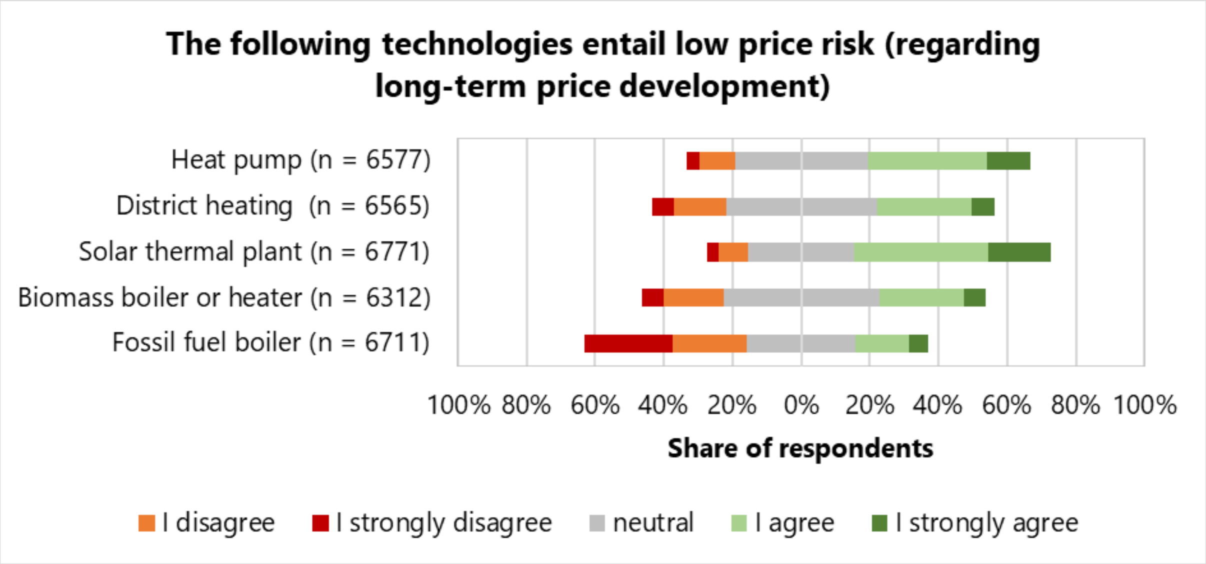

Figure 5: Perception of households regarding the price risk of heating options

Figure 6 shows the respondents' perception of **technical reliability** concerning the supply of heat, heat quality and temperature level. The results show that most of the respondents were very confident with respect to the technical reliability of the given heating options. Only fossil fuels were rated as slightly less reliable, which could be explained by the bottlenecks in gas supply at the time of the survey.

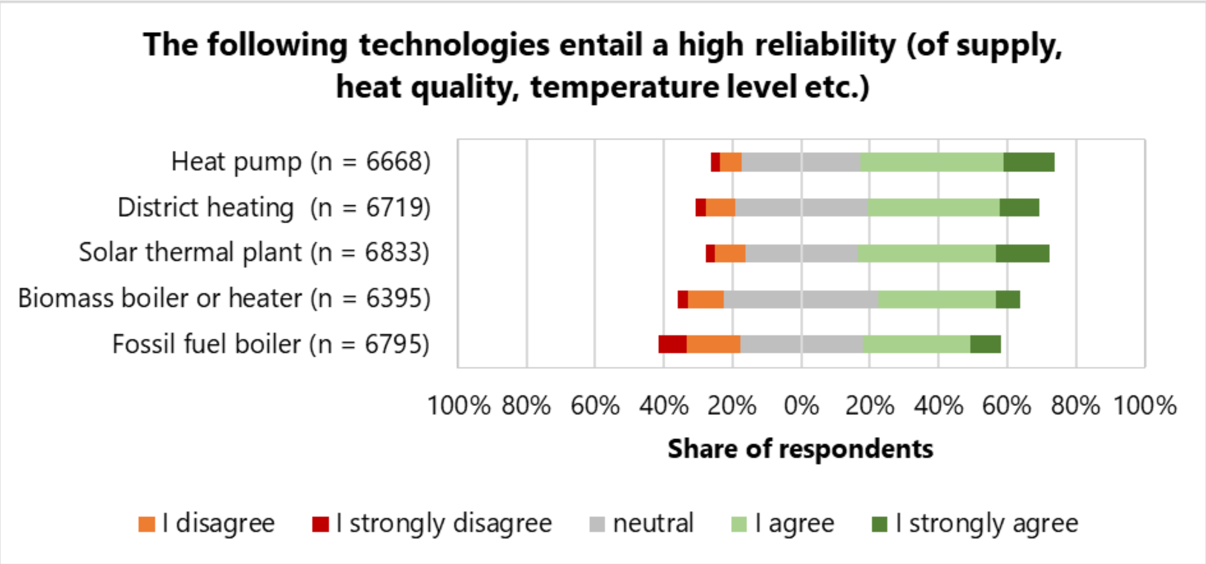

Figure 6: Perception of households regarding the reliability of heating options

The fifth statement is presented in Figure 7 and addresses the perceived **dependency on one energy supplier**. For this figure (and the next figure), the colours are switched due to the inverted logic of the statements (compare Figure 2). The majority of respondents perceived a high dependency on fossil fuels, which can also be explained by the current Ukraine crisis and the widely discussed dependency on natural gas from Russia. Furthermore, the respondents saw a high dependency for DH. In contrast to electricity or gas markets, DH markets are not unbundled, and heat consumers cannot choose their heat supplier but must take the available one. Thus, the high dependency on one energy supplier is a fact and was perceived as such. In contrast, for small solar thermal installations and HP, the respondents perceived no or a very low dependency on one supplier. Solar thermal has low operational costs and the electricity for HP is provided through highly competitive markets, in which the market power of single suppliers is small and citizens can choose their supplier accordingly.

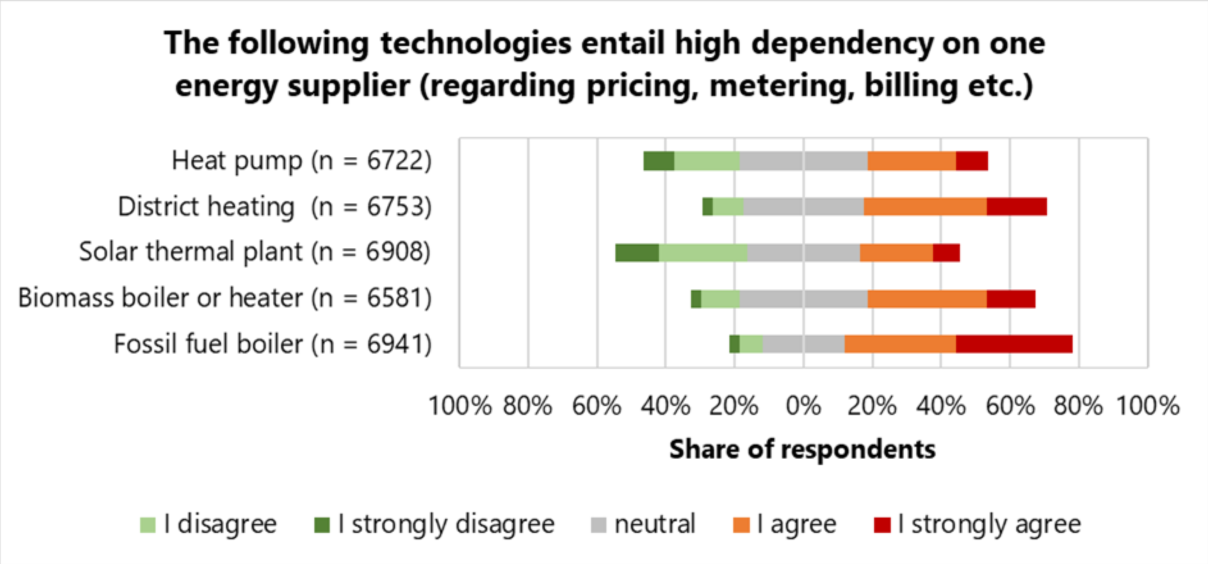

Figure 7: Perception of households regarding the dependency on suppliers

Finally, Figure 8 displays how much **work, time and effort** respondents assigned to the adoption of one of the listed heating systems assuming they needed a new one. According to the respondents, fossil-fuel-based boilers require the lowest effort, followed by DH. For the adoption of the other technologies such as solar thermal, biomass boiler and HP, the respondents expected relatively high effort and work. Thus, it seems that the familiarity with (still dominant) fossil-fuel-based technology translates into a "low effort for the adoption of the technology".

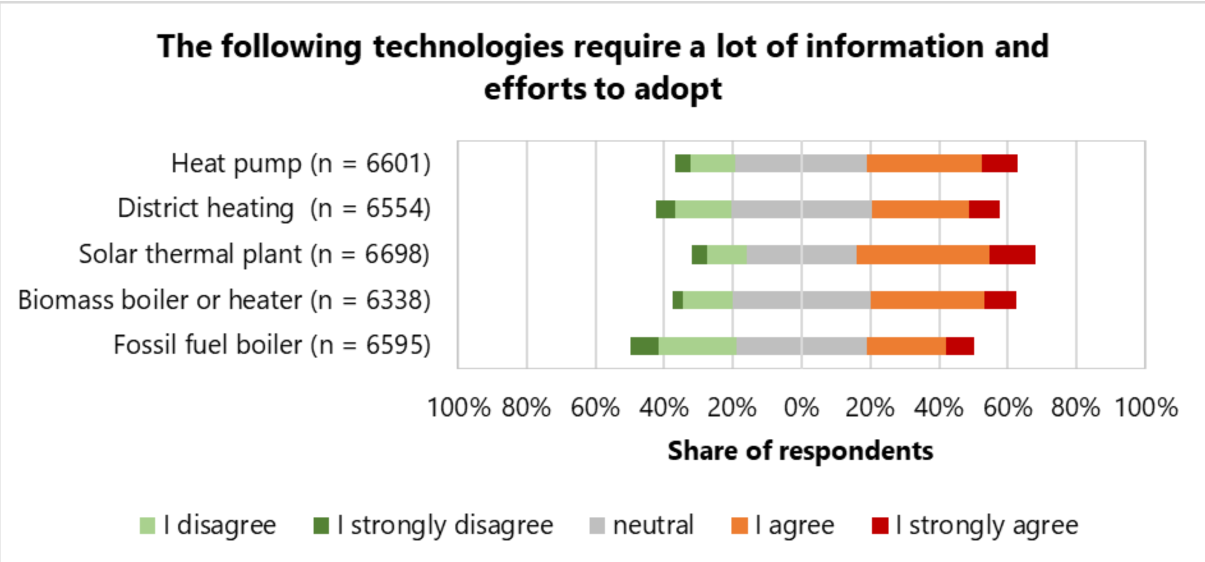

Figure 8: Perception of households regarding efforts for adopting a heating option

Overall, these results are in line with findings from the literature review (compare Task 1). The monopolistic nature of **DH** leads to the perceived risk of becoming dependent on a single provider. Potentially higher costs and no choice of supplier if prices change (price risks) are moderately pronounced. At the same time, the technical reliability, climate friendliness and simple use of the technology were clearly perceived and appreciated by households. The perception of **HP** is overall quite positive: HP were seen as reliable, moderately costly and climate-friendly. Further, they were connected with low price risks and low risks of becoming dependent on one supplier. In contrast, installing HP was seen as requiring quite some effort. However, this perception might also be due to the low familiarity of residents with this technology, since the shares of HP in the building stock are still very low.

3.2.1.2 Differences in the perceived features of H&C options between countries

We also tested for differences between countries and found significant[5] differences for all the technologies and attributes that we asked the participants to rate.

We find that, in all countries, citizens did not consider **fossil fuels** to be climate-friendly, but Poland and Lithuania rated them as the least climate unfriendly. Regarding costs, citizens in most of the countries disagreed with the low-cost statement, Poland and Slovakia disagreed the least. In all countries, citizens agreed that there is a long-term price risk, but this agreement was lowest among respondents from Poland and Lithuania, and highest among respondents from Germany and Denmark. Regarding a reliable supply of heat, fossil fuels were rated as reliable by citizens from the Netherlands and Spain, and not reliable by citizens from Denmark and France. While respondents from Germany and Spain saw a high dependency on fossil fuel suppliers, respondents from the Czech Republic, Denmark and Sweden perceived the least dependency. Citizens in the Netherlands and Denmark associated low efforts with fossil fuel heating technologies, while citizens in Sweden and Poland associated major efforts with fossil fuel boilers.

The ratings of the perceived features of **biomass boilers** differed significantly by country. In Spain, Germany and France, citizens rated biomass as a more climate-friendly heating option than citizens in the other countries. Among the analysed countries, citizens in France and Spain considered heating with biomass as the least costly and highly reliable heating option with low price risks and dependency on energy suppliers.

Solar thermal heating was rated the highest with respect to its climate friendliness in Denmark, Sweden and Lithuania, but the lowest in France. In France, this option was also seen as the least low-cost and most price-risky solution, while in Lithuania it was rated the most low-cost option. Citizens from Denmark and Sweden perceived low price risks as the most positive feature. Further, reliability was rated the highest in Italy and Spain, and the lowest in Poland. The risk of becoming dependent on an energy supplier was considered to be the lowest by citizens in Germany and Italy, and the highest by citizens in France and Poland. Efforts to adopt and use this technology were assessed to be the highest by citizens in Lithuania and the lowest by citizens in Denmark and the Netherlands.

For **DH,** the ratings per country are presented in Figure 9 and Figure 10. The ratings differ significantly between countries. Overall, the rating is positive to neutral. In some countries, such as Lithuania, the Netherlands, Spain or the Czech Republic, the rating is less positive. Furthermore, citizens in all countries perceived a certain risk of becoming dependent on an energy supplier (i.e. DH supplier). Similarly, the efforts to adopt or use DH as a heating option was rated the least positive on average by all countries.

[5] At significance level < 0.05 with the Kruskal-Wallis test, a non-parametric test that is used to test whether the independent samples (more than 2) originate from the same distribution that is not necessarily normally distributed and homogeneous in variances.

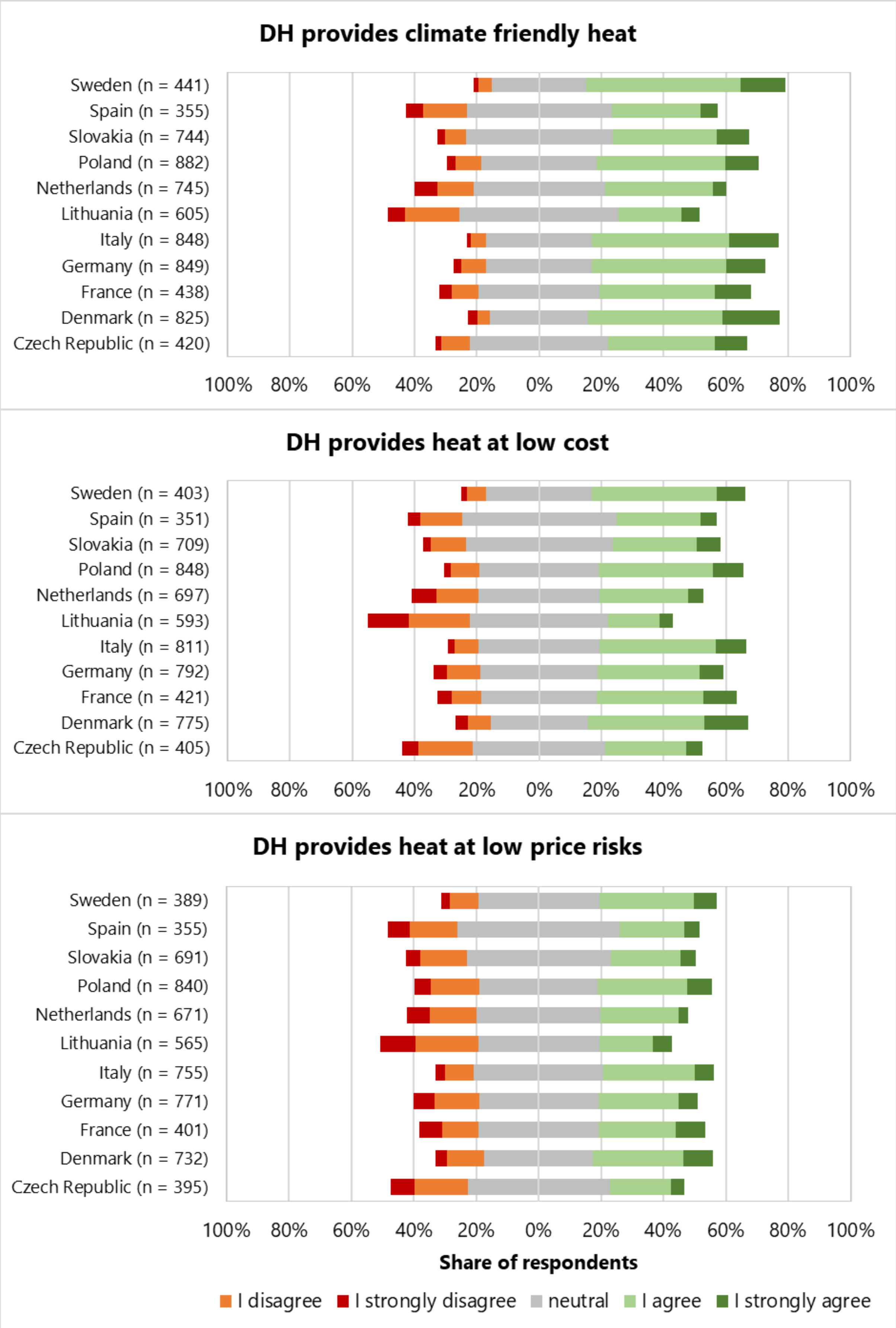

Figure 9: **Perception of DH by countries (part 1)**

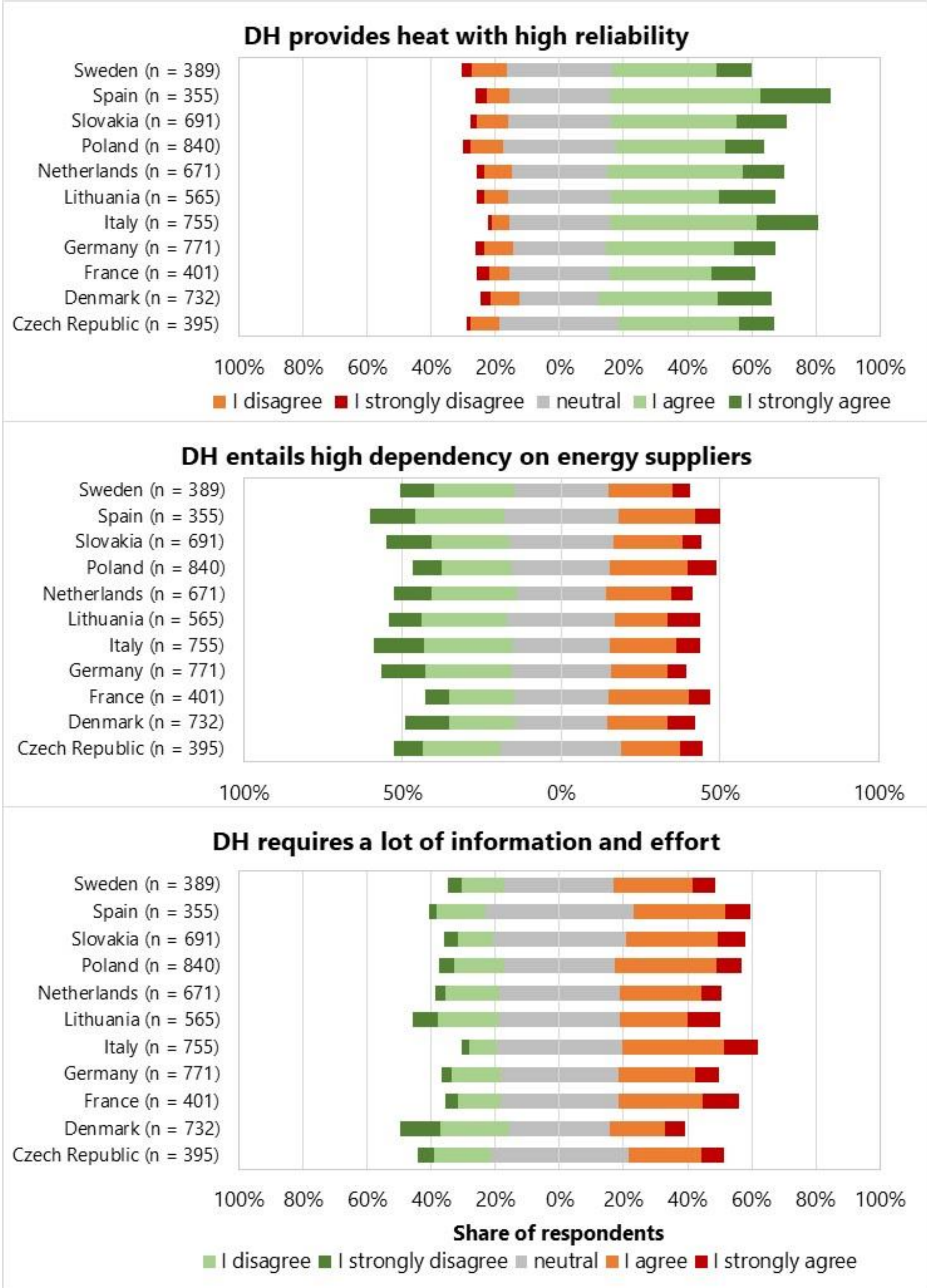

Figure 10: Perception of DH by countries (part 2)

For **HP,** the ratings per country are presented in Figure 11 and Figure 12. The ratings differ significantly by country. Overall, the technology is rated quite positively, except for the efforts needed to adopt or use it. Citizens in Italy, Spain and partially Lithuania tended to have a slightly more negative image of HP than citizens in the other countries of the sample.

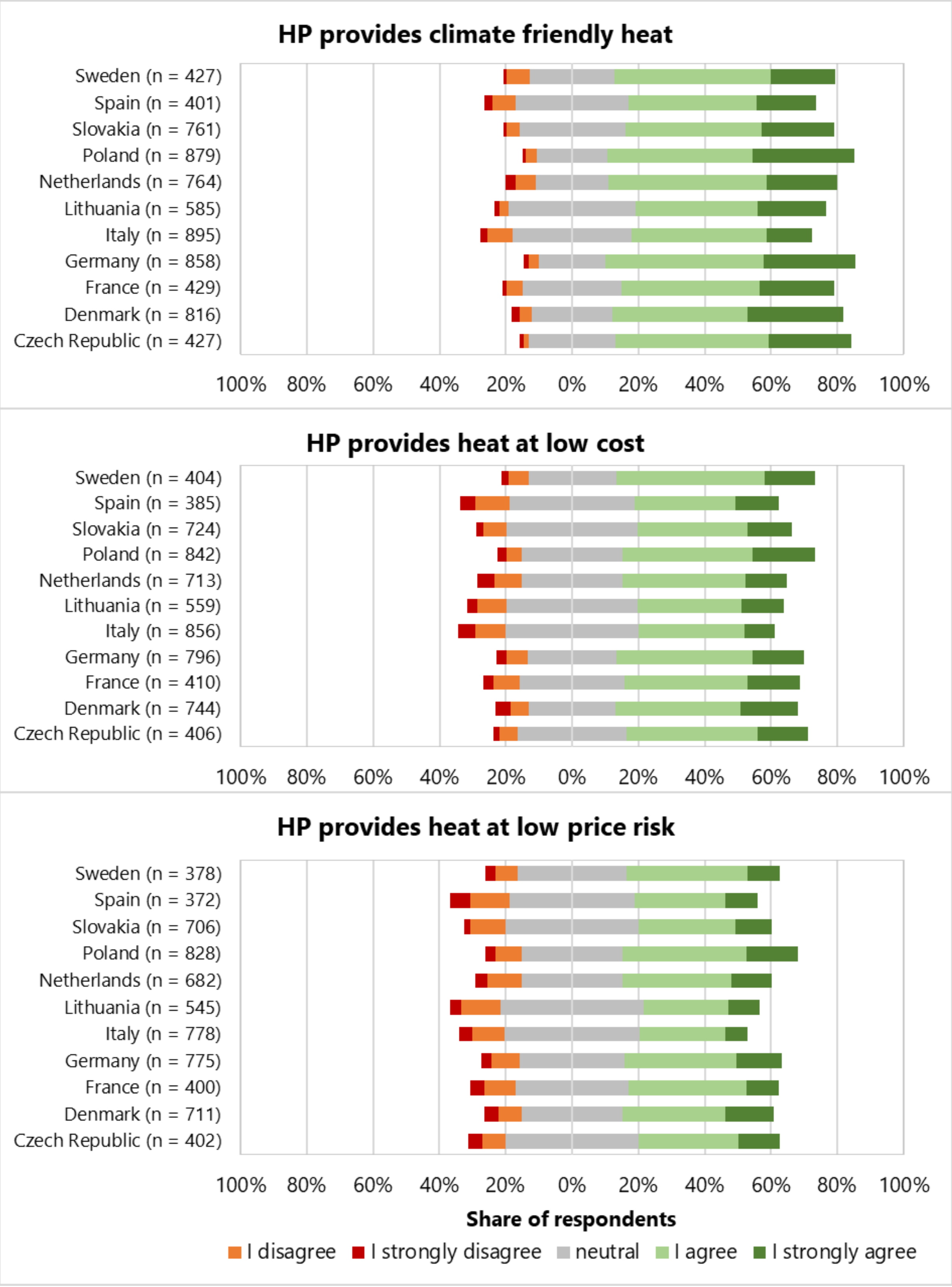

Figure 11: Perception of HP by countries (part 1)

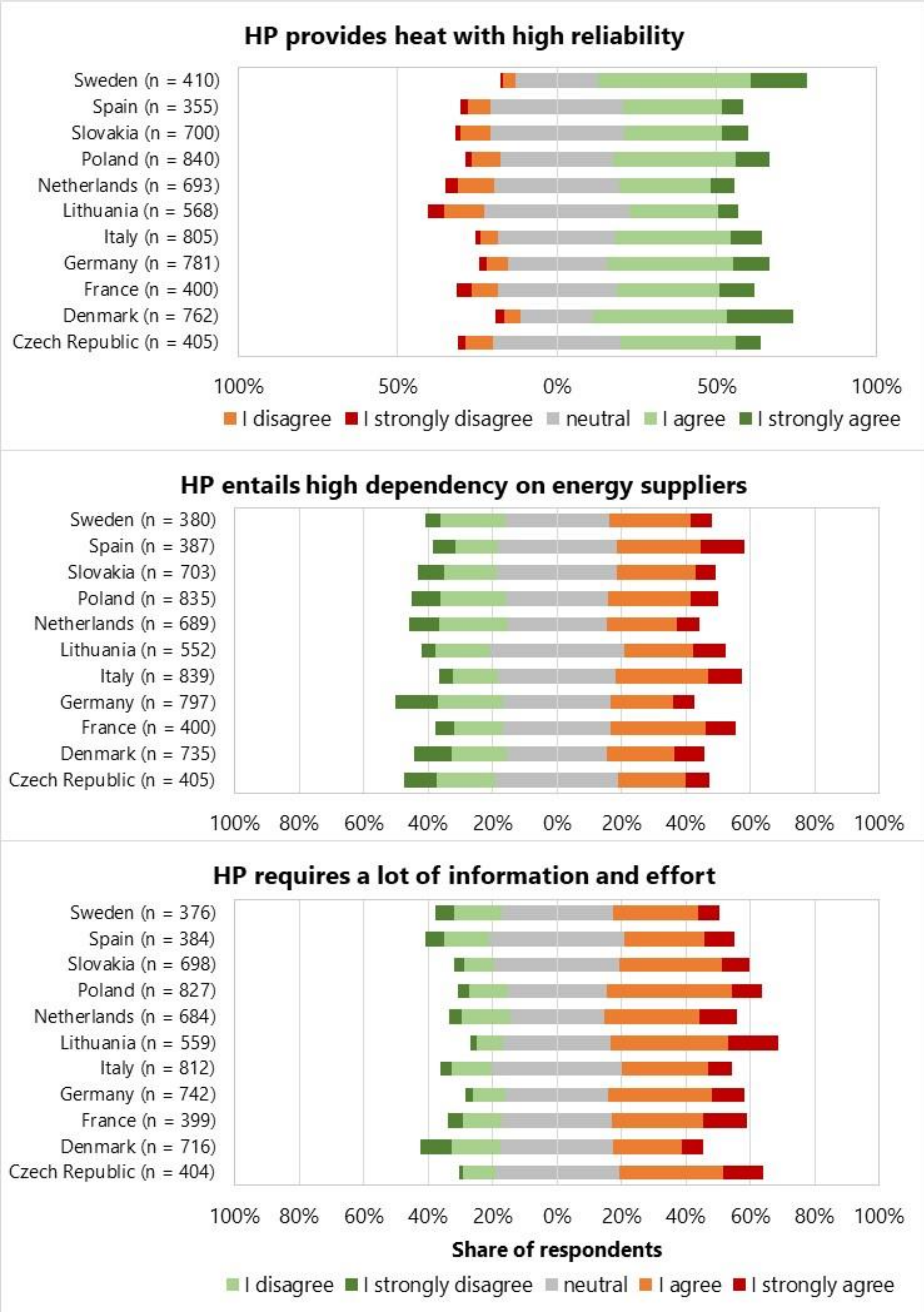

Figure 12: **Perception of HP by countries (part 2)**

Detailed information on country results per technology and feature is available in Annex A.2.

3.2.1.3 Differences by socio-demographic factors

The perception of citizens regarding heating supply is shaped by personal values and attitudes that are in turn influenced by many different external factors. Based on the literature review in Task 1, we differentiated external factors comprising macro-level and meso-level aspects such as social rules, economic system, energy system, and peers' energy culture. The external factors potentially influence individual factors at the micro level that can be differentiated into demographic factors (e.g. family size, income, features of their dwelling) and personal values and attitudes. In this context, we analysed whether and how the perception of the selected heating options differed by socio-demographic factors – education, location of their home, and home ownership. We examined the same features as before – climate friendliness, cost level, price risk, reliability of supply, dependency on supplier and adoption effort – of the selected heating options HP, DH, solar thermal, biomass and fossil fuel boilers. We used parametric and non-parametric tests[6] to check differences between selected socio-demographic characteristics. Table 3 depicts the selected socio-demographic factors and the significance level per technology and perceived feature. The key objective was to identify whether the answers of respondents differ by the respective socio-demographic factor. For example, the heating option fossil fuel boilers displays a high number of significant tests, which suggests that responses of house owners might differ significantly from those of tenants or of apartment owners.

Overall, the test results show very different perceptions of the heating options DH and fossil fuel boilers, i.e. the responses differ by education, location and ownership characteristics.

Table 3: Perceived features of heating options by socio-demographic factors

Socio-demographic characteristics	Perceived features	FF	Bio	ST	DH	HP
Ownership	Climate-friendly	***	***		**	***
Owner of house	Low-cost	***	***		***	**
Owner of apartment	Low price risk	***				
Tenant of house	Reliability	**	***	***	***	***
Tenant of apartment	High dependency	**	**		***	
	High information, efforts	*	**	***	***	***
Location	Climate-friendly	*			**	***
Town < 20 000 inhabitants	Low-cost	**			***	
City < 200 000 inhabitants	Low price risk				***	
Large city < 1 000 000 inhabitants	Reliability				***	**
Mega city > 1 000 000 inhabitants	High dependency					
	High information, efforts	*	**	***	***	***
Education	Climate-friendly	***		**	***	**
Primary education	Low-cost	**			***	*
Secondary education	Low price risk	***	*		***	
Professional training	Reliability	*		*	***	
Tertiary education	High dependency	***	**	***	***	***
	High information, efforts	***		***	*	**

Note: * sig < 0.1; ** sig < 0.5; *** sig < 0.01 based on (non-) parametric tests; FF: fossil fuel boiler, Bio: biomass boiler, ST: solar thermal

Tenants of apartments disagreed the most with the climate friendliness, reliability, low-cost and low-price risk properties of fossil fuel boilers, while apartment owners disagreed with the statement concerning the dependency on energy suppliers. Tenants of a house disagreed the most with the

[6] Kruskal-Wallis test, a non-parametric test that is used to test whether the samples (more than 2) originate from the same distribution without the assumption of a normal distribution and homogeneous in variances.

statements on climate friendliness, low-cost, reliability, dependency and adoption or usage effort of biomass boilers. Similarly, they disagreed the most with the statements on reliability and adoption or usage effort of solar thermal heating. DH is the least positively perceived with respect to climate friendliness, low cost, reliability and adoption or usage effort by house owners, while dependency on an energy supplier is rated the highest by apartment owners. House owners rated HP as the most reliable, climate-friendly and low-cost heating solution, while tenants considered HP to involve less effort than the owners of a dwelling.

The analysis shows that **location size** can affect the perception of some heating technologies. For example, fossil fuels are considered the least climate-friendly and the least low-cost option by citizens in mega cities. The perception of biomass and solar thermal did not differ between locations apart from the required effort, which was rated the highest by those living in mega cities. The climate friendliness rating of DH was the most positive in large cities, and on low-cost, low price risks, and reliability, it was the most positive in mega cities and the most negative in villages, while effort to adopt or use DH was perceived as high in both villages and mega cities. HP was perceived as the least climate-friendly and reliable in mega cities and large cities, and the most demanding with respect to the effort involved by villages and towns.

When looking at **education**, we found that citizens with tertiary education rated the climate friendliness of DH and fossil fuels the lowest, and that of solar thermal and HP the highest. Regarding the low-cost potential, we found high agreement among the primary education group and the lowest agreement in the tertiary education group, while the group with professional training considered HP a low-cost heating option. Price risks were considered to be high for fossil fuels, biomass and DH, especially by the group with tertiary education. Reliability was rated the highest for solar thermal by citizens with tertiary education, and the lowest for DH by citizens with primary education. Becoming dependent on an energy supplier was rated high for fossil fuels and biomass by trained people, high for solar thermal and HP by people with primary education, and high for DH by persons with tertiary education. To use or adopt a heating technology requires the lowest effort for solar thermal and HP according to the primary education group, and for DH and fossil fuels according to the tertiary education group

Detailed information on the socio-demographic results per technology and feature is available in Annex A.3.

3.2.2 Perception and satisfaction of households with DH

In this section, the analysis is based on the sample that focused on users and non-users of DH. It comprised general questions on the perception of DH (three questions) and very specific questions addressing selected characteristics of DH.

3.2.2.1 Overall perception and satisfaction of households with DH

General perception of DH

This section presents the results concerning the general perception of DH ("How do you rate DH as a heating system overall?") and the acceptance of this heating technology ("How acceptable do you consider the use of DH?"). The results regarding satisfaction with the current heating system are also shown, but this question was only analysed for users of DH (not for non-users).

As a key result of the online survey, it can be concluded that, overall, **the perception of DH by European households was positive**. Figure 13 shows the perception and acceptance of DH by users and non-users as well as user satisfaction with DH (n = number of respondents and M = mean). The majority of the respondents rated DH as positive or even very positive (53%), while only 10% rated the technology as negative or very negative. Similarly, the acceptance of DH is very high. 56% stated that they considered DH as acceptable or completely acceptable. There are higher results regarding user satisfaction with DH: 66% of DH users were satisfied, although 16% of DH users were not satisfied with their DH connection.

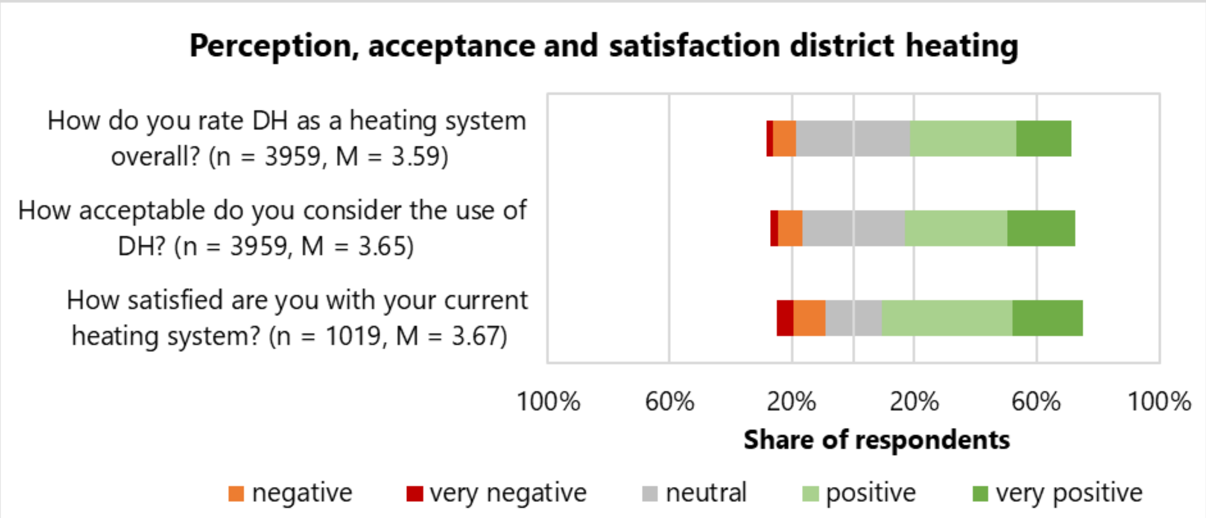

Figure 13: Perception of and satisfaction with DH of households

The next figures focus on differences between users and non-users. Figure 14 shows the perception and acceptance of users vs. non-users of DH. It becomes clear that **users had a significantly better perception and higher acceptance** of DH compared to non-users. An independent sample t-test (with Welch-correction since the variances differed significantly[7]) shows significant differences in the average level of acceptance between users (n = 1019, M = 3.95) and non-users (n = 2940, M = 3.55).[8] There were

[7] Welch's t-test, also known as Welch-test or t-test with Welch-correction, is a two-samples test, which is used to test the hypothesis that two populations have equal means but are not homogeneous in their variances. Its name is based on its creator, Bernard Lewis Welch. If we do not specify the test name, we conducted a t-test.

[8] $t = 11.20$, $p < .001$, 95%-CI [0.33; 0.47], Cohen's $d = .41$, small effect

similar results regarding the perception of DH: users' (n = 1019, M = 3.83) perception of DH was significantly more positive than non-users of DH (n = 2940, M = 3.50).[9]

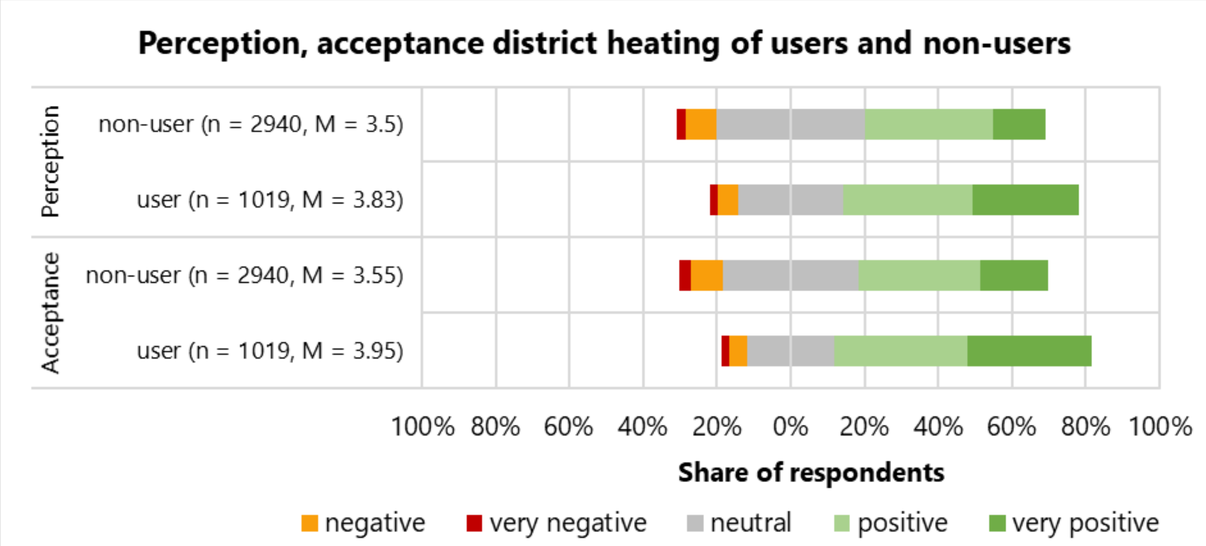

Figure 14: Perception and acceptance of DH of users and non-users (households)

Questions addressing specific characteristics of DH

We also asked the respondents to rate specific characteristics of DH. Figure 15 visualises the rating of different DH characteristics by users and non-users, such as interesting vs. uninteresting or cheap vs. expensive (semantic differential). At first sight, the perception of the different characteristics seems to be quite similar between users and non-users, but significant differences are revealed by statistical analyses (t-tests, partly with Welch-correction, and Mann-Whitney-U tests).

On the one hand, **non-users perceived DH to be slightly more** interesting[10], **innovative[11]**, controllable[12] and good for the environment[13] **than users of DH**. In addition, compared to users, non-users thought DH leads to slightly higher independence[14]. On the other hand, compared to users, non-users perceived DH as slightly less safe[15], reliable[16], convenient[17], and comfortable[18]. Further, non-users associated connection to a DH network with **significantly greater effort[19]**. Only the t-test for the rating on cheap vs. expensive did not differ significantly between users and non-users (see means for each group from the inference statistical in Figure 15).

[9] t = 9.50, p < .001, 95%-CI [0.26; 0.39], Cohen's d = .35, small effect

[10] Welch -test, t = -8.06, p < .001 , 95%-CI [-0.40; -0.25], Cohen's d = .28, small effect

[11] t-test, t = -12.57, p < .001 , 95%-CI [-0.61; -0.45], Cohen's d = .46, small to medium effect

[12] Welch-test, t = -4.69, p < .001, 95%-CI [-0.31; -0.13], Cohen's d = .18, very small effect

[13] t-test, t = -3.45, p = .001, 95%-CI [-0.20; -0.05], Cohen's d = .12, very small effect

[14] t-test, t = 2.63, p = .009, 95%-CI [0.20; 0.03], Cohen's d = .10, very small effect

[15] t-test, t = 6.12, p < .001, 95%-CI [0.15; 0.30], Cohen's d = .23, small effect

[16] t-test, t = 7.42, p < .001, 95%-CI [0.21; 0.36], Cohen's d = .27, small effect

[17] t-test, t = 9.29, p < .001, 95%-CI [0.29; 0.44], Cohen's d = .34, small effect

[18] Welch-test, t = 9.10, p < .001, 95%-CI [0.28; 0.43], Cohen's d = .33, small effect

[19] Welch-test, t = 14.79, p < .001, 95%-CI [0.50; 0.65], Cohen's d = .54, medium effect

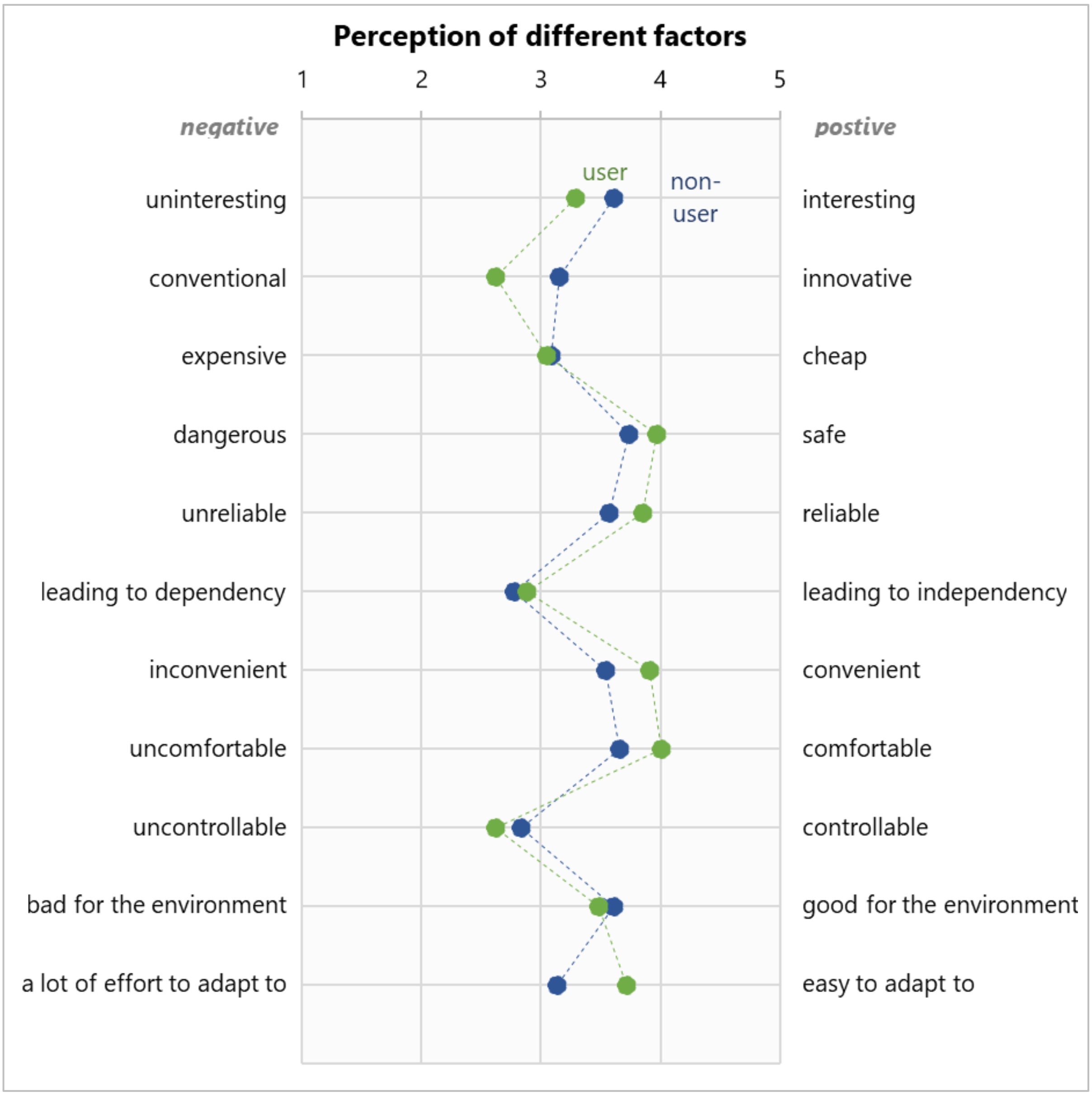

Figure 15: Perception of different DH factors by users and non-users (households)

3.2.2.2 Perception and satisfaction of households with DH by countries

General perception of DH

This section focuses on country-specific differences in the general perception of and satisfaction with DH between the surveyed countries. Figure 16 shows the overall perception and Figure 17 shows satisfaction with DH (n = number of respondents and M = mean). An overview of the samples per country, the connected population and more country results are shown in the **country fact sheets in Annex A.4**.

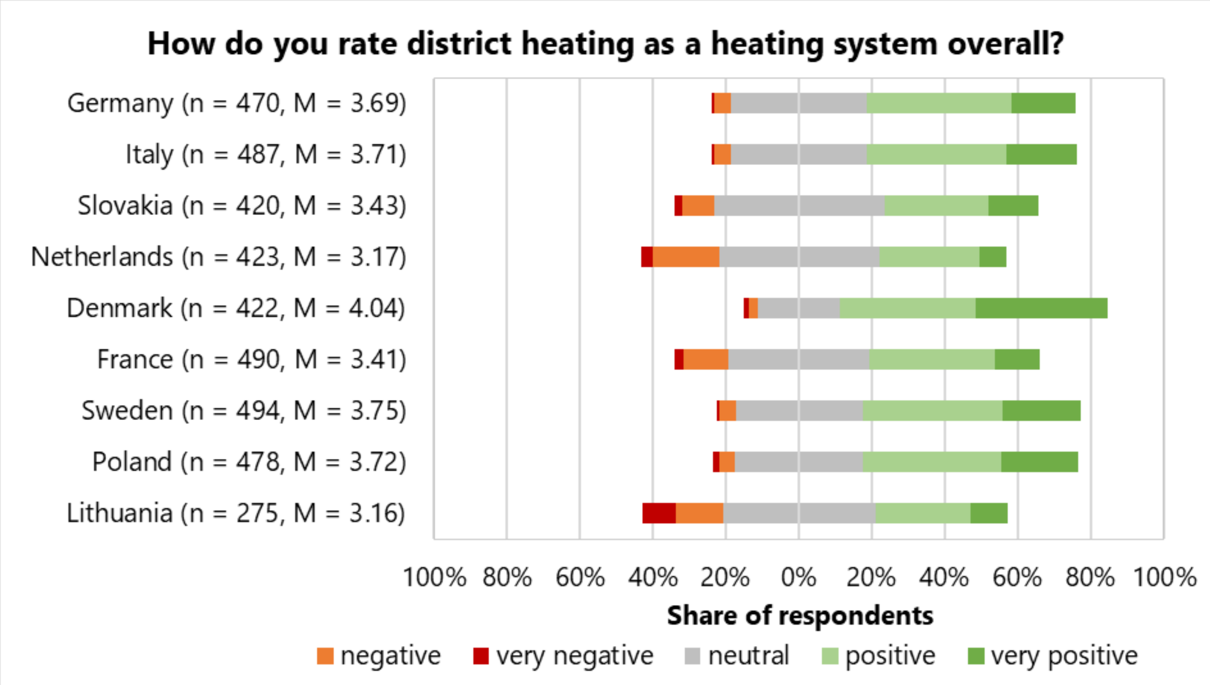

Figure 16: **Perception of households of DH in different countries**

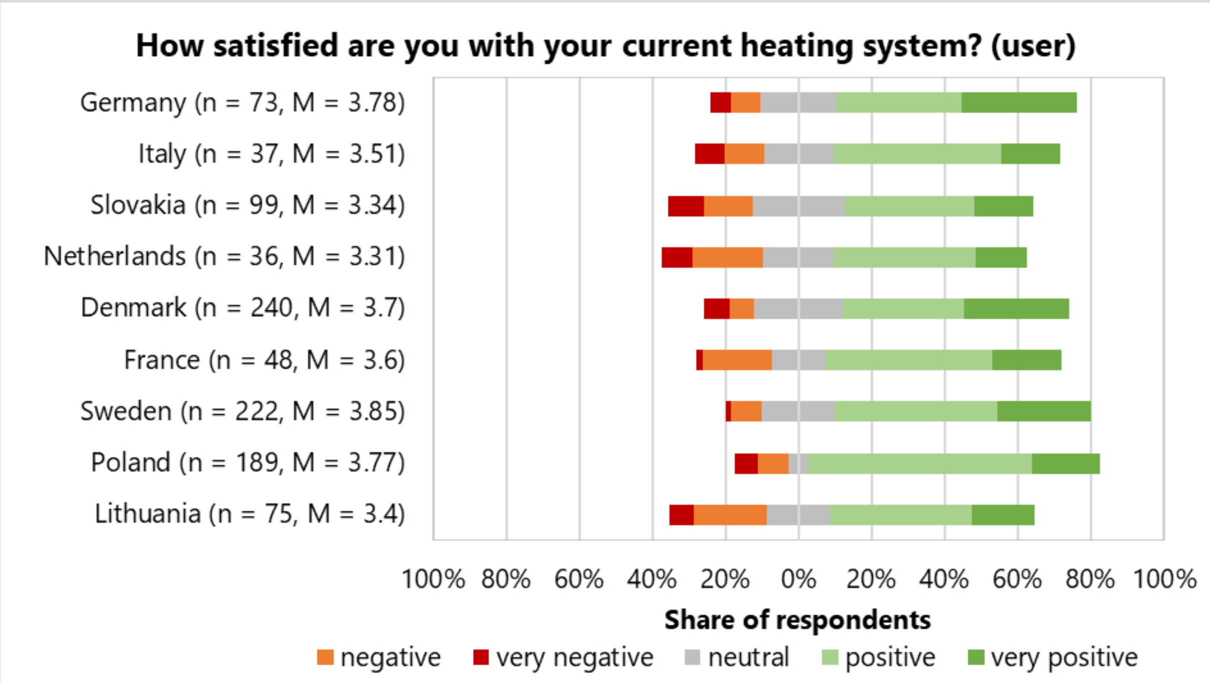

Figure 17: **Satisfaction of households with DH in different countries**

The perception of DH was particularly positive in Denmark, followed by Sweden and Poland (compare Figure 16). In Italy and Germany, DH also had a very positive image. In the Netherlands and in Lithuania, the perception was slightly less positive, with more than 35% rating DH as negative or even very negative. However, the mean is still relatively high with 3.17 and 3.16 (on a 5-point Likert scale ranging from 1 = very negative to 5 = very positive), indicating a neutral to positive image on average. The level of satisfaction with the use of DH resembles the results in the perception of DH. The highest satisfaction with DH was in Sweden, followed by Germany, Poland and Denmark (compare Figure 17). In the Netherlands and Lithuania, the respondents were slightly less satisfied. However, on average, high satisfaction was also reached in those countries (M = 3.31 and 3.40). Thus, the overall picture regarding satisfaction is similar to the overall perception of DH in these countries.

Questions addressing specific characteristics of DH

In addition to these results, Figure 18 visualises the rating of different DH characteristics in the countries. It can be observed that almost all factors were rated rather negatively in Lithuania, while several factors were rated very positively in Denmark.

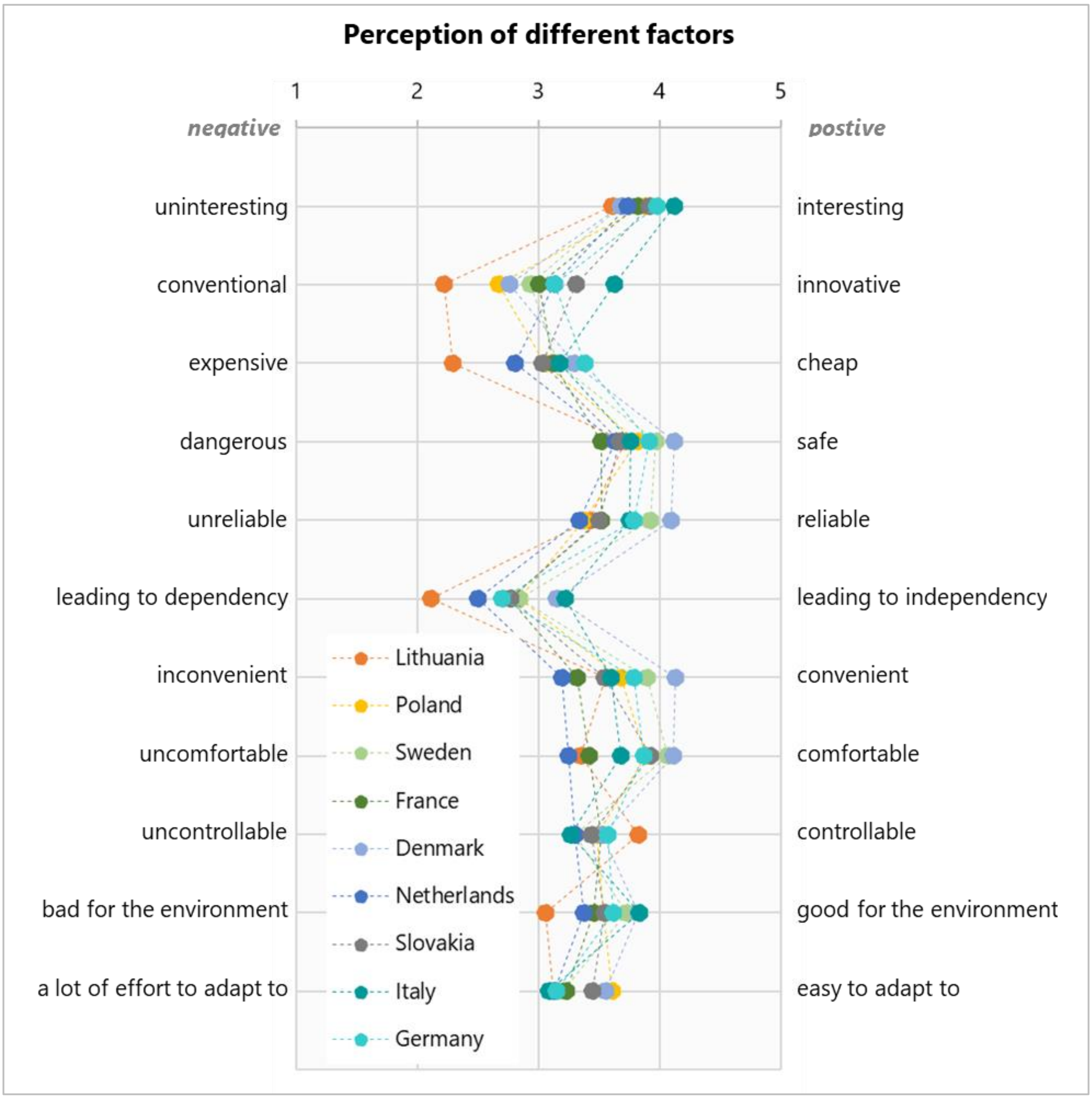

Figure 18: **Perception of different DH factors in the countries (households)**

3.2.2.3 Socio-demographic factors and attitudes and their influence on the perception of households with DH

Socio-demographic factors and attitudes can have an impact on the perception and satisfaction of households with DH, so this section focuses on factors and attitudes and their influence. Figure 19 shows different groups and their rating (general perception) of DH. It becomes clear that there are only very small, statistically non-significant differences between males and females. Non-binary respondents are similar to males and females. Slight differences can be observed regarding education, and age as well as between respondents from cities and villages (i.e. less than 20,000 inhabitants).

When conducting inference statistical analyses, the results show that people with higher education have significantly better perceptions than people with lower levels of education.[20] However, the effect is so small (Cohen's d = 0.06) that it should be treated as no effect. Regarding age, older respondents perceived DH significantly better than younger respondents.[21] However, this effect is again very small. Respondents from cities seemed to have a significantly more positive perception.[22] Again, with a very small to no effect. This result is most likely explained by the fact that DH users are often located in cities (because DH needs higher heat densities) and, as shown in section 3.2.2.1, users have an overall more positive perception of DH. Moreover, there is a significant difference in perception of DH between the owners of a house and the tenants/owners of an apartment.[23] However, the effect is so small that it cannot be considered.

In addition to these socio-demographical standard variables, differences linked to environmental awareness and affinity to (new) technologies were also assessed. A mean split (Group 1 >= Mean, Group 2 < Mean) was performed to create the groups. The comparison shows that respondents with higher environmental awareness (n = 2340, M = 3.73) had a significantly better perception of DH compared to respondents (n = 1584, M = 3.38) with lower environmental awareness.[24] The same applies to respondents with a higher affinity to (new) technology (n = 1798, M = 3.74) compared to their counterparts (n = 2129, M = 3.46).[25] It is noteworthy that the effect sizes for these groups are larger (although still small) than the effects of the other socio-demographic factors. Hence, values and attitudes seem to have a stronger influence on the perception of DH than socio-demographic factors.

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[20] Welch-test, t = -2.15, p = .032, 95%-CI [-0.12; -0.005]

[21] Welch-test, t = -4.32, p < .001, 95%-CI [-0.19; -0.07], Cohen's d = .14

[22] t = -2.99, p = .003, 95%-CI [-0.15; -0.03], Cohen's d = .10

[23] t = -2.73, p = .006, 95%-CI [-0.14; -0.02], Cohen's d = .10

[24] t = -11.38, p < .001, 95%-CI [-0.40; -0.28], Cohen's d = .38, small effect

[25] t = -9.51, p < .001, 95%-CI [-0.34; -0.23], Cohen's d = .30

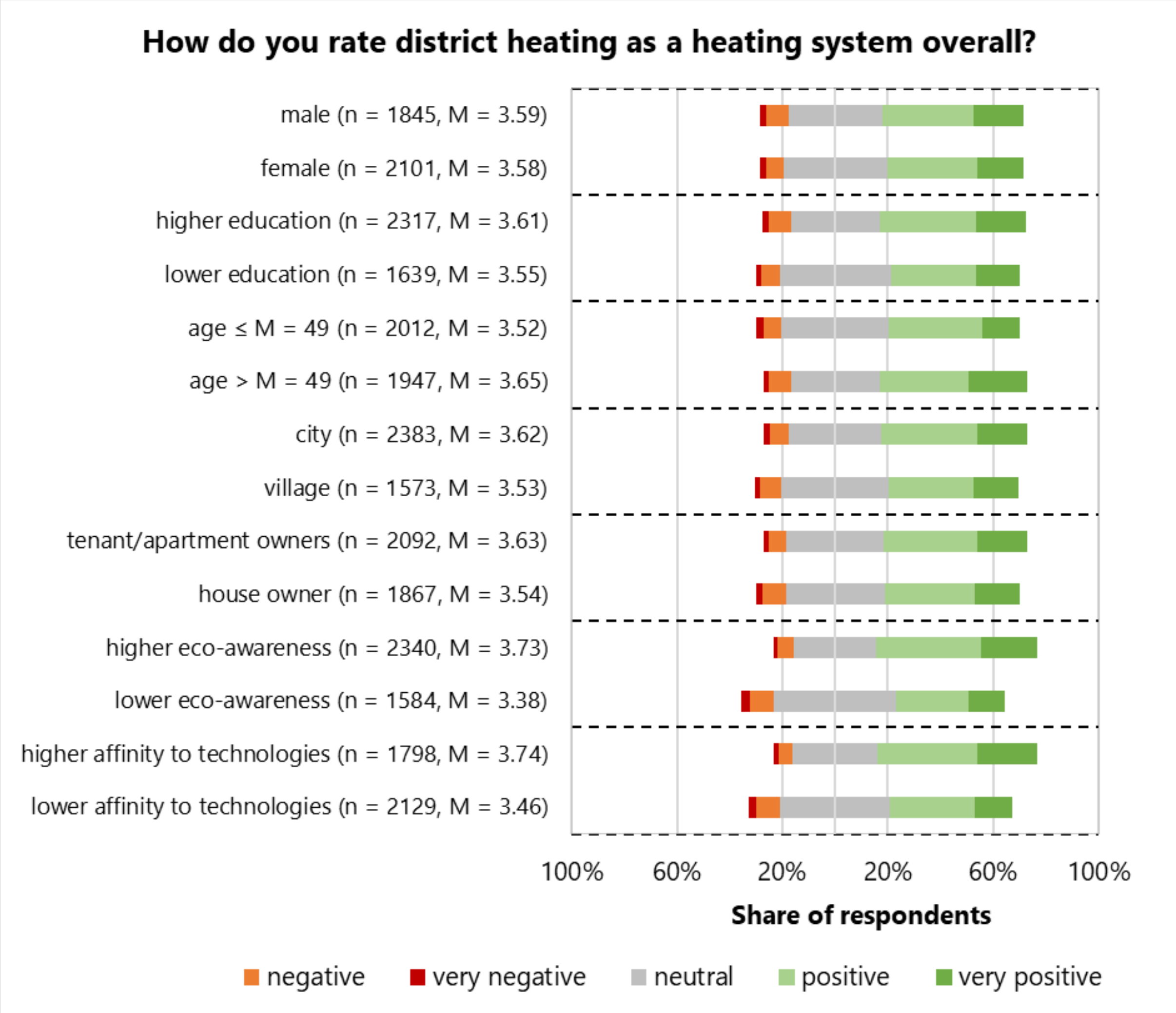

Figure 19: Perception of DH in different groups (households)

3.2.2.4 Perception and satisfaction with DH in context of regulatory aspects

One characteristic of DH is the potential excessive use of market power, because of the monopoly structure of DH infrastructure. Consequently, DH is framed by institutional settings and regulations to ensure market transparency, competition and consumer rights. Different approaches towards regulation addressing these settings can be observed in European countries, ranging from more market-oriented approaches to stricter, more rule-based regimes (Bacquet et al. 2022). Analysing the interrelations between institutional settings and regulations and the perception of consumers can reveal whether these settings contribute to a positive perception of DH. Thus, the following analysis focused on interrelations between three regulatory aspects: (i) mandatory connection for consumers (ii) pricing and price regulation and (iii) financial support for the connection.

Mandatory connection for consumers

Connecting consumers to local DH networks is a highly relevant topic, as DH networks often face the challenge that not enough citizens are motivated to connect to the network, leading to low profitability of the systems (Bacquet et al., 2022). Therefore, some countries or regions have introduced mandatory grid connections for consumers, which means that consumers are obliged to connect to their local DH network under certain conditions. In most cases, the obligation applies only to new buildings in certain regions.

Table 4 shows the number of respondents per country that stated they were obligated to connect to their local DH network (i.e. mandatory connection) in relation to the total number of respondents. This question was only directed at DH users owning a house, because only they were able to answer the question. Tenants and apartment owners are not always free to choose, e.g. if the building owner has decided on the connection, regardless of whether there is a connection obligation for the property or not. In total, 60% of the respondents (DH users and house owners) indicated that they were obligated to connect to their local DH network and 23% stated there was no mandatory connection for their house. An additional 17% indicated that they did not know if there was an obligation or not.

Table 4: Number of respondents with mandatory connection per country

Country	Number of respondents with mandatory connection (DH users and house owners)	Total number of respondents (DH users and house owners)
Lithuania	1	3
Poland	26	42
Sweden	25	46
France	4	6
Denmark	65	104
Netherlands	10	17
Slovakia	2	3
Italy	9	16
Germany	7	11

Figure 20 shows the perception of and satisfaction with DH of house owners using DH, with and without mandatory connection. The comparison shows that respondents with mandatory connections displayed more extreme values. However, the mean of the rating is more or less the same (with mandatory connection: M = 4.00 vs. M = 3.78 without mandatory connection). This was confirmed by statistical analysis (t-test) comparing the means. Hence, there was no significant difference in the perception of DH between respondents with or without mandatory connection. There is a similar result for satisfaction with DH, i.e. also statistically non-significant.

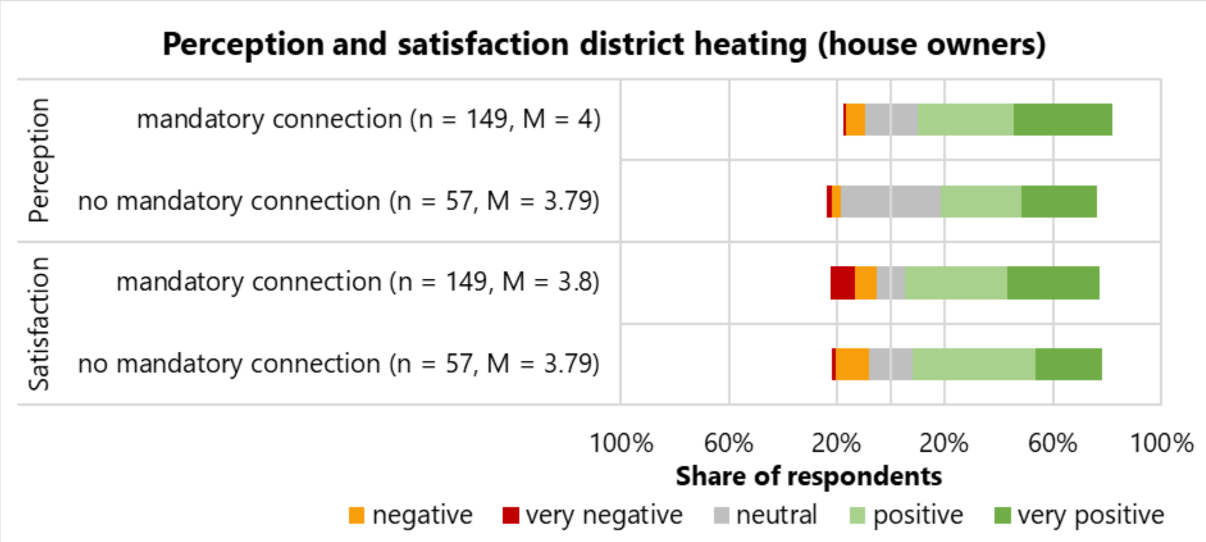

Figure 20: **Perception of and satisfaction with DH of house owners with mandatory connection and without (households)**

Pricing and price regulation

DH prices differ according to the network and possibly even according to the consumer. Prices are not published in most countries, so there is a lack of DH price data. Thus, one question in the online survey was used to obtain an estimation of DH prices. The participants were asked to describe the price in comparison to their income (see Figure 21). Around half of the users stated that they perceived their DH price as neutral. However, around one-third described the price as high and nearly 15% as very high. Only 1% described their price as very low. Thereby, respondents with lower education shared a similar overall perception.

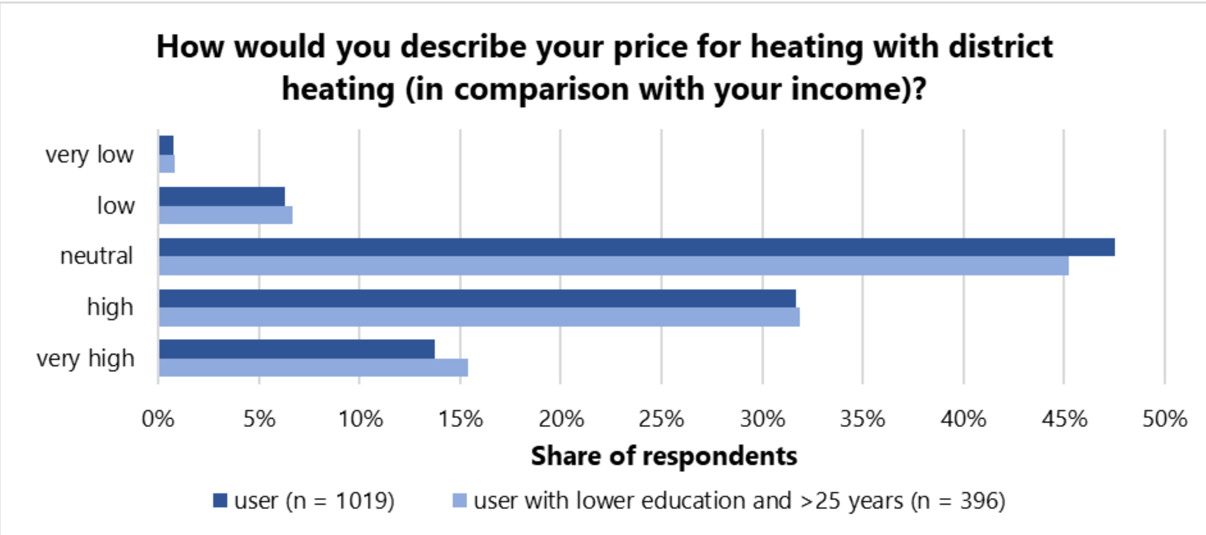

Figure 21: **Rating of prices for heating with DH (households)**

There are different approaches in the countries regarding the regulation of consumer prices (Bacquet et al. 2022). Some countries do not have specific DH price regulations and thus only rely on cartel law. However, several countries rely on price regulation that goes further than cartel law supervision. They have specific price rules, such as a maximum value or the rule that prices must be set in a proportionate and cost-based manner. In addition, prices must be authorized before being used in some countries or prices are even set by the regulatory authority. Table 5 indicates the price regulation in place in the countries of the online survey.

Table 5: Price regulation in the countries (based on Bacquet et al. 2022)

Country	Price regulation in place 1. No specific regulation or supervision (e.g. only cartel law) 2. Price is defined by DH operator with a price calculation rule (e.g. price limits) 3. Price is defined by regulator or by operator with approval of price by regulator
Lithuania	3
Poland	3
Denmark	2
The Netherlands	2
Slovakia	2
Italy	1
Germany	2
France	3
Sweden	2

Based on the price regulation in place, the countries can be divided into two groups: (i) strict price control and regulation (Lithuania, Poland and France) and (ii) market-oriented price regulation (Denmark, the Netherlands, Italy, Slovakia, Germany and Sweden). Figure 22 shows the means of the answers for the overall perception and the rating of the prices for the two groups (DH users).[26]

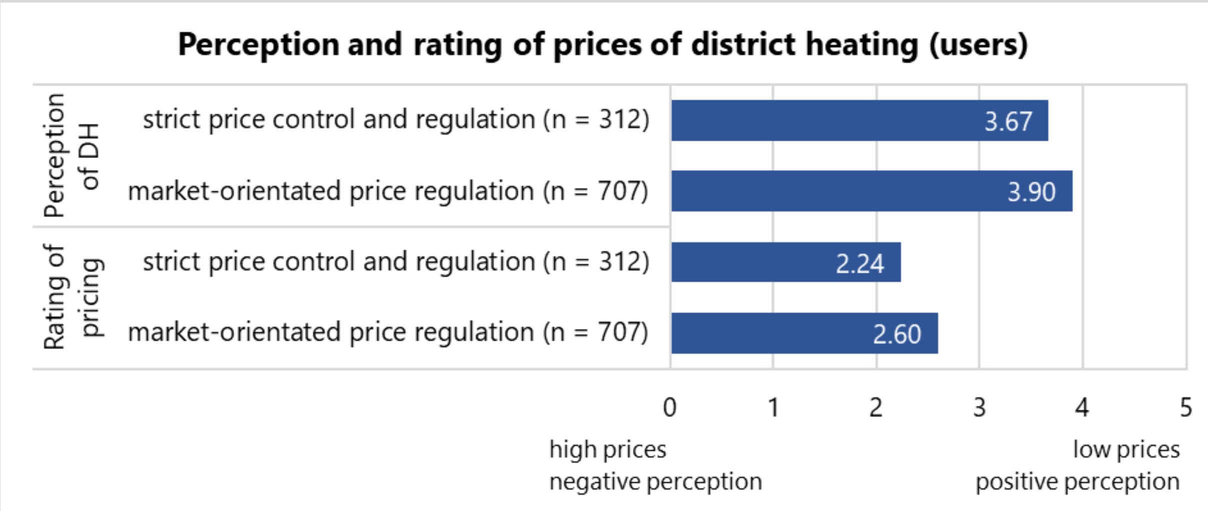

Figure 22: Overall perception and rating of prices for heating with DH in the context of price regulation (households)

In this comparison, countries with more market-oriented price regulation (Denmark, the Netherlands, Italy, Germany and Sweden) showed a more positive perception[27] and also a better rating of the prices[28], i.e. respondents in this group seemed to have a better image of DH and perceived their price for DH as lower compared to the other group. Even though we see a significant difference here, the perceptions

[26] The overall perception in Figure 22 is based on the question: "How do you rate district heating as a heating system?" and the rating of prices is based on the question: "How would you describe your price for heating with district heating (in comparison with your income)?"

[27] t = -3.39, p = .001, 95%-CI [-0.36; -0.09], Cohen's d = .23, small effect

[28] t = -6.46, p < .001, 95%-CI [-0.47; -0.25], Cohen's d = .44, small effect

are most likely also influenced by other factors, e.g. cultural aspects in the countries. Hence, further research could help to arrive at a definite conclusion about the relationship between price regulation and perception.

Furthermore, in the online survey, participants were asked to indicate their preferred type of price regulation, as shown in Figure 23.[29] The majority of respondents preferred prices to be regulated. Only small differences can be observed between the different types of price regulation. Users and non-users rated "mandatory price controls by an authority to avoid excessive pricing" the highest. Furthermore, users of DH tended to prefer the publication of price calculations (i.e. greater transparency).

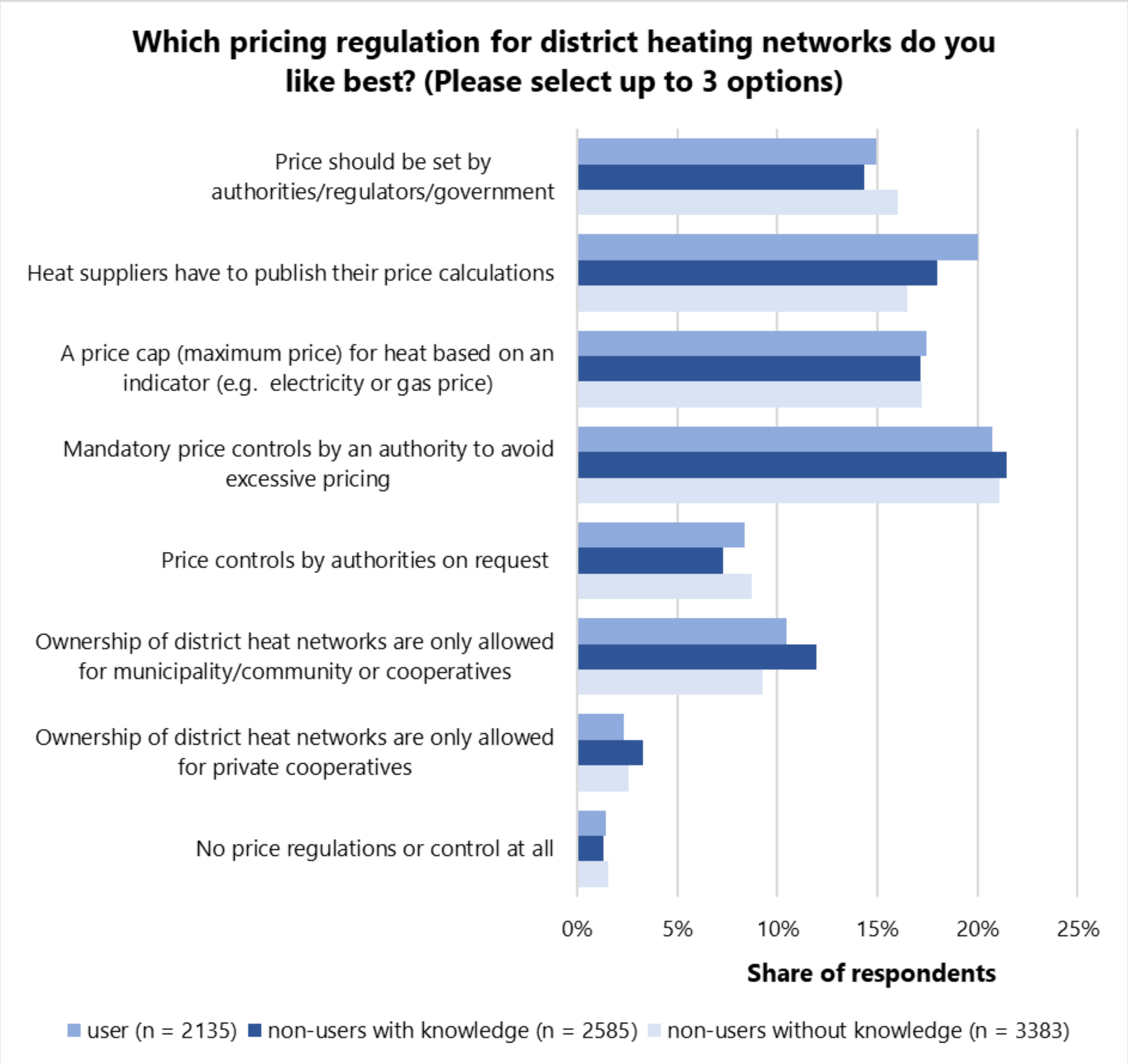

Figure 23: Preferred price regulation for DH (households)

Financial support for the connection

As stated before, the connection of consumers to DH networks is highly relevant for the profitability of the systems. Therefore, some municipalities or DH operators provide financial support for consumers if they decide to connect to their DH grid, for example a one-time payment of €2,000 for the connection.

[29] Non-users with knowledge in Figure 23 indicated that they have heard of DH and know what it is before they participated in the survey.

In the online survey, 15 house owners indicated that they had received support/funding or a discount for the connection to their local DH network.

Figure 24 shows the perception of and satisfaction with DH of (i) house owners who indicated that they had received support/funding or a discount and (ii) house owners who indicated that they had not received support or a discount. House owners who did not know if they were refunded were excluded in the following analysis. The comparison shows that the overall perception of DH is slightly better in the group that received support/funding or a discount. However, this difference is not statistically significant as indicated by a Mann-Whitney-U test.[30] This result might be different with a larger sample. In terms of satisfaction, the statistical analysis indicated similar results without a significant difference between the two groups (house owners with support vs. house owners with no support), Mann-Whitney-U test.[31]

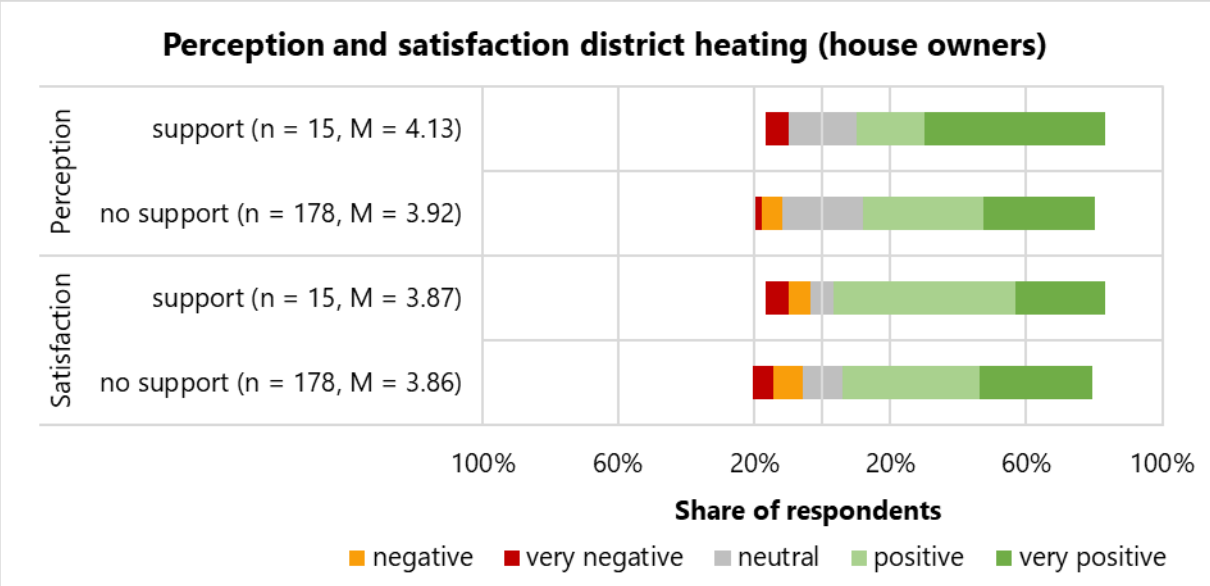

Figure 24: Perception of and satisfaction with DH of house owners who received support or no support for the connection (households)

Concluding and summarising, we found some significant and some non-significant interrelations between regulatory aspects and perception and acceptance of DH:

- Regarding mandatory connection, the analysis shows that respondents with mandatory connection showed more extreme values compared to respondents without mandatory connection. However, the mean of the rating is more or less the same, so there is no difference in perception.
- Regarding price regulation, countries with more market-oriented price regulation (Denmark, the Netherlands, Italy, Germany, and Sweden) had a more positive perception than countries with a more rule-based approach and stricter price control (Lithuania, Poland and France). In addition, the analysis shows that the majority of respondents preferred prices to be regulated, and users of DH tended to prefer greater transparency. Further research is needed to give a definite conclusion about the relationship between price regulation and perception.
- Regarding support for the connection process, the analysis shows that the overall perception of DH is slightly better in the group that received support/funding, or a discount. However, this difference is not statistically significant.

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[30] Non-parametric test used to compare two small samples that are not normally distributed, with differing variances. $U = 1113$, $Z = -1.12$, $p = .265$

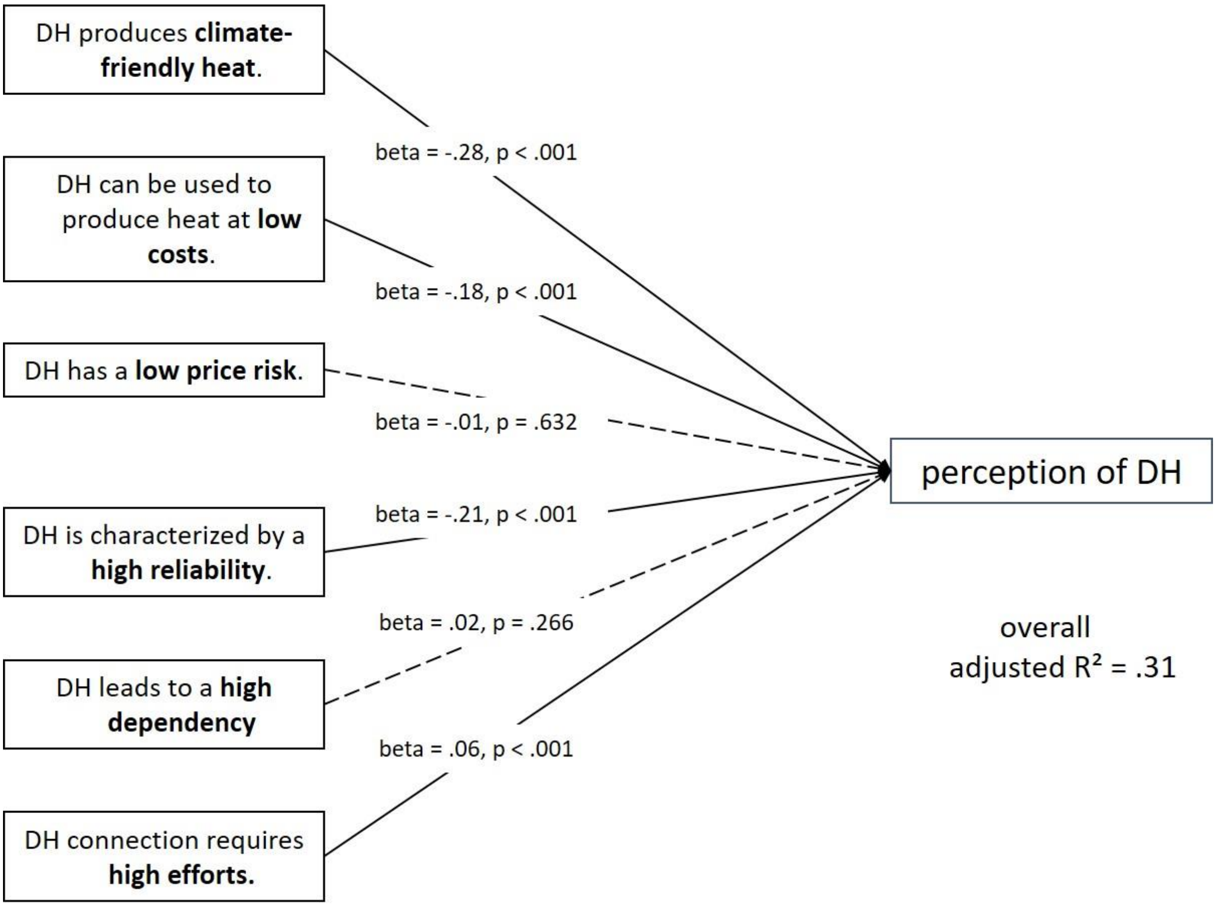
[31] $U = 1318$, $Z = -0.08$, $p = .938$

Factors explaining the perception of DH

Finally, to examine the factors explaining people's perception of DH in more detail, we conducted a linear regression analysis with the perception of DH as the dependent variable. As independent variables, we included six attributes potentially contributing to the perception of DH in the analysis, namely, its perceived **climate-friendliness**, **cost**, **price risk**, **reliability**, the **dependency** it brings and the **efforts** required **for its use and connection** (see section 3.2.1). This resulted in the regression model displayed in Figure 25.

Although some independent variables correlate to a small or medium extent, the results of the linear regression analysis can still be considered reliable. The linear regression shows that four of the six variables are significant predictors of the perception of DH. The standardized beta coefficients and significance levels are presented in Figure 25. The model explains 31% of the variance in the perception of DH, indicating that additional variables may affect the perception of DH, but four variables explain about one-third of it.[32]

The climate-friendliness of DH has the highest predictive power of DH perception, followed by its high reliability and its low costs. The efforts associated with DH explain only a smaller part of the perception of DH. The price risks and the dependency do not explain a significant share of the DH perception.



Note: Low values in the six independent variables present high agreement with the statements on the left; high values in perception of DH indicate a positive perception; dotted arrows are non-significant.

Figure 25: Model of the linear regression showing that climate-friendliness, reliability, price and efforts explain about one-third of the perception of DH

[32] F(6, 2846) = 216.27, p < .001, adjusted R2 = .312

3.2.3 Perception and satisfaction of households with HP

In this section, the analysis is based on the sample that focused on users and non-users of HP. It comprised general questions on the perception of HP (three questions) and very specific questions addressing selected characteristics of HP.

3.2.3.1 Overall perception and satisfaction of households with HP

General perception of HP

Similar to the section on DH (compare section 3.2.2), this section presents the results on the perception of HP ("How do you rate HP as a heating system overall?") and results on its acceptance ("How acceptable do you consider the use of HP?"). The results regarding satisfaction with the current heating system are also shown, but this question was only analysed for users of HP.

The overall **perception of HP by European households was positive** according to the results of the online survey. Figure 26 shows the perception and acceptance of HP for users and non-users as well as the satisfaction with HP of users (n = number of respondents and M = mean). The majority of the respondents rated HP as positive or even very positive (61%), while only a few rated the technology as negative or very negative (6%). Similarly, the acceptance of HP was very high: 62% stated that they considered HP acceptable or completely acceptable. Regarding satisfaction, the picture is slightly different, as 64% of the users indicated that they were satisfied, but 17% were not satisfied with their HP.

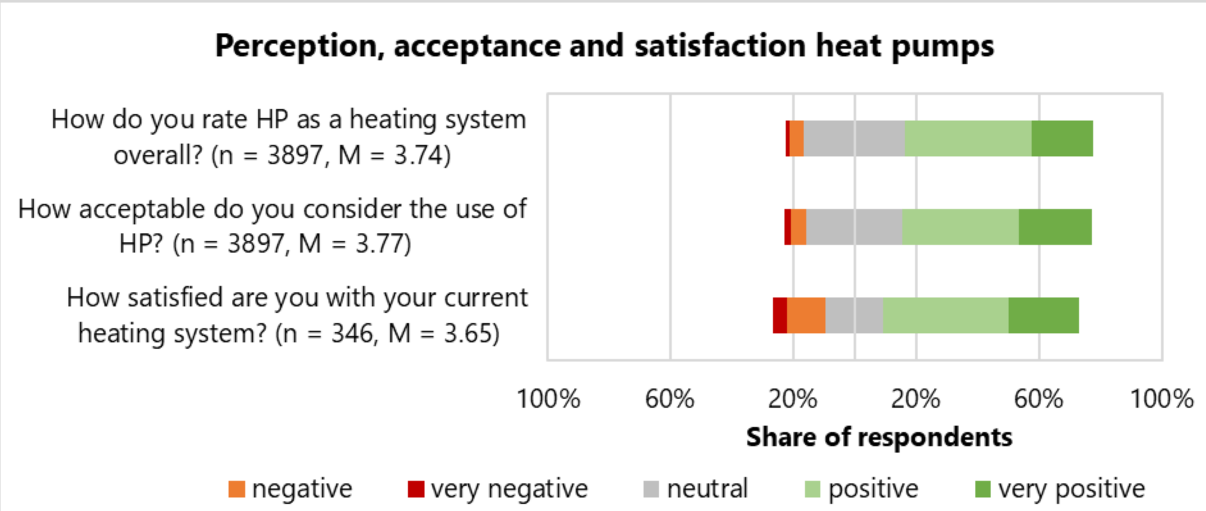


Figure 26: Perception, acceptance of and satisfaction with HP of households

The next figures focus on differences between users and non-users. Figure 27 shows the perception and acceptance of users vs. non-users of HP. Not only descriptively when examining the means, but also when conducting statistical analyses, it becomes clear that **users had a significantly better perception of HP than non-users**.[33] **The same applies to the acceptance of HP**. However, due to the lack of homoscedasticity, we conducted a Welch-test[34], which indicated that users had a higher acceptance of HP than non-users. Moreover, both effects are small and should be interpreted with caution. Overall, the

[33] t-test, $t = 3.92$, $p < .001$, 95%-CI [0.10; 0.29], Cohen's $d = .22$, very small effect

[34] $t = 3.85$, $p < .001$, 95%-CI [0.10; 0.30], Cohen's $d = .21$, very small effect

results indicate a positive perception and acceptance of HP (above the scale's midpoint) in the surveyed European countries.

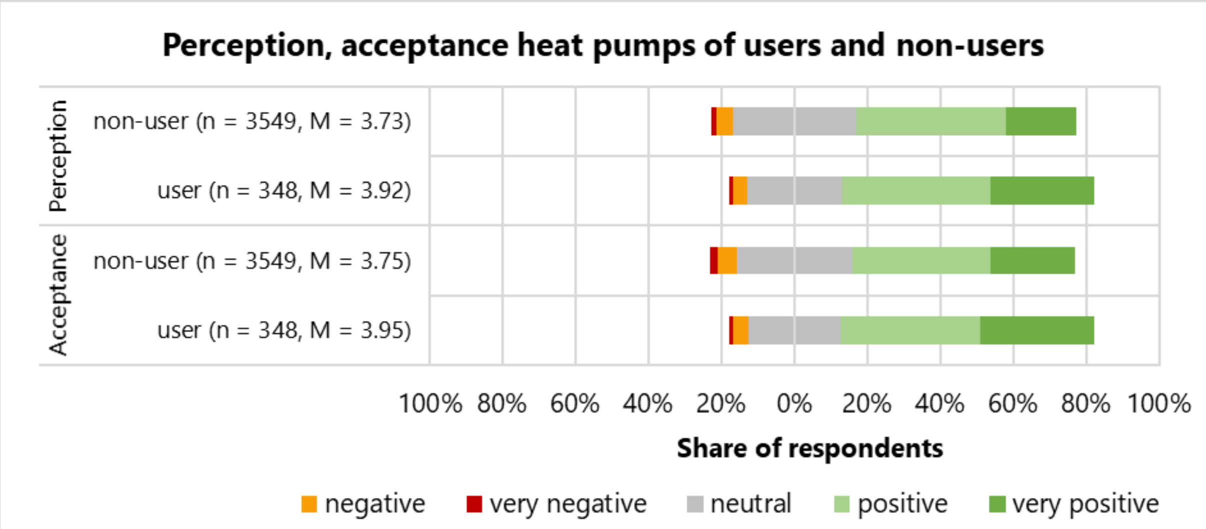


Figure 27: Perception and acceptance of HP of users and non-users (households)

Questions addressing specific characteristics of HP

Figure 28 visualises the rating of different HP characteristics by users and non-users, i.e. participants were asked about their perception of HP based on different characteristics, such as interesting vs. uninteresting or cheap vs. expensive (semantic differential). Overall, users and non-users shared a similar perception of the different factors. Descriptively when looking at the means, only slight differences can be observed regarding a few factors.

However, when conducting inference statistical analyses, the results showed that **users and non-users differed significantly** in their perception of HP; the only factor that did not differ significantly between the groups is the perception of HP leading to (in)dependence. Compared to users, non-users perceived HP as more interesting[35], more innovative[36], and better for the environment[37].

In contrast, compared to users, non-users perceived HP as more expensive[38], less safe[39], less reliable[40], less convenient[41], and less controllable[42], as well as less comfortable[43]. Further, non-users associated HP with greater installation effort[44], than users. It is important to mention that most of these effects are small or very small and should be interpreted with caution. Only the differences regarding **innovation**, **controllability** and the **effort to adopt** seem to be more pronounced, but are still small.

[35] t-test, $t = -2.50$, $p = .012$, 95%-CI [-0.27; -0.03], Cohen's $d = .15$, very small effect

[36] $t = -6.25$, $p < .001$, 95%-CI [-0.52; -0.27], Cohen's $d = .36$, small effect

[37] Welch-test, $t = -2.77$, $p = .006$, 95%-CI [-0.30; -0.05], Cohen's $d = .18$, very small effect

[38] Welch-test, $t = 2.23$, $p = .026$, 95%-CI [0.02; 0.26], Cohen's $d = .13$

[39] $t = 3.11$, $p = .002$, 95%-CI [0.06; 0.29], Cohen's $d = .18$

[40] $t = 4.04$, $p < .001$, 95%-CI [0.11; 0.33], Cohen's $d = .23$

[41] $t = 3.67$, $p < .001$, 95%-CI [0.11; 0.35], Cohen's $d = .21$

[42] $t = 5.40$, $p < .001$, 95%-CI [0.19; 0.40], Cohen's $d = .31$

[43] $t = 4.64$, $p < .001$, 95%-CI [0.15; 0.37], Cohen's $d = .27$

[44] $t = 7.89$, $p < .001$, 95%-CI [0.35; 0.58], Cohen's $d = .45$

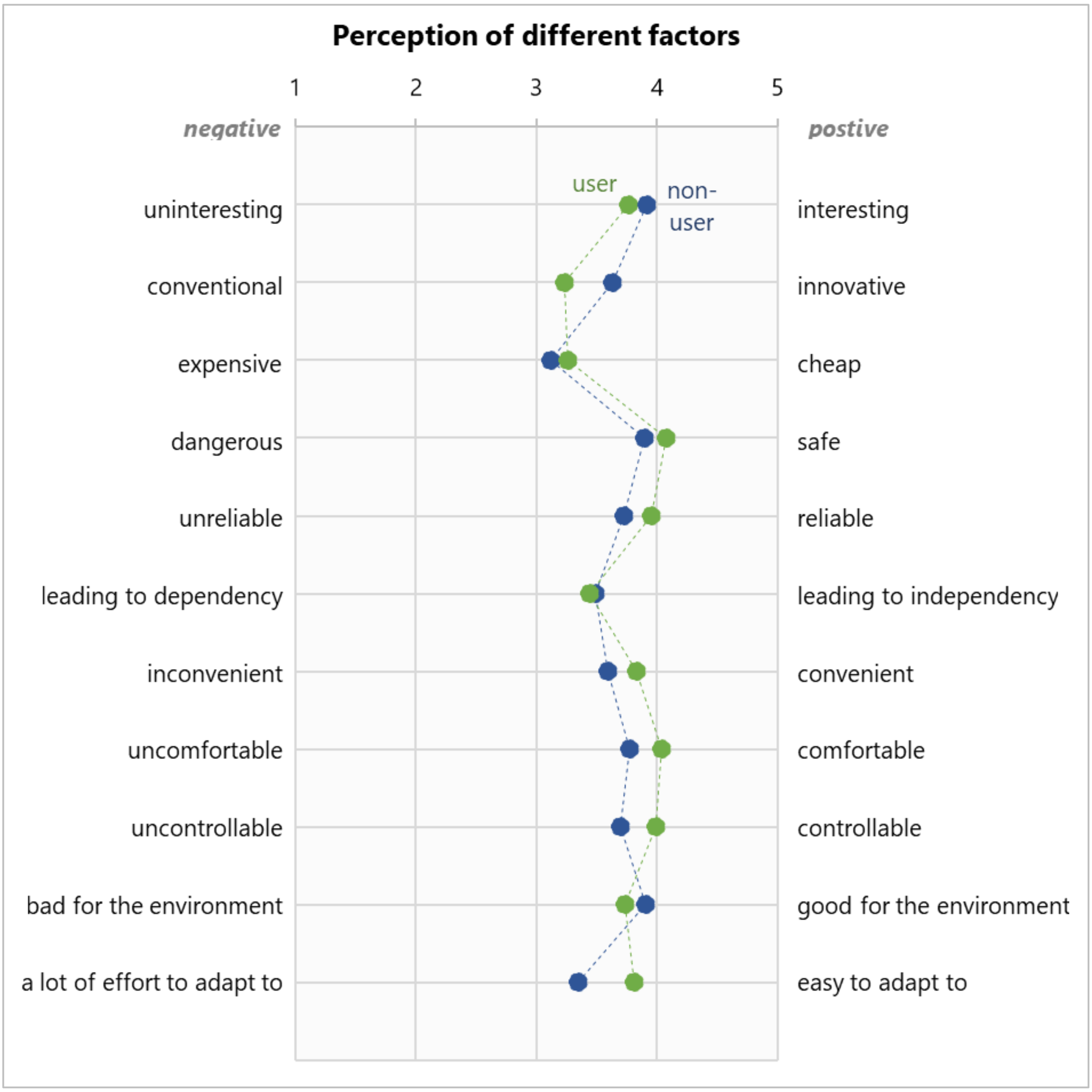


Figure 28: Perception of different HP factors by users and non-users (households)

3.2.3.2 Perception and satisfaction of households with HP by countries

General perception of HP

This section focuses on differences in the perception of and satisfaction with HP between countries. Figure 29 shows the overall perception and Figure 30 shows the satisfaction with HP in the different countries (n = number of respondents and M = mean). An overview of the samples per country and the connected population as well as more country results are shown in the **country fact sheets in A.4**.

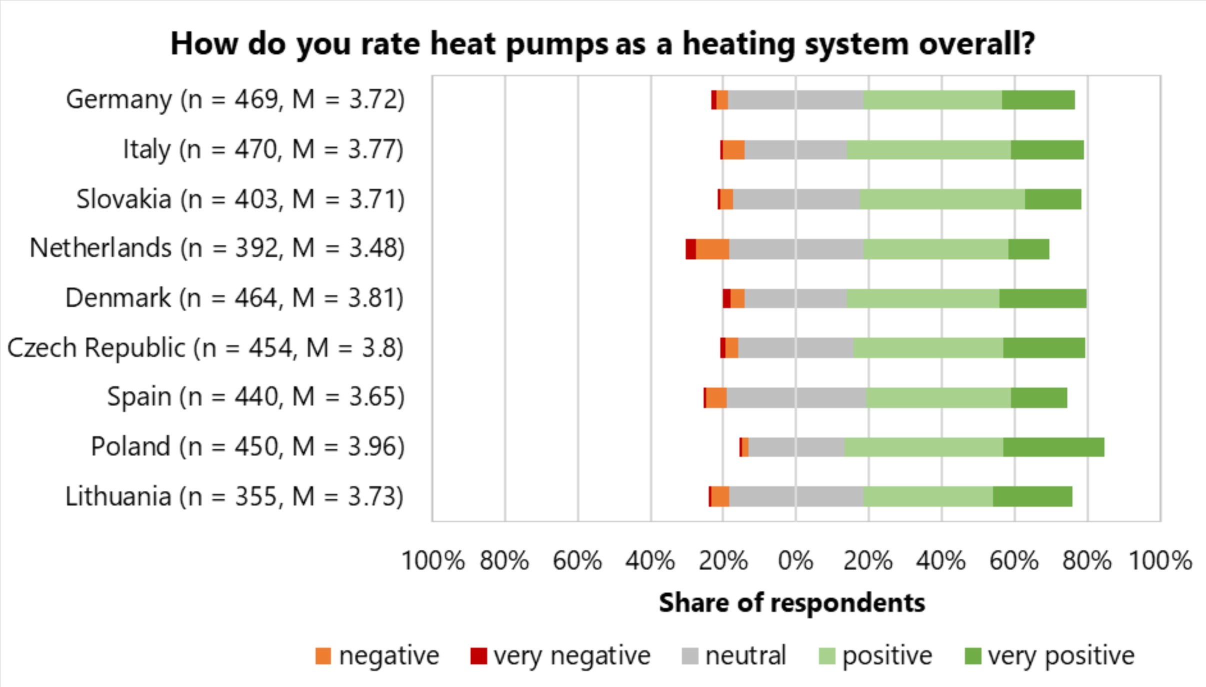


Figure 29: Households' perception of HP in different countries

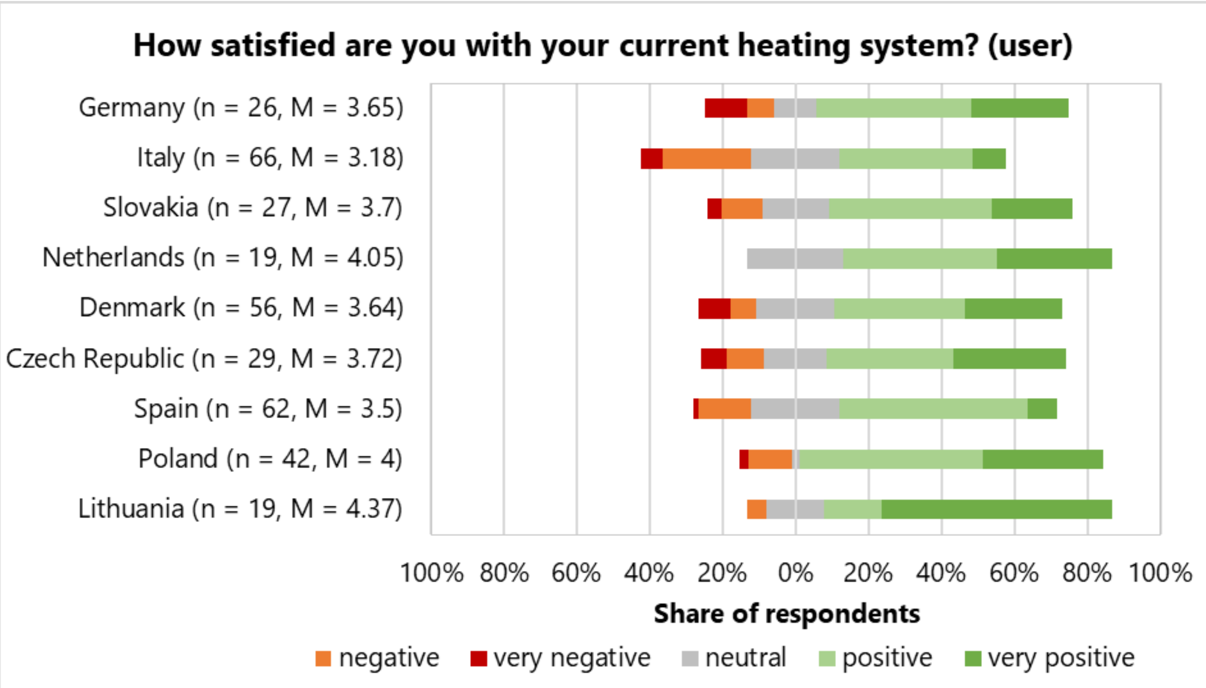


Figure 30: Satisfaction of households with HP in different countries

The perception of HP was particularly positive in Poland, followed by Denmark and the Czech Republic. In the Netherlands, the perception was slightly less positive, with 12% rating HP as negative or even very negative. However, the mean is still quite high at 3.48, indicating a positive image of HP on average. The highest level of satisfaction among HP users was reached in Lithuania, closely followed by Poland and the Netherlands. In Italy, the respondents were slightly less satisfied with HP. However, even here medium satisfaction is reached with an average above the scale's midpoint (M = 3.18).

Questions addressing specific characteristics of HP

Figure 31 visualises the rating of different HP factors in the countries. It can be observed that almost all factors were rated quite positively in Poland. What stands out is the fact that HP were perceived as quite inconvenient in the Czech Republic. Moreover, the less positive overall perception of HP in the Netherlands may be explained by its perception there as rather expensive and less convenient and comfortable (than in other countries).

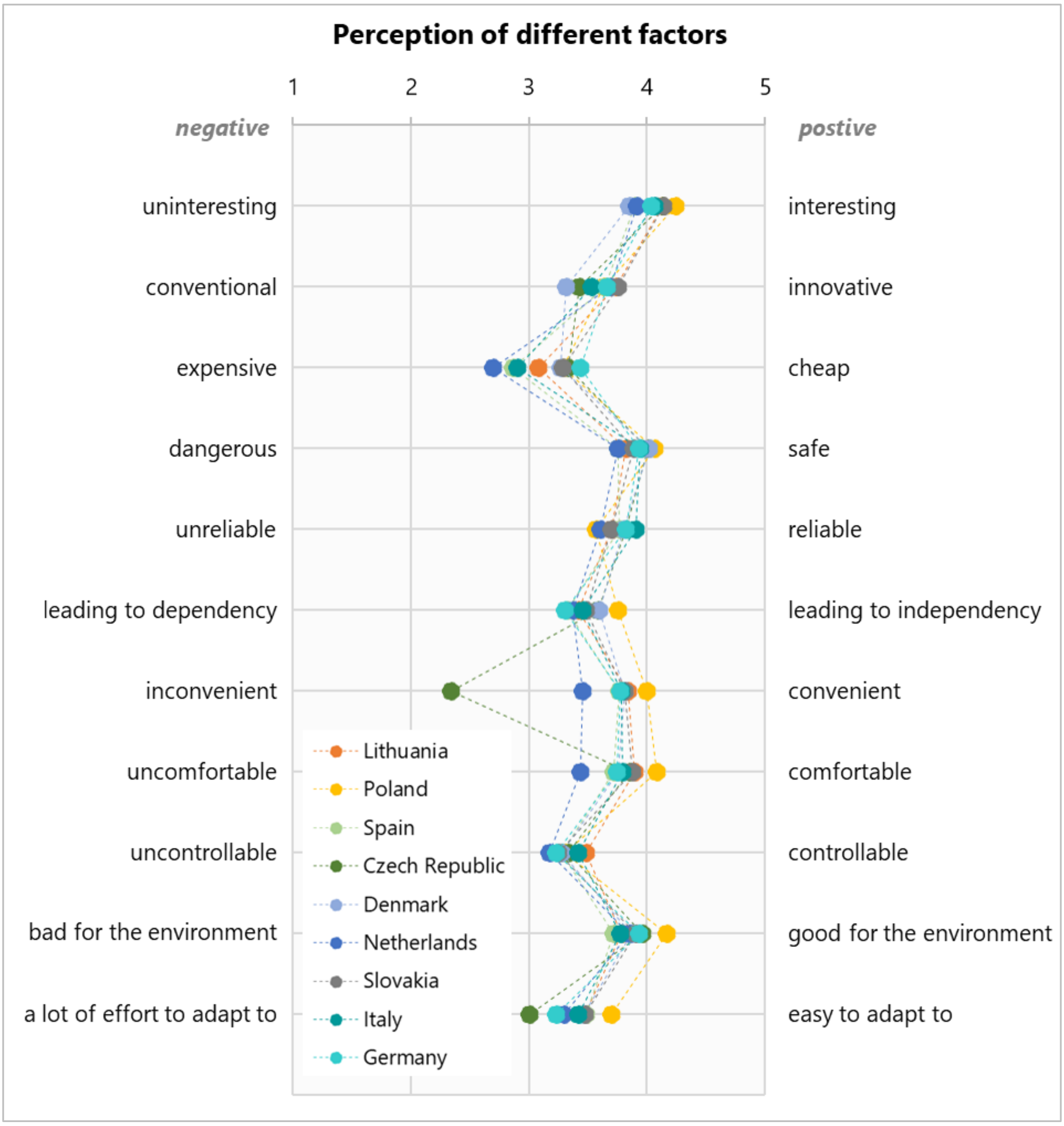


Figure 31: Perception of different HP factors in the countries (households)

3.2.3.3 Socio-demographic factors and attitudes and their influence on the perception of households with HP

Socio-demographic factors can influence the perception and satisfaction of households with HP. However, Figure 32 shows that the perception was quite similar between males and females (non-significant Welch-test), house owners and tenants/apartment owners (non-significant t-test), as well as regarding age for respondents older than 49 and respondents 49 or younger (non-significant Welch-test). Also, descriptively, non-binary respondents shared a similar perception to male and female respondents.

Inference statistical analyses revealed statistically significant differences in HP perception between respondents with higher or lower education and between respondents from cities or villages: People living in a city had a slightly more positive perception of HP than people living in a village.[45] Similarly, respondents with higher education perceived HP slightly more positively than people with lower education.[46] It is noteworthy that both effect sizes are very small and should be interpreted cautiously.

In contrast, respondents' attitudes and values seemed to have a larger impact on the perception of HP. Respondents with **higher environmental awareness** had a better perception of HP than respondents with lower environmental awareness.[47] For this analysis, we performed a mean split and created one group with an average environmental awareness higher and equal to the mean, and a second group with an average environmental awareness lower than the mean across the entire group.

Similarly, for **respondents' affinity to (new) technology**, our results indicated that respondents with a higher affinity to (new) technology had a more positive perception of HP than their counterparts.[48] Hence, values and attitudes seemed to have a stronger influence on the perception of HP than socio-demographic characteristics.

[45] Welch-test, $t = -2.33$, $p = .020$, 95%-CI [-0.12; -0.01], Cohen's $d = .10$, very small effect

[46] $t = -2.62$, $p = .009$, 95%-CI [-0.13; -0.02], Cohen's $d = .10$, very small effect

[47] Welch-test, $t = -13.78$, $p < .001$, 95%-CI [-0.45; -0.34], Cohen's $d = .47$, small to medium effect

[48] ,Welch-test, $t = -13.10$, $p < .001$, 95%-CI [-0.41; -0.30], Cohen's $d = .42$, small effect

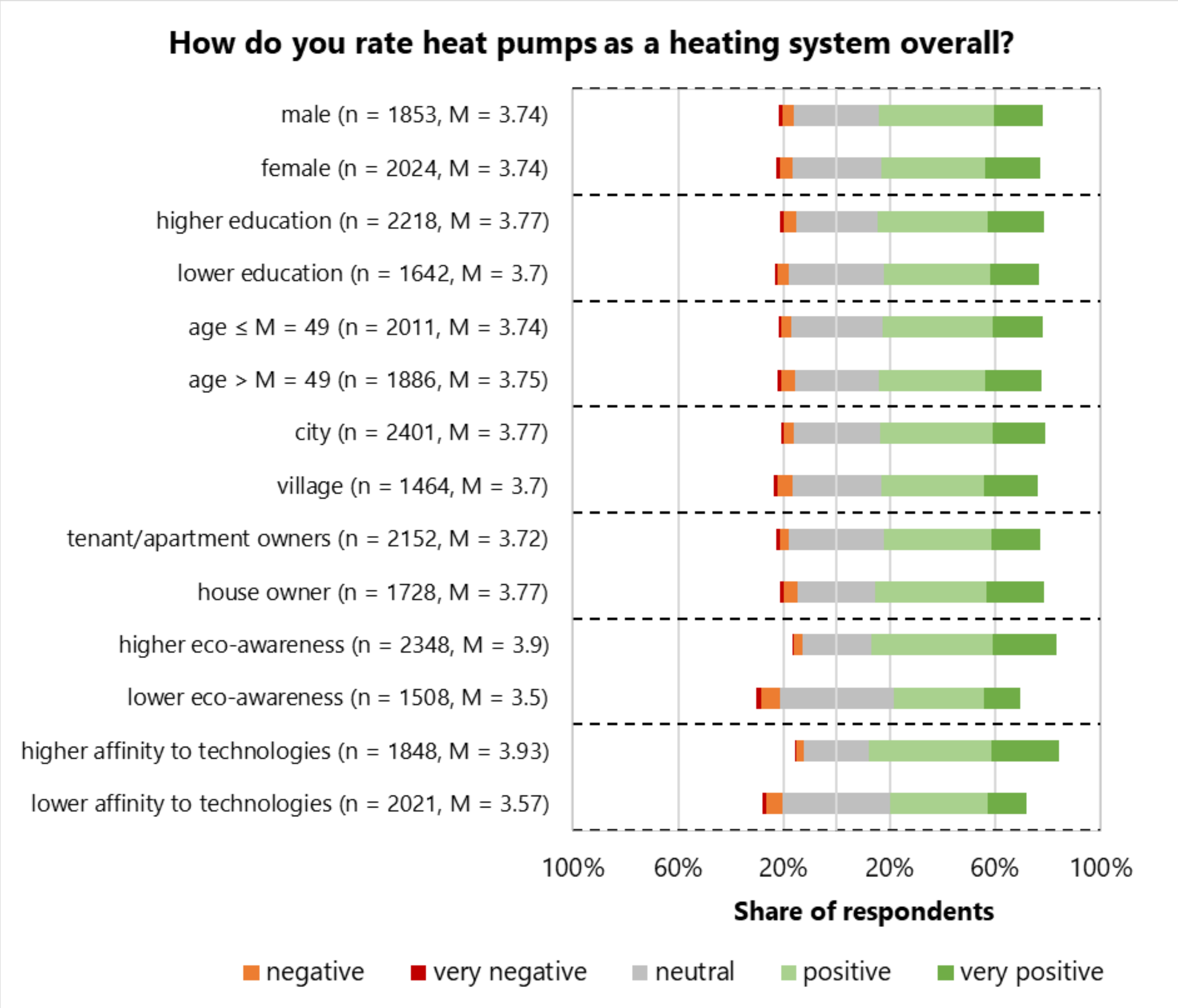


Figure 32: Perception of HP in different groups (households)

3.2.3.4 Perception and satisfaction of households with HP in the context of the diffusion of HP

The relevance of knowledge (non-users)

For the diffusion of HP, **knowledge** about the technology is an essential aspect. Thus, the survey asked whether participants (non-users only) had heard about HP before the survey. In total, 3535 respondents answered this question: Of these, 13% stated that they had never heard of HP before and did not know what it was before the survey. Another 19% said that they had heard about HP but only learned what it was from the survey. Combining these groups indicates that **almost one-third of the surveyed persons did not know what a HP is**. Another 31% stated that they had heard of it, but had only a vague idea what it is. Thus, there is high potential for spreading knowledge about HP and educating the general population. To underline this result, only about 5% chose the answer "Yes, I had heard about it and would have been able to explain it in detail before this survey".

As it is problematic to install a HP when renting a dwelling or even when owning an apartment, we performed a Mann-Whitney-U-test to assess the difference in knowledge (ordinal variable) about HP between **house owners and tenants/apartment owners**. The results from the statistical analysis show that house owners (n = 1480) had a significantly higher level of knowledge about HP than tenants and apartment owners (n = 2039), indicating a small but significant effect.[49]

Regarding the diffusion of HP, we asked respondents (non-users only) **how likely it would be for them to choose HP as their new heating system if their current heating system broke down** on a scale ranging from 1 = very unlikely to 5 = very likely. All non-users except one (n = 3549) answered the question (M = 3.31, SD = 1.08). Roughly 20% stated that it was (very) unlikely, whereas about 44% stated that it was (very) likely that their next heating system would be a HP. Interestingly, we did not find a difference in the likelihood to install a HP in the future between homeowners (n = 1488, M = 3.29), who have more possibilities to decide themselves which heating system to install, and tenants/apartment owners (n = 2045, M = 3.33). One reason for this result may be the fact that tenants envisioned themselves as future homeowners with the ability to decide about their heating system in the future.

To further examine the effect of knowledge on the perception and potential installation of HP, we split the non-users of HP into two groups: (i) respondents who did not know what a HP was before the survey and (ii) those who had a vague idea to very detailed knowledge about HP. For these groups, the performed t-tests show significant differences: **Respondents with a low level of knowledge** (n = 1126, M = 3.52) had a **significantly less positive perception of HP than non-users with some level of knowledge** (n = 2408, M = 3.83)[50] (although their perception was still slightly positive as indicated by an average above the scale's midpoint). Similarly, respondents with a low level of knowledge (n = 1126, M = 3.15) were also significantly **less likely** than non-users with (some) knowledge about HP (n = 2408, M = 3.39) **to choose a HP as their new heating system**.[51] Interestingly, the percentage of negative answers was comparable between the groups, but respondents with higher knowledge stated more often that it would be (very) likely for them to install a HP in the future. Although both effects are small, the results underline the importance of knowledge about the technology for the diffusion of HP.

[49] U = 1212801, Z = -10.33, p < .001, Cohen's d = .34

[50] t = -10.07, p < .001, 95%-CI [-0.37; -0.25], Cohen's d = .37, small effect

[51] Welch-test, t = -6.47, p < .001, 95%-CI [-0.31; -0.17], Cohen's d = .22, small effect.

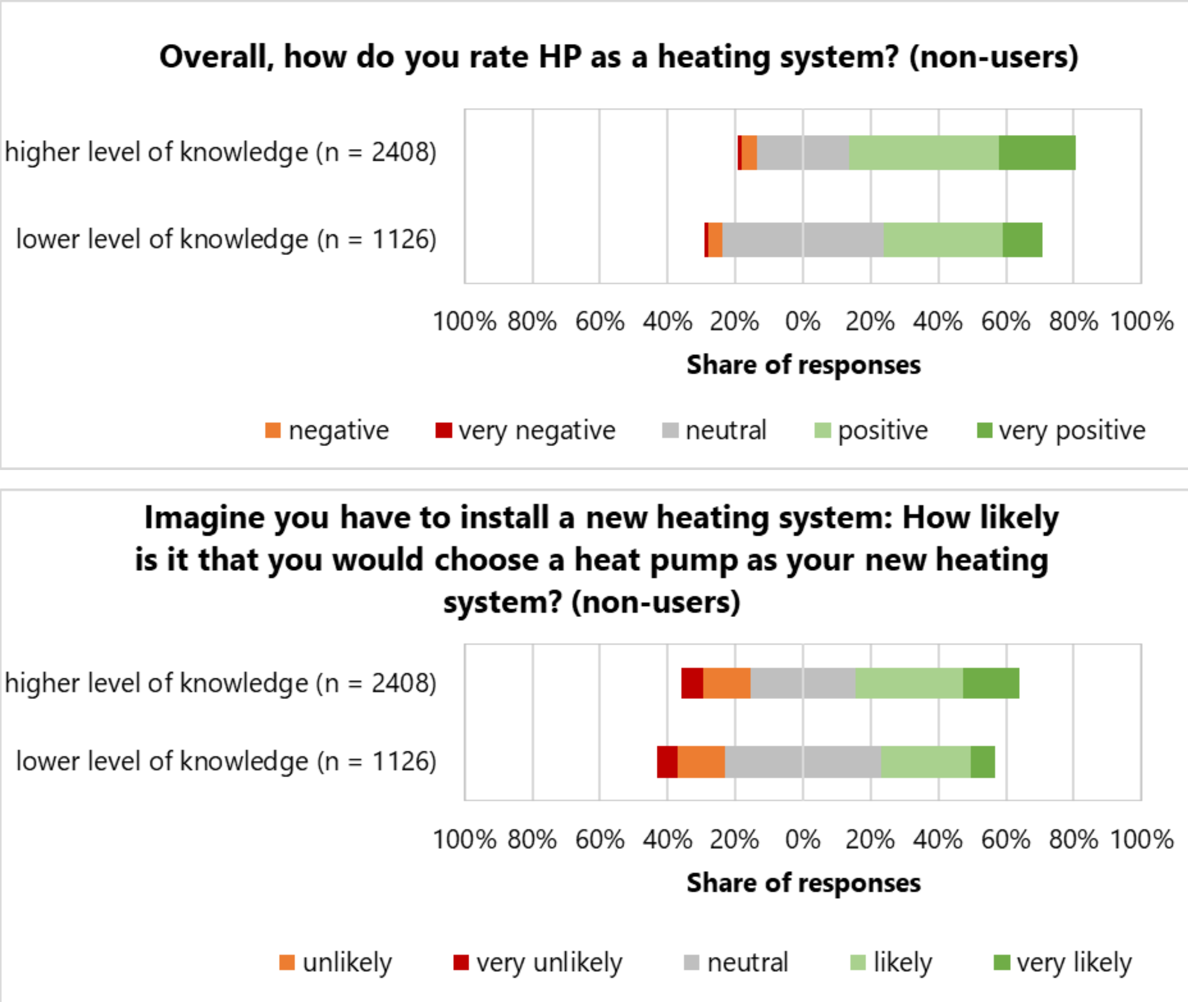


Figure 33: Perception and likelihood to choose HP (non-users) by level of knowledge (higher vs. lower)

The impact of financial support (users, house owners)

To take a closer look at the users of HP, we examined the role of financial support that HP users had or had not received when installing a HP and its impact on user perception and satisfaction.

We asked house owners whether they had received financial support when installing a HP. Of 223 house owners, 42 respondents stated that they had received some financial support. Using this variable as a grouping variable, we performed a t-test to assess whether the perception of and satisfaction with HP differs between house owners who had received financial support and those who had not. The inference statistical analyses show a significant difference: Those house owners who had received financial support for HP (n = 42, M = 4.43) had a significantly more positive attitude towards HP than those who had not received financial support (n = 181, M = 3.92).[52] This medium effect indicates **the positive effect of providing financial support to households installing a HP**. Regarding the satisfaction with HP, a t-test showed similar but non-significant results: House owners who had received financial support (n = 42, M = 3.81) were slightly but non-significantly more satisfied with their HP than those who had not received financial support (n = 181, M = 3.70).

[52] t = -3.34, p = .001, 95%-CI [-0.80; -0.21], Cohen's d = .58

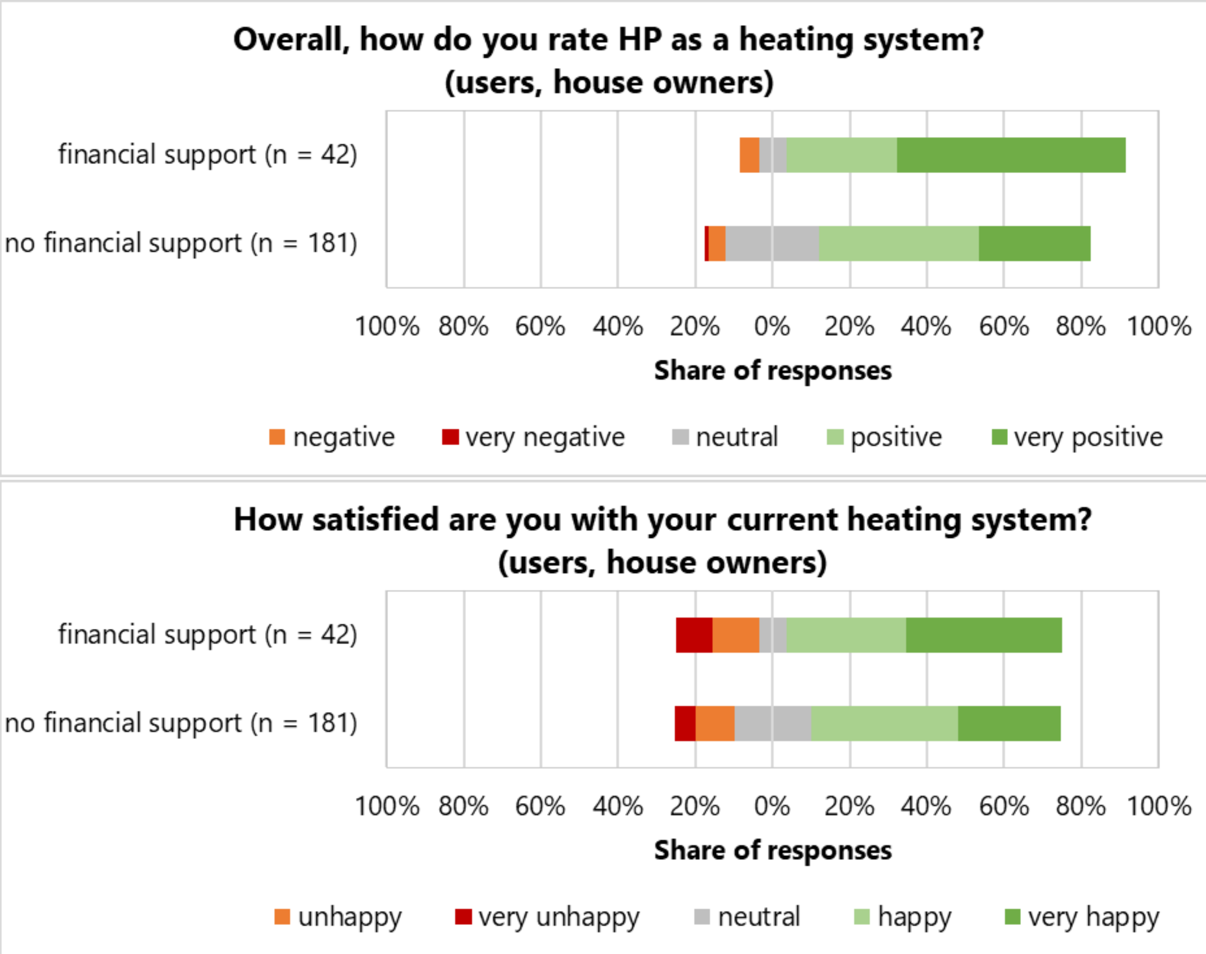


Figure 34: **Perception of and satisfaction with HP (users, house owners) by financial support**

The role of the diffusion of HP within the country

Besides knowledge and financial support, the process of diffusion itself can impact the perception of and satisfaction with HP. When looking at the diffusion of HP within the surveyed countries (see Table 6), three groups of countries result: (i) those in which HP are used in more households, i.e. Denmark and Italy, (ii) those countries in which the installation of HP is rather rare, i. e. Poland and Slovakia, and (iii) those countries in-between with medium sales of HP per 1000 households and market stock share. Countries in which only one of the two diffusion indicators (see Table 6) was high were categorized in the middle and thus not considered in subsequent analyses.

Table 6: **Diffusion of HP in the different countries**

Country	Group	HP sold per 1000 households (1)	HP market stock share (2)
Lithuania	Medium	9	2%
Poland	Low	2.2	1%
Czech Republic	Medium	4.1	2%
Spain	Medium	6.5	4%
Denmark	High	21	13%
The Netherlands	Medium	4.5	2%
Slovakia	Low	2.6	1%
Italy	High	7.8	7%

Country	Group	HP sold per 1000 households (1)	HP market stock share (2)
Germany	Medium	2.5	6%

Sources: 2019 Databased on (1) EHPA 2019 and (2) RES'Observer 2021

To further assess differences based on diffusion, we performed statistical analyses to see whether the perception of and satisfaction with HP differed between countries with high and low diffusion. The results reveal that the perception of HP did not differ significantly between respondents from Denmark and Italy with higher diffusion rates of HP (n = 934, M = 3.79) and respondents from Poland and Slovakia with lower diffusion rates of HP (n = 853, M = 3.84). The diffusion of HP might be more relevant for house owners than for tenants and apartment owners, so we also examined the responses from house owners only. Performing the same analysis (t-test) with house owners only shows the same result: The average perception in countries with higher diffusion rates of HP (n = 479, M = 3.84) was almost the same as for house owners in countries with lower diffusion rates (n = 370, M = 3.86).

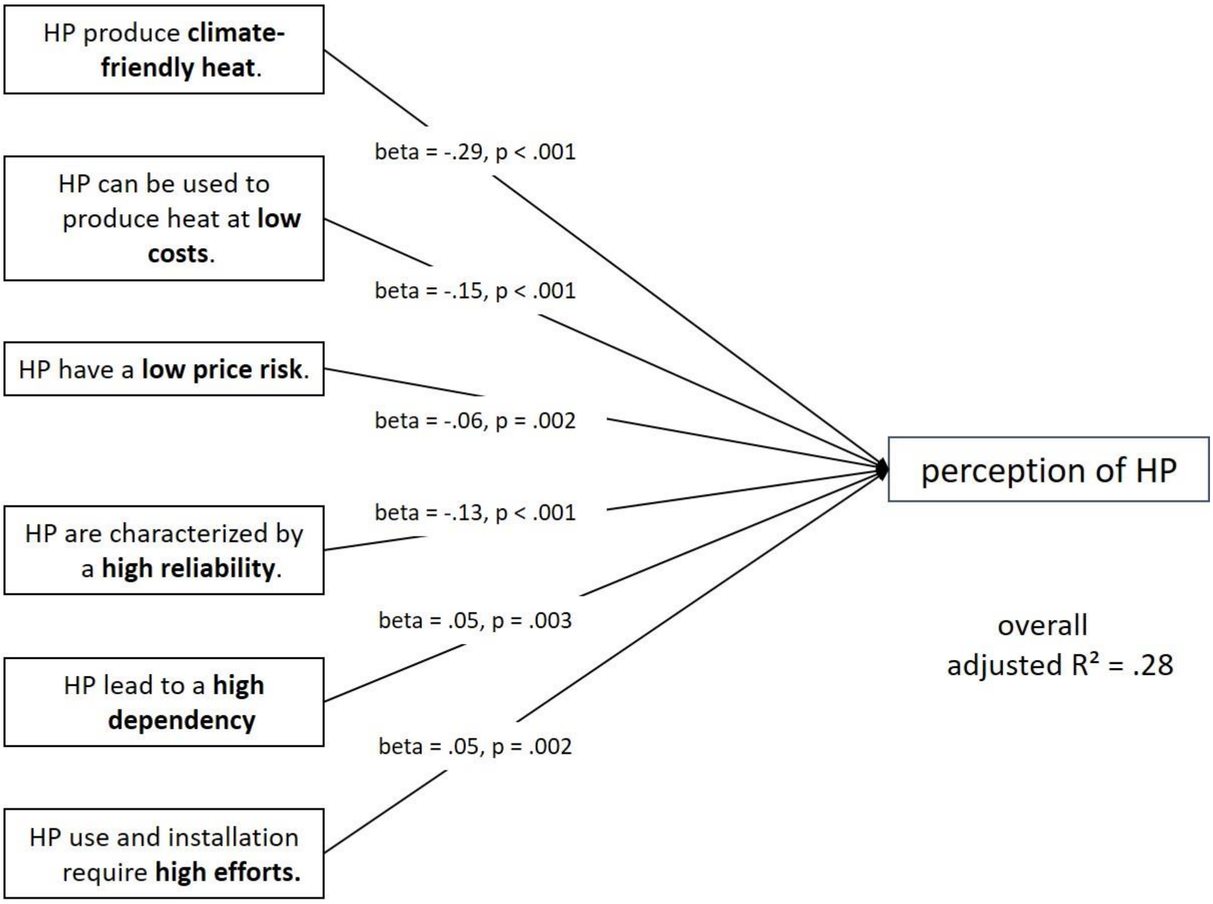
Regarding the satisfaction with HP and the relevance of diffusion in the country, we kept the differentiation into countries with lower (Poland and Slovakia) and higher diffusion rates (Denmark and Italy), but only assessed the answers from HP users and their level of satisfaction. The t-test results show that there was a significant difference in satisfaction between countries with higher and lower diffusion rates.[53] However, the direction of the effect is counter-intuitive: Users of HP in countries with a higher diffusion rate (n = 122, M = 3.39) were less satisfied with their HP than users of HP in countries with lower diffusion rates (n = 69, M = 3.88). One explanation might be the fact that the diffusion rates in most countries are still quite low (below 10% except in Denmark). Future research should assess this variable in more detail.

Factors explaining the perception of HP

To examine people's perception of HP and the underlying factors more closely, we performed a linear regression analysis with the perception of HP as the dependent variable and six HP attributes as independent variables that may contribute to its perception: its **climate-friendliness**, **costs**, **price risk**, **reliability**, the **dependency** it brings and the required **efforts** (see section 3.2.1). Specifically, we asked respondents to what extent they agreed with the six statements displayed on the left-hand side in Figure 35 (ranging from 1 = completely agree to 5 = completely disagree). We used these as independent variables in the regressions analysis resulting in the model displayed in Figure 35. The independent variables are interrelated. However, their correlations are small to medium (not high). Thus, the results of the linear regression analysis are still reliable. The linear regression shows that all six variables are significant predictors of the perception of HP. The model explains 28% of the variance in the perception of HP, thus, additional variables may impact the perception of HP, but these six variables explain a considerable share of it.[54] **The climate-friendliness of HP has the highest predictive power, followed by its low cost and high reliability.** The low price risks of HP, the independency related to HP and the small efforts associated with it explain a smaller part of the perception of HP. The standardized beta coefficients and significance levels are presented in Figure 35.

[53] Welch-test, $t = 2.98$, $p = .003$, 95%-CI [0.17; 0.82], Cohen's $d = .43$, small effect

[54] $F(6, 2907) = 192.73$, $p < .001$, adjusted R2 = .283



Note: Low values in the six independent variables represent high agreement with the statements on the left; high values in perception of DH indicate a positive perception.

Figure 35: Model of the linear regression showing that all included independent variables explain a share of the perception of HP

3.3 Conclusions for the Residential Sector

Based on an online survey in 11 countries with more than 7800 participants, we obtained the following results regarding the perception of different heating options in Europe. Citizens rated **fossil fuel** boilers as the least climate-friendly, low-cost and reliable heat supply or provision option. Furthermore, they considered them an option with the highest dependency on the energy supplier and the highest price risks among the given heating options. On the other hand, they also associated fossil fuel boilers with little effort required for use or application. This may be because fossil fuel boilers have been a well-established and widespread heating technology for many years. The current conflict with Russia might have influenced the perception of fossil fuels, especially of natural gas, as this survey was conducted during the energy price crisis caused by the Russian-Ukrainian war.

Citizens showed neither an overarching positive nor negative rating of **DH** concerning its climate-friendliness, reliability, effort, low cost and low-price risk potential, but they did associate DH with a high dependency on the energy supplier. Overall, the majority of respondents rated DH as a positive (Denmark, Poland, Italy and Germany) or even very positive (Sweden) heating option in general, but this generally positive perception varied slightly across countries.

- The rating of the selected DH **features** was mainly low in Lithuania, Spain, the Czech Republic, and the Netherlands and rather positive in Sweden and Denmark.

- This rating also applied to selected **characteristics of DH** such as safety, convenience, comfort, control, etc. In these characteristics, Lithuanian and Dutch respondents displayed a (slightly more) negative perception, while Danish, Swedish and German respondents had a rather positive image of DH in general and its specific characteristics.
- Citizens that are already connected to DH (**users**) showed a different, slightly more positive rating of DH. Overall, users had a significantly better perception and higher acceptance of DH than non-users. When looking at the characteristics of DH, users and non-users of DH rated them differently: it seems that, with ongoing use of DH, the perceived novelty fades (innovative, interesting), but issues such as safety, reliability, convenience, comfort, and efforts to adapt are perceived (even) more positively.
- **Socio-demographic** factors showed some significant but very small effects that could be explained by experiences with DH and a better understanding of DH: older citizens tended to have a better image of DH, as did people living in cities or persons with higher education. These effects are very small and should be interpreted with caution.
- More importantly, attitudes and **values** had an effect on the perception of DH: persons with a stronger affinity to technology or higher environmental awareness tended to rate DH more positively. Although these effects are larger than for socio-demographic factors, they are still small.
- Other aspects that might affect the image and perception of DH are **policies and regulations**. The analysis revealed that mandatory connection to DH seemed to have no impact on the perception of DH, but the degree of price control might: market-oriented pricing regulation goes together with a positive image of DH in general, and a positive rating of prices. Further research is needed to validate these conclusions.
- Overall, the majority of respondents rated the **prices for DH** as neutral, but one-third perceived these prices as high. Further, the respondents preferred a price control mechanism such as mandatory control and publication of DH prices and their components (high transparency).
- Finally, **financial support** for connecting to a network might have a positive impact on the image of DH, but the sample size of citizens with financial support was too small for a meaningful analysis.
- Major aspects influencing the general perception of DH include its climate friendliness, reliability, and costs.

In comparison**, HP** were rated rather positively in general terms as well as in all features (climate-friendly, cost, price risk, reliability, dependency on energy suppliers, efforts to adapt or adopt). However, solar thermal options were even assigned a better rating than HP in most features.

- The ratings of the **features** (climate friendliness, low-cost, low price risk, reliability, dependency, and effort) were all rather positive, but citizens from Italy, Spain and partly Lithuania displayed a slightly more negative attitude towards HP, while citizens from Sweden and Denmark gave slightly better ratings, as did citizens from Poland and Germany. Overall, country differences in the ratings of the selected features were small for HP.
- These results deviated from the ratings of the **specific characteristics** of HP: Polish citizens gave a very positive rating for many characteristics, while Dutch respondents gave the lowest rating for some characteristics, as did citizens from the Czech Republic. However, Dutch HP users stated they were very satisfied with their choice when asked about their overall level of satisfaction with HP.
- Differentiation of the general rating of HP **by countries** revealed only small differences, with the Netherlands displaying the least positive (but still positive) image. Regarding **satisfaction**, Italian citizens using the HP were least satisfied in comparison to the other EU countries.
- **Users of HP** had a better perception and acceptance of HP than non-users. This was also reflected in the ratings of HP **characteristics**. Similar to DH, HP users displayed a habituation effect and considered HP less innovative and interesting than non-users, but they had a significantly better perception of HP than non-users in terms of comfort, convenience, control, safety, reliability and effort.

- With respect to **socio-demographic factors** such as gender, age, different levels of education, or place of residence (small village vs. big city), the differences were very small and should be interpreted with caution.
- Similar to DH, people with **high environmental awareness and affinity to technology** as well as with a good level of **knowledge** about HP had a significantly more positive perception of HP (than their counterparts). Thereby, house owners had a significantly higher level of knowledge than tenants and apartment owners.
- Regarding the diffusion of HP, almost half of the respondents stated that it was (very) likely that their next heating system would be a HP. Further, the results indicate that the level of knowledge may play a role in the diffusion of HP. Here, there is a high potential for spreading knowledge about HP and educating the general population, as almost one-third of the surveyed citizens stated they did not know what a HP is.
- In addition, **financial support policies** seemed to improve the rating of HP. Regarding the diffusion rates in different countries and their impact on the perception of HP, we did not find significant effects, probably because these rates are still rather low in Europe. Future research should examine diffusion rates in more detail.
- Besides policies, knowledge, attitudes and social-demographic factors, its perceived features are influencing the rating of HP, especially its climate friendliness, low costs and reliability.

The analysis shows that the perception and image of DH and HP are influenced by several factors at different levels. Surprisingly, individual factors such as age, education or place of residence had only minor correlations with the overall rating of the heating options, while individual attitudes showed a stronger correlation. Furthermore, at the meso level, the impact of policies and regulations could neither be clearly and significantly proved nor rejected. Thus, further research is needed to get a better understanding of the role of policies.

When looking at the differences between countries, we found an indirect impact of energy culture. Countries that are more advanced in their energy system transition (e.g. Denmark) or countries with a long history in the deployment and use of certain heating options (e.g. Poland, Lithuania) displayed different views of DH and HP. The influence of country-specific technology experiences and the resulting perception of heating options was supported by the differences in the perceptions between users and non-users of DH and HP. Although we did not investigate macro-level impacts, changes at the macro level such as rising prices due to the EU energy crisis might bring about a shift in perception in that the reliability and security of supply become much more important.

These findings raise the question of what policy makers could do to bring about change, and support clean and sustainable heating options.

- Policy makers can only mitigate the consequences of external shocks and factors at the macro level. Further, energy policies can hardly change the influence of socio-economic or demographic factors at the micro level such as education, age, and residence.
- On the other hand, values and attitudes might change over time – slowly but continuously. These are also influenced by factors at the macro, meso and micro levels (socio-demographic factors) and can be nurtured by the relevant policies. In addition, personal interests and affinities (technology, environment) can be stimulated through information and societal discourse on energy topics.
- Policy makers could address the perception of DH and HP at the meso level through direct financial support instruments and regulations addressing market or system failures (natural monopoly of networks, coordination efforts for network-based investments).
- Finally, policy makers could provide detailed and trustworthy information about sustainable heating technologies, and ensure transparency concerning markets and prices, because familiarity with a heating technology goes hand in hand with a better rating of this technology – as our findings demonstrate.

4 Perception of HP and DH in Industry and the Public Sector (Task 2.2)

4.1 Methodology

To obtain a sample for qualitative analysis, we chose a different approach for industry and the public sector than for the residential sector (see section 3). We abstained from using a purely survey-based approach, as the response rates of organisations to surveys are usually low and result in non-representative samples. At the same time, the target population is not known in detail, thus, making it difficult to prescribe sample characteristics. Therefore, we applied a **mixed methods approach** including the results of the literature review (Task 1), a brief online survey, interviews and a case study (Task 2.2).

The results of the **literature review** outlined the diverse factors that affect energy investment or energy service decisions (EIS) of different actors at three levels i) the macro level and ii) the meso level, depicting contextual factors at different aggregation levels, and the iii) micro level, representing individual factors (compare Task 1, Breitschopf and Billerbeck 2021). The macro level represents a high level of abstraction for HP and DH and encompasses regulation and economic issues; the meso level addresses the operationalisation at the programme level and market-specific regulations regarding DH and HP; while the micro level encompasses specific factors of individuals and firms, such as specific on-site requirements and personal affinities and preferences or attitudes.

We then conducted a **short online survey** to get a broader picture of the driving factors at the micro level. We asked identified stakeholder organisations (e.g., Eurovent, CoqenEurope) to forward a link to other organisations and interested persons in industry and public. This online survey encompassed a very limited set of questions (country, sector, industry, perceptions/images, contact details (see Annex A.5)) and aimed at two aspects: i) surveying the perceptions of industrial and public sector actors of selected H&C systems, as well as ii) collecting potential contacts. The European Commission signed a letter of support (LoS) to promote participation in the online survey. As the sample is biased with respect to nationality and sector affiliation, and the population of the sample is unknown with respect to sectors, branches, sizes, locations etc., the results of the online survey are not representative for the sectors.

Following this survey, interested actors were invited for an **interview** (ca. 20 min) concerning their perception of H&C and potential drivers. Interviews were conducted based on an interview guideline (Annex A.7). The number of interviews and selected countries depended on the willingness of firms' representatives to participate. This turned out to be very low at EU level.

Finally, to get a deeper understanding of the decision-making process regarding H&C technologies, we conducted a **case study** based on twelve in-depth interviews (30 min to 1.5 hrs – semi-structured guideline, see Annex A.8; for case study approach, see e.g. Yin 2018) in the city of Mannheim in south-west Germany. This city is shaped by its industry. The case study was intended to gain a deeper understanding of the decision-making process in firms and highlight the interrelationships of different factors governing decisions in H&C.

The mixed methods approach is illustrated in Figure 36.

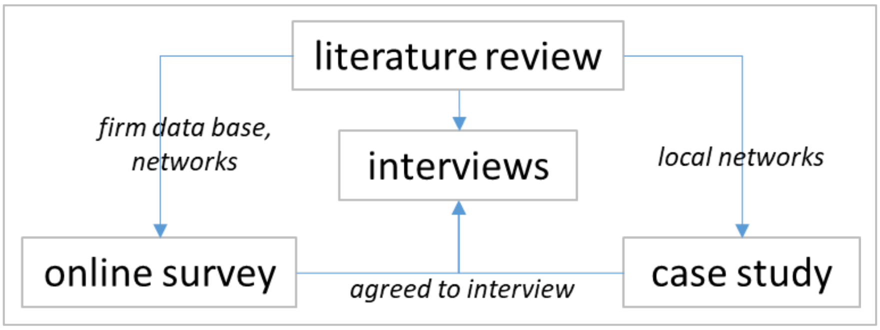


Figure 36: Mixed methods approach for the industrial and public sectors

4.1.1 Online survey approach

The brief online survey was aimed at obtaining a broad picture of how H&C technologies are perceived in the industrial and public sectors. Therefore, we conducted the following activities:

- Identification of industries using heat or cold in their processes, and the respective associations via a web search
- Identification of public services associations for all EU countries
- Brief review of the literature on potential image and perception of DH and HP
- Deciding the structure and questions of an online survey and setting up the online survey at a (Fraunhofer) online portal
- Approaching associations (LoS and web search of associations) and communities for contacts in industry and the public sector (LoS) and asking them to answer the limited number of questions and forward the link to others
- Selection of companies and public institutions in all EU countries from a business database (Amadeus)55 and search for the email addresses
- Approaching over 10,000 companies and public institutions across the EU and inviting them to participate in our brief online survey
- Asking for support from the European Commission via the Member State representatives (contacts)
- Final analysis of the responses to the online survey

The online survey contained six questions covering the following topics: country of residence, activity/sector of the respective institution or company, annual heat consumption in MWh, currently used heating system and perceived characteristics of different H&C technologies (see Annex A.7). The question about the perceived characteristics was split into six sub-questions and for each sub-question, the participants were asked to indicate their agreement or disagreement with the statements using a 6-point Likert-type scale[56]. Based on the findings of the literature review, we selected environmental, economic and personal factors such as reliability, risks, effort and dependency aspects. The interviewees answered these questions for six key heating systems: fossil fuel boilers, biomass boilers, DH, HP, solar thermal, combined heat and power. At the end, we asked the respondents to provide their contact information, if they were interested in participating in an interview. The survey questions are attached to this report in Annex A.5.

To identify potential participants and interview partners, we approached associations such as EHPA from the project team or Euroheat & Power, EUREC, EPEE or REHVA (who have signed LoS) and other

[55] https://www.eui.eu/Research/Library/ResearchGuides/Economics/Statistics/DataPortal/AmadeusBvD

[56] A Likert scale is a psychometric scale commonly used in research that employs questionnaires. It is the most widely used approach to scaling responses in survey research. When responding, respondents specify their level of agreement or disagreement on a symmetric agree-disagree scale for different statements.

organisations such as the European Heating Industry (EHI), Eurovent, CoqenEurope. In addition, we conducted a web search to identify additional potential representatives, e.g. NGOs. We identified several stakeholders and representatives of industry and the public sector by compiling contact addresses from European Associations of industry and the public sector.

We also searched for further suitable private and public organisations by size, sector and location within the scope of our study. We approached more than 10,000 identified organisations within the EU via e-mail. They received the link of the online survey together with an accompanying letter and the LoS of the European Commission. The search for suitable associations and enquiries was completed in December 2021 and the online survey was closed at the end of December 2021. The evaluation of the data from the year 2021 took place in January 2022.

4.1.2 Interview approach

Experts in industry, service sector organisations and public sector organisations including public administration, education, social and health services are considered in studies (see Task 1, e.g. Hodges et al. 2019, Graff et al. 2018) to be suitable interview partners who could shed light on the factors, heuristics and decision processes regarding their EIS decisions. Due to the general assumption that companies and organisations prefer short personal interviews, the conducted interview should not take more than 20 minutes. If the interlocutor is interested in a longer interview, this is accepted and further developed.

More than 50 representatives shared their contact details and indicated their availability for interview (in the brief online survey). However, only 20 representatives finally participated in the interview, 12 of them in the framework of the case study. Unfortunately, despite first indicating an interest in the interview, many were no longer available or willing to be interviewed. The reasons given included increased workload, loss of interest or unavailability of the representative. The interview focused on decision structures, the factors driving energy decisions and their current energy supply technology. The aim of the interviews was to gain a deeper understanding of the perception and image of HP and DH and the relevant factors influencing decisions for HP and DH. The interviews were semi-structured, and were especially designed to shed light on knowledge gaps with respect to EIS decisions. These gaps had been identified based on the information collected via the literature review (Task 1) and the online survey. Further, we wanted to understand the interconnectedness and interdependencies of the different drivers and barriers, as well as knockout criteria. The interview questions are attached to this report in Annex A.7. The interview period started in March/April 2021 and ended in August 2021.

4.1.3 Case study approach

A case study was used to generate a deeper understanding of the interrelationships between the factors influencing the decision-making process of actors in private sector organisations regarding RE and EE H&C technologies. The methodological framework for the case study was based on the guidelines for exploratory case study research outlined by Yin (2018), and the qualitative research guidelines by Gläsel and Laudel (2010). One key strength of case study research is that it uses a variety of data sources such as documentation (local newspaper and publications), archival records, interviews, direct observations, participant-observations and physical artefacts (Yin 2018). Therefore, all the observed data can be taken into consideration and smaller-scale factors can be uncovered.

The focus of the exploratory case study in this project was on actors from private sector organisations in the city of Mannheim in south-west Germany who had been approached through existing local networks. The exploratory case study consisted of three parts (see Figure 37). First, the discourse of the "status quo" in the city of Mannheim was established according to Yin´s (2018) criteria using a variety of sources and three expert interviews, one with an energy consultant company, one with the sustainability section of the local energy supplier and one with a local citizens' initiative. The interview partners of the case study were selected according to the above-mentioned characteristics. Second, the actors from Mannheim participated in the online survey and were willing to participate in a longer in-depth interview. Only eleven of the twelve participants completed the whole questionnaire. Third, the semi-structured in-depth interview focused on the decision-process as well as the drivers and barriers regarding H&C technologies. It included the position of the interviewee in the company, decision structures of the organisations, the factors, drivers and challenges that play an important role in the decision-making process, as well as local relationships and dependencies, networks and alliances in Mannheim (see Annex A.8).

The answers to the questionnaire were analysed and displayed using MS-Excel and the interviews were analysed with MAXQDA[57], including previous transcribing and coding. In the period from May to August 2021, a total of 12 interviews were conducted with decision-makers responsible for the energy and heat supply in their companies. The interviews lasted between 30 min and 1.5 hrs.

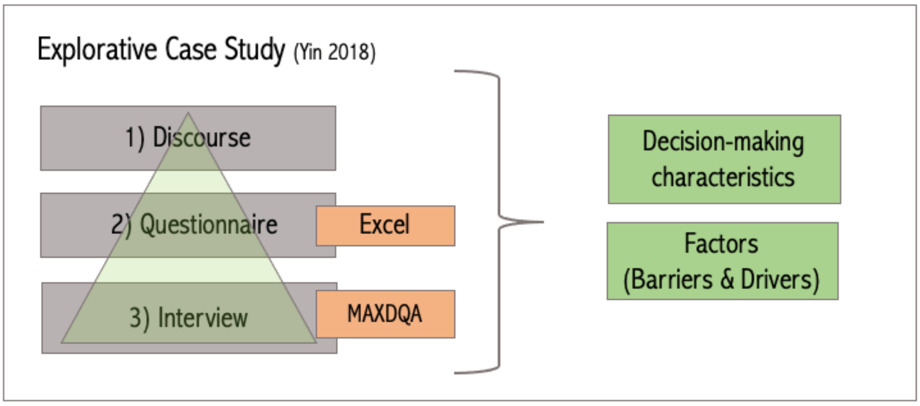


Figure 37: Research framework of the exploratory case study

4.2 Results in Industry and the Public Sector

4.2.1 Literature

The results of the literature research (Task 1) show that industry and the public sector are much less investigated than the residential sector. This is also reflected in the participation rate achieved in the online survey, which indicates that industries are not very willing to participate in interviews or surveys and that their propensity to share information is low. Despite this, industry is a large consumer of heat[58] and consequently a key actor in H&C, while the public sector has the potential to become a key lead user in demonstrating the feasibility of the energy transition in the H&C sector (see Task 1). Therefore, it is important to understand the factors governing EIS decisions in these two sectors.

One main finding of the literature review was that DH is of particular interest and concern because of its monopolistic nature. In several countries, there is the threat of the misuse of market power with

57 MAXQDA is a software program designed for computer-assisted qualitative and mixed methods data, text and multimedia analysis. https://www.maxqda.com/

58 https://www.researchgate.net/figure/Industrial-heat-consumption-in-the-EU-classified-by-industrial-section-Eurostat-2015_fig1_324368919, https://ec.europa.eu/eurostat/statistics-explained/index.php?title=File:Gross_derived_heat_generation_by_fuel,_EU,_2000-2020_(GWh).png

dependency and loss of free choice and switching of supplier. Therefore, one topic for the interviews was a closer look at the perceived threats. In addition, the review revealed a strong need for long-term commitment and planning, especially for DH, but the reviewed studies did not address the extent to which this finding is related to processes, structures and/or contents (strategies) to expand and decarbonize DH. Interestingly, energy culture and literacy, including attitudes, practices, technical understanding and know-how of complex contexts were mentioned as drivers for both technologies (HP and DH) and sectors (public and industry), as well as the need for coordination and cooperation across levels, sectors and actors. These factors are more contextual in nature, addressing the closer (social) environments of the actors. Thus, we used the interviews to explore these topics in more detail.

At the micro level, we found a long list of factors influencing EIS decisions in industry and the public sector. These are mainly economic and technical in nature, including market, capacity and business factors as well as uncertainty and dependency aspects. Environmental and climate concerns are indirectly reflected in the market, cost and benefit considerations of public and industrial actors, but were not mentioned explicitly as major features or drivers for using DH or HP technologies. To sharpen our understanding of how HP and DH are perceived among public sector and industrial actors and of the potential drivers of DH and HP applications, we explicitly focused our interviews on these factors and their form or magnitude at the micro level.

4.2.2 Survey

This section presents the results of our brief online survey in industry and the public sector (see methodology in section 4.1.1). In total, we obtained 143 responses from 21 countries, but statistical tests were not conducted as the sample was not representative (population).

There was a high response from Germany, which may reflect two aspects: language (contact in German, while all others were approached in English) and recognition of the Fraunhofer name as a trustworthy organisation in Germany. We discussed several ideas to increase the response rate of other countries. In addition to our contact database, we posted the survey link at different stakeholder events and workshops, and asked the European Commission for support through their network of Member State representatives.

The participants were grouped into two sectors: i) industry, including agriculture, forestry and fishing, wholesale and retail trade or repair, manufacturing and construction and non-social services, and ii) social services, including education, health, administration and public services. In some cases, based on the information given, we assigned the specific sector to "Other". However, it was not possible to clearly assign a sector for 28 responses (Annex A.6).

Table 7 gives the range of annual heat consumption for the total number of participants and per sector. The majority of respondents stated a low annual heat consumption of below 100 MWh/yr., but some indicated an annual heat consumption of between 1 000 and 10 000 MWh/yr. It should be noted that several respondents selected the "Not available" answer option and therefore did not specify their annual heat consumption. The respondents assigned to “Other” (28 respondents) are considered in the “Total**”** column in Table 7.

Table 7: Annual heat consumption in MWh in total and per sector (industry and public sector)

Annual heat consumption	Total	Industry	Social services
< 100 MWh	39	27	5
100 to 500 MWh	10	5	2
500 to 1 000 MWh	6	6	0
1 000 to 10 000 MWh	24	13	6
10 000 to 100 000 MWh	10	7	1
100 000 to 4 000 000 MWh	16	9	0
> 4 000 000 MWh	9	8	0
Not available	29	16	10
Total number of responses	143	91	24

Figure 38 shows the currently used heating system by annual heat consumption range. Some respondents indicated more than one current heating system in-use within their company or institution (see also Table 8). The results reveal that fossil fuel-based heating systems were still the dominant heating option.

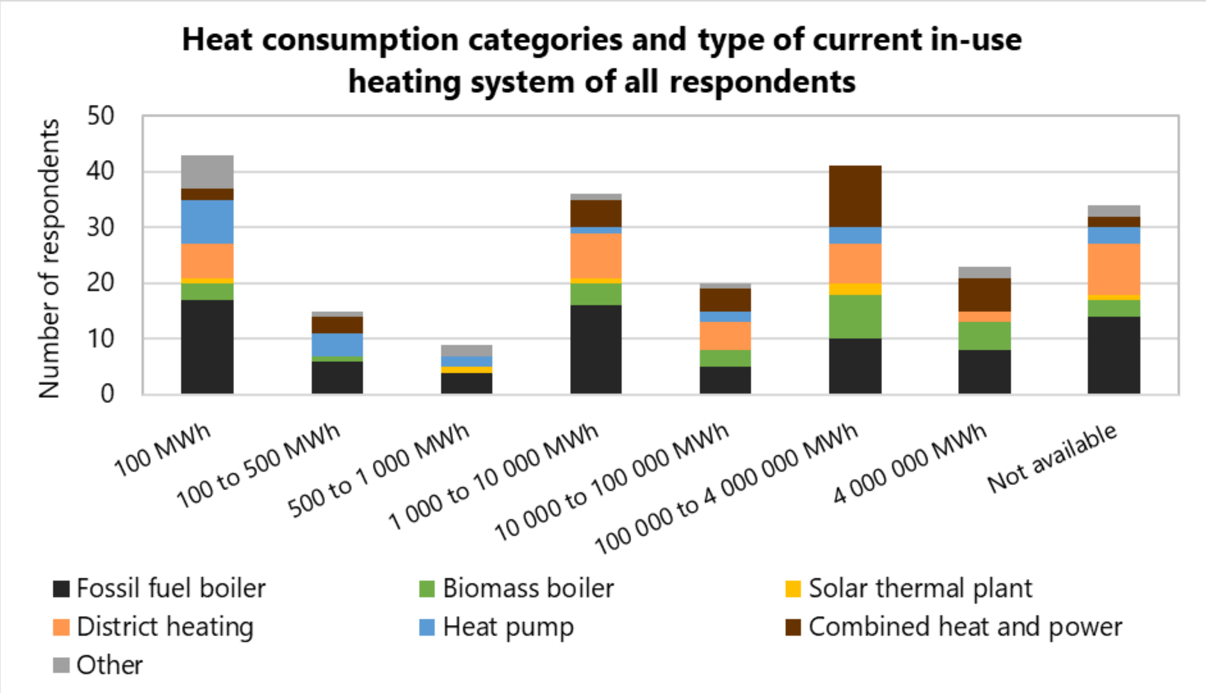


Figure 38: Type of heating system in use by annual heat consumption (industrial and public sector; not representative)[59]

An overview of the current **heating system in use by sector** is given in Table 8. The results indicate a clear tendency in industry towards fossil-fuel based heating systems. It should be noted that some respondents reported that currently more than one heating system was in use. As a result, the combination of heating technologies varies among respondents. Our results show that 9 respondents used fossil fuel heating in combination with a HP, whereas the combination of fossil fuels and renewable

[59] Not available means that respondents selected "Not available" in the question regarding the annual heat consumption.

heating options appeared in 21 cases, 4 times with a solar thermal plant and 17 times with a biomass boiler.

Table 8: Current in-use heating system of respondents (industrial and public sector)

Annual heat consumption	Total	Industries	Social services
Fossil fuel boiler	80	59	10
Biomass boiler	27	19	5
Solar thermal plant	6	3	0
District heating	38	12	11
Heat pump	23	15	4
Combined heat and power	33	21	5
Other	15	8	2
Number of responses	222	137	37

Table 8 illustrates the shares of currently used types of heating systems by sector: DH (16%), HP (10%), biomass boiler (12%) und combined heat and power (15%) had almost equal shares. Fossil fuel boilers accounted for the largest share (37%). In the social service sector, respondents used more DH (30%), whereas industry had a higher share of fossil fuel boilers (44%), followed by combined heat and power plants (15%) and biomass boilers (14%).

The last questions of the online survey were dedicated to how respondents **perceived** the different features of H&C options. The respondents were asked to indicate whether they agreed or disagreed with statements using a 6-point Likert-scale. In the following, the statements are displayed in the heading above the respective figures. The respondents could only select one option; multiple selections were not possible. We visualise the Likert-scale with an intuitive colour scheme where "agreement" is indicated by positive, green shades and "disagreement" by negative, red shades (see Figure 39).

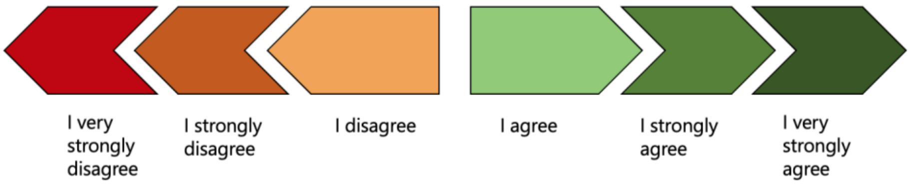


Figure 39: Colour aligned to the level of agreement

In the survey, a few respondents did not provide an assessment for all statements. As a result, some cases have a minimum of 132 responses out of the total of 143 completed questionnaires. The missing answers are indicated in the following figures next to the heating technology option (see n = x).

The first statement focused on **climate friendliness,** i.e. respondents were asked to indicate which technologies they perceived as climate-friendly. The responses are presented in Figure 40. Fossil fuel boilers were not perceived as climate-friendly by the majority of respondents (126). In contrast, an impressive number of respondents (93 responses) agreed very strongly with the statement that solar thermal plants are climate friendly, with 134 positive responses in total. HP were also seen as very climate-friendly (120 positive responses) and were only slightly below the perception of combined heat and power with 105 positive responses and slightly above the perception of DH with 94 positive responses. Overall, the respondents' answers showed a strong understanding that fossil-fuel based boilers are the least climate-friendly heating option.

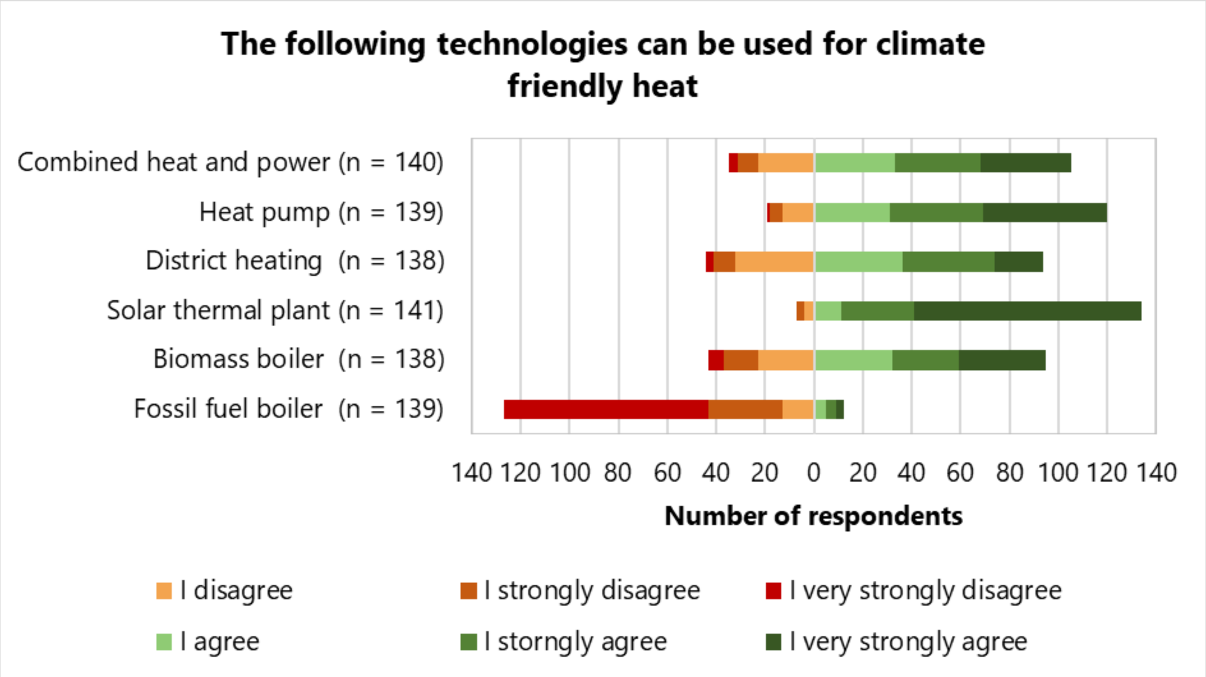


Figure 40: Perception of industry and the public sector regarding the perceived climate friendliness of heating options

The second statement addressed economic aspects and asked which technology option can provide **heat at low cost.** The responses are presented in Figure 41. The answers reveal a relatively homogeneous perception across heating options, although biomass seemed to be regarded as the more costly option, and combined heat and power (CHP) as the least costly heating option. 99 respondents gave a positive response for combined heat and power, 88 respondents for HP, 88 respondents for DH, 89 respondents for solar thermal plants, 74 respondents for biomass boiler and 80 respondents for fossil-fuel based boilers. Solar thermal plants were considered cheaper than biomass boilers, most likely due to their low operational expenses compared to fuel (wood) expenditures for biomass-based heating. The relatively low-cost image of CHP can be explained by the combined generation and use of electricity and heat as well as the possibility to mix fossil and biomass resources in larger plants. The high "costs" of biomass and fossil fuel boilers are due to the operational expenditures, which are dominated by fuel and biomass prices. While wood prices have displayed a continuous, slight price increase over time, e.g. in Germany[60], oil prices are characterised by their high volatility implying price uncertainty, and hence potentially higher costs.

[60] https://www.tfz.bayern.de/mam/cms08/festbrennstoffe/dateien/merkblatt_entwicklung_der_brennstoffpreise.pdf

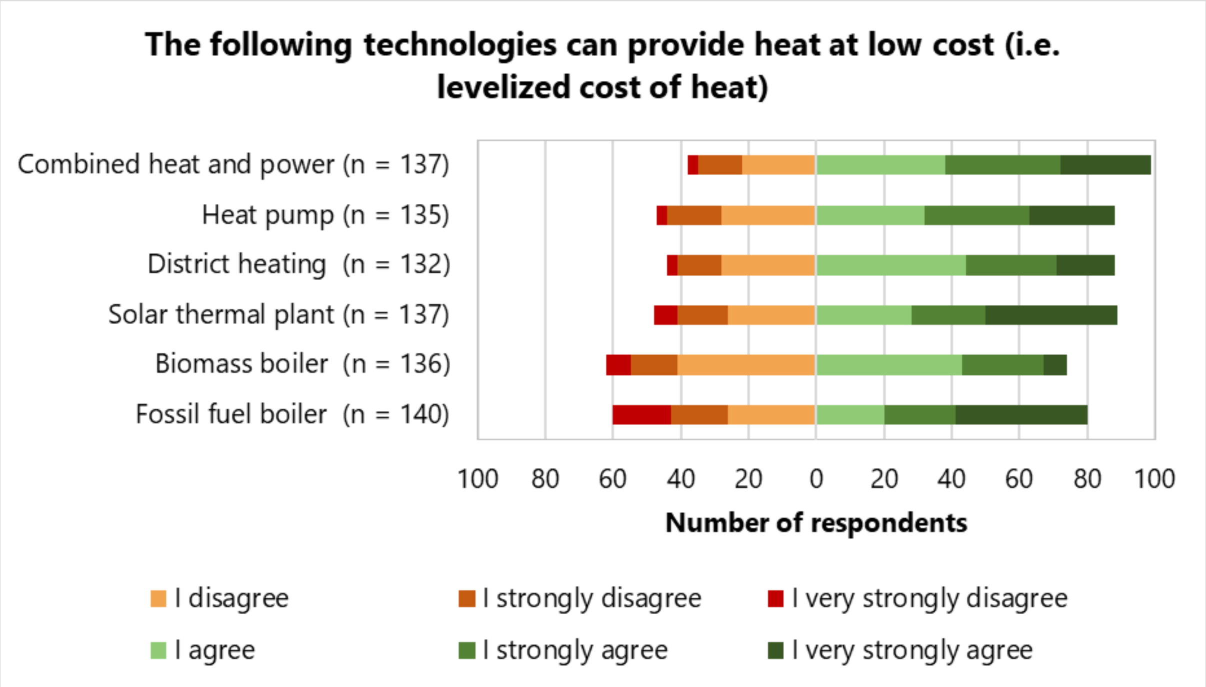


Figure 41: **Perception of industrial and public sector regarding low-cost heating options**

The third statement focused on **price risks**, considered to reflect uncertainty when deciding for one heating option or another if future price and cost developments are unclear. The answers are presented in Figure 42. Solar thermal plants were perceived as a low-price risk heating option (105 positive answers) due to their low operational expenditures, followed by HP with 80 positive answers and CHP (75 positive answers). It is surprising that the respondents considered HP as the second low-risk option even though expenditure here depends on the development of electricity prices. However, at the retail level, the volatility of electricity prices has been low in the past. Obviously, the respondents felt that future fuel prices (fossil and biomass) were more uncertain than electricity prices. This is underpinned by strong disagreement with this statement for fossil fuels: 95 of the respondents stated that fossil fuel boilers entailed a high price risk, of which 31 agreed very strongly with the statement. The high rating of price risks for DH could be due to the perceived dependency on one heat supplier, while the market in the electricity sector is unbundled and rather competitive for final energy consumers, who are free to choose a supplier. The perceived price risks of biomass heating might have their roots in the changing prices for pellets and firewood.

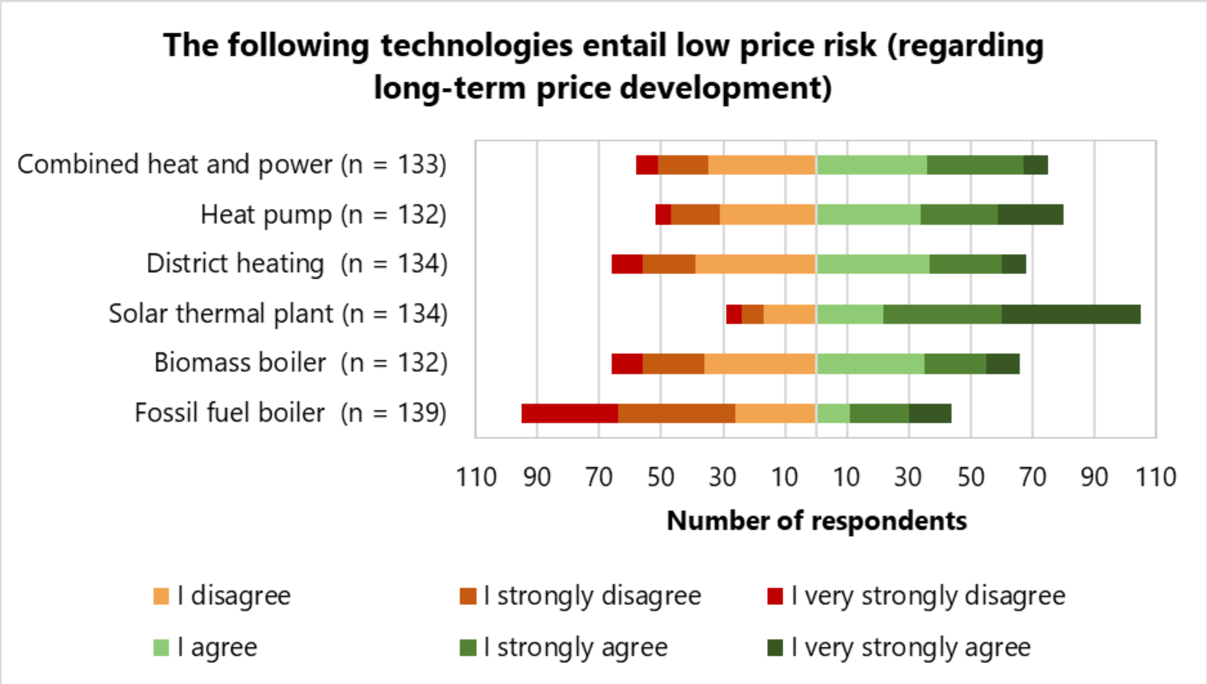


Figure 42: Perception of industry and public sector respondents regarding the price risk of heating options

Figure 43 shows respondents' perceptions regarding the **technical reliability** of the heating options, e.g. supply and quality of heat or temperature level. The results show that most of the respondents were very confident with respect to the technical reliability of the given heating options. Solar thermal installations were rated as least reliable by 61 respondents. The high dependency of solar thermal heat on intermittent solar radiation probably plays a role in these statements. In contrast to solar thermal options, the following options were perceived as very reliable: HP (99), combined heat and power (103) and DH (109), as were fossil fuel boilers (112 positive responses).

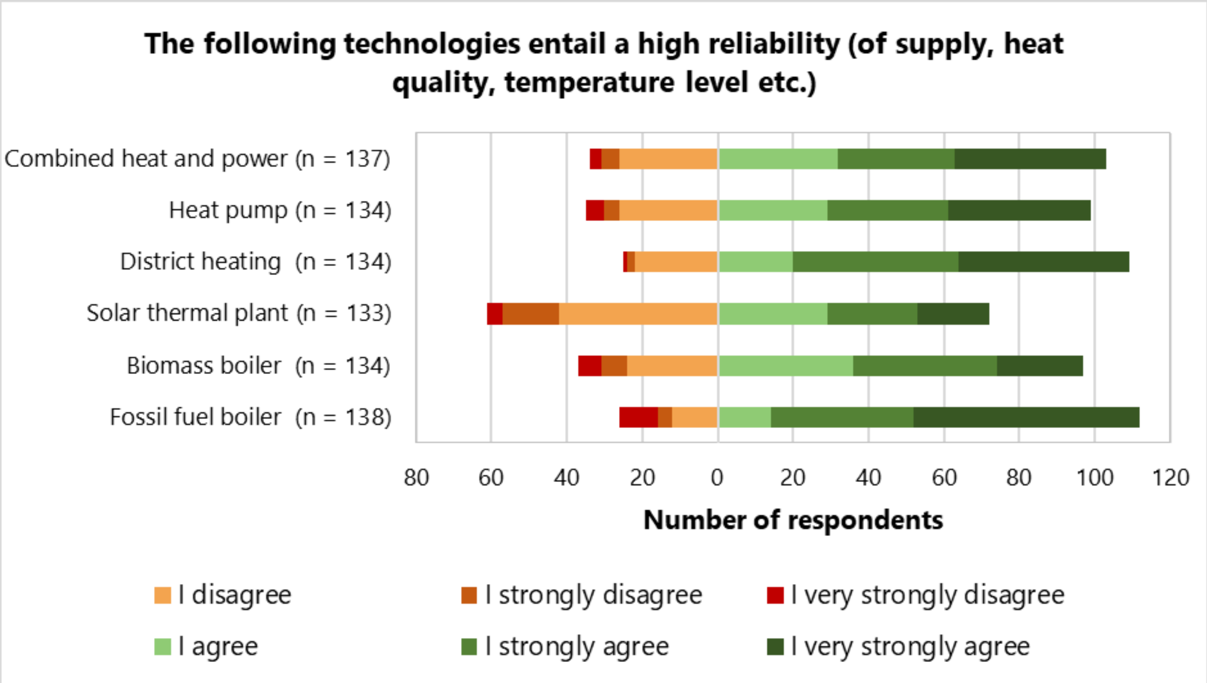


Figure 43: Perception of industry and public sector respondents regarding the reliability of heating options

The colour scheme is switched in the next two figures (Figure 45, Figure 46) to capture the inverted logic of the statements (see Figure 44).

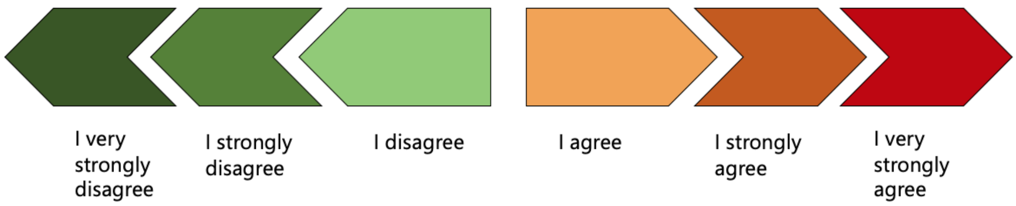


Figure 44: Colour aligned to the level of agreement

The fifth statement is presented in Figure 45 and addresses the perceived **dependency on one energy supplier**. The majority of respondents perceived high dependency in DH, as the supply or network is usually managed by one energy supplier (117 respondents). In contrast, 106 and 93 respondents for solar thermal plants and HP, respectively, perceived no or very low dependency on the supplier. This seems logical, as solar thermal has low operational costs and hence inputs, and the “fuel” for HP is provided on highly competitive markets, in which the market power of single actors is small. Regarding fossil fuel heating options, the perceived dependency might originate from the market situation, in which large fossil fuel suppliers are seen as price setters and consumers as price takers.

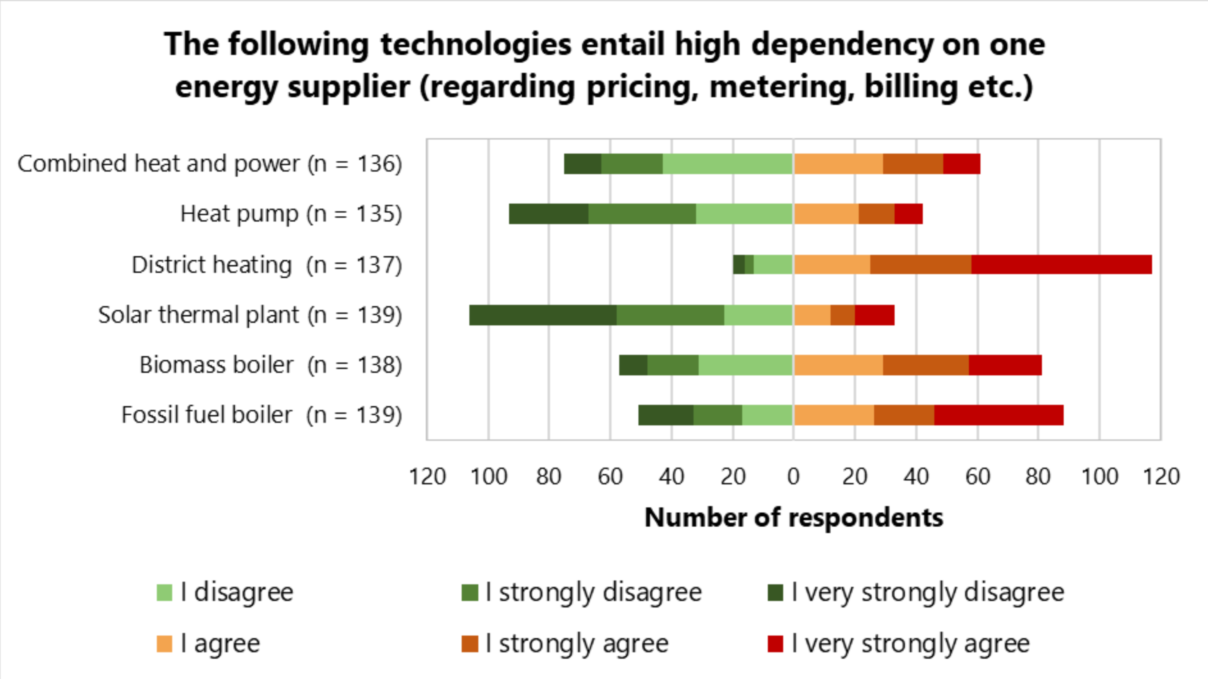


Figure 45: Perception of industry and public sector respondents regarding the dependency on suppliers

Finally, Figure 46 displays how much **work, time and effort** respondents assigned to adopting one of the listed heating systems. Fossil fuel-based boilers (123 respondents) were seen as the heating option that requires the lowest efforts, followed by DH (85 respondents) (green shades, left-hand side). Respondents expected relatively high efforts and work for collecting information, understanding and using the technology (red shades, right-hand side) when adopting the other technologies such as combined heat and power (81 respondents), solar thermal plant (80 respondents) biomass boiler (73 respondents) and HP (69 respondents). Obviously, the familiarity and experiences consumers have with the still dominant fossil-fuel based technology translates into its perception as a “low-effort” technology.

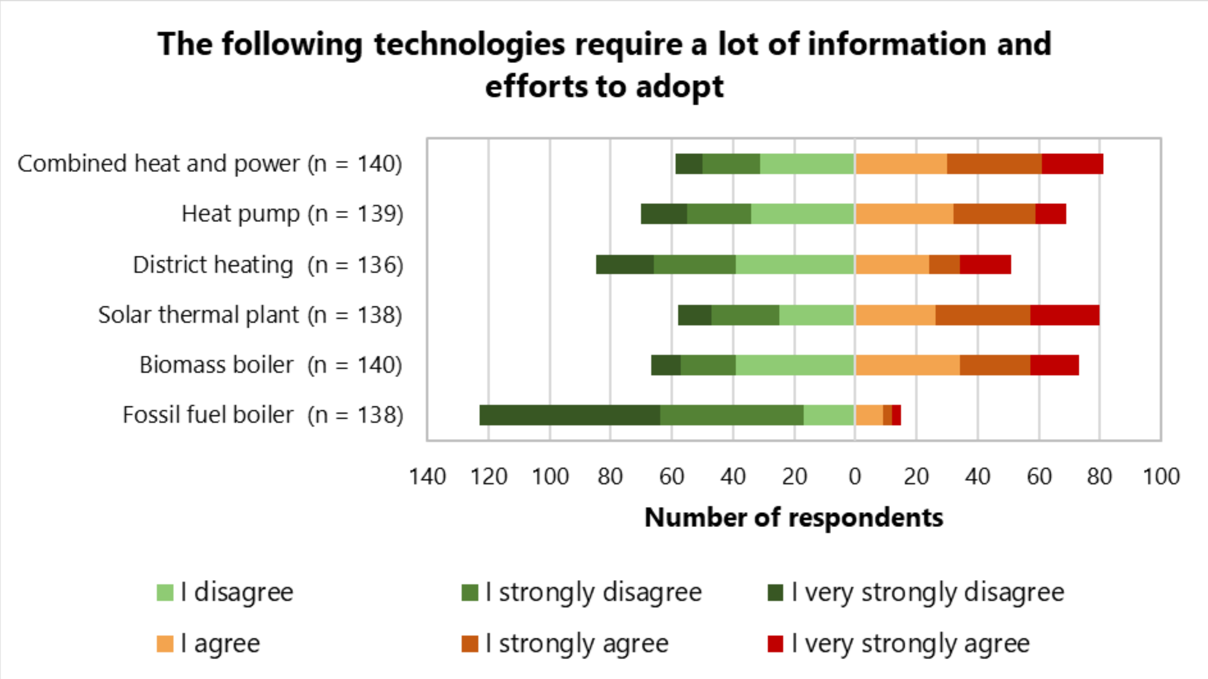


Figure 46: Perception of industry and public sector respondents regarding information and efforts for adopting a heating option

Differentiated results are also shown for **users and non-users** of DH and HP. Figure 48 uses a combined colour logic as it represents all the statements within one illustration. Figure 47 shows the colour aligned to the level of agreement with each statement.

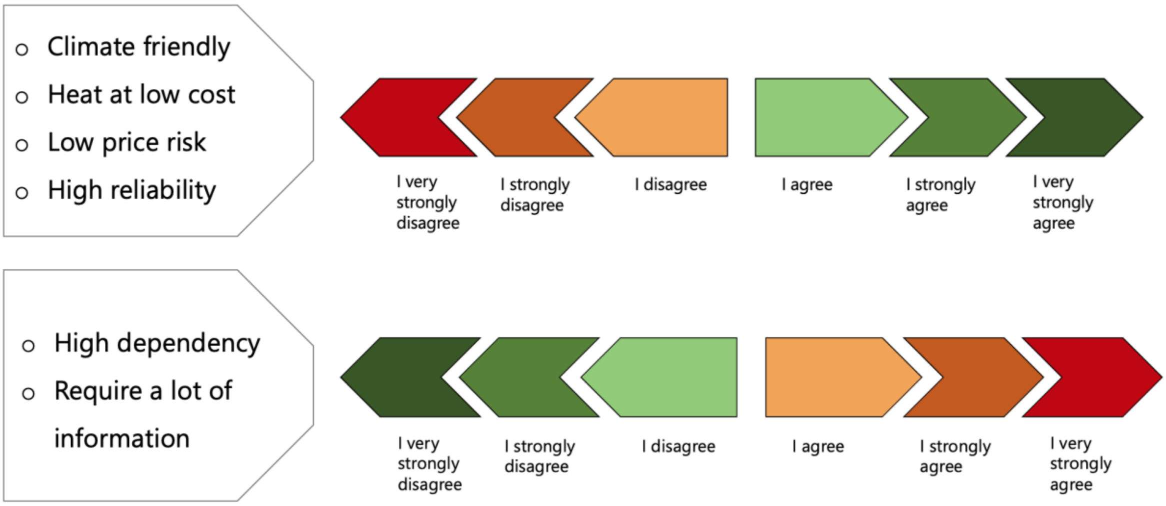


Figure 47: Colour aligned to the level of agreement

Figure 48 and Figure 49 illustrate how **DH users and non-users perceived the selected characteristics of DH**. Overall, the respondents considered DH to be a system that entails a relatively high dependency on the supplier. This dependency is also reflected in price risks, as price risks are high if no other short-term alternatives or substitutes are available. The huge advantages of DH, which were strongly perceived by DH users and non-users, are its climate friendliness, reliability and simple adoption. Thus, the main challenge here is how to ensure DH suppliers are perceived as less market dominating and thus alter the perception of DH's high dependency on suppliers.

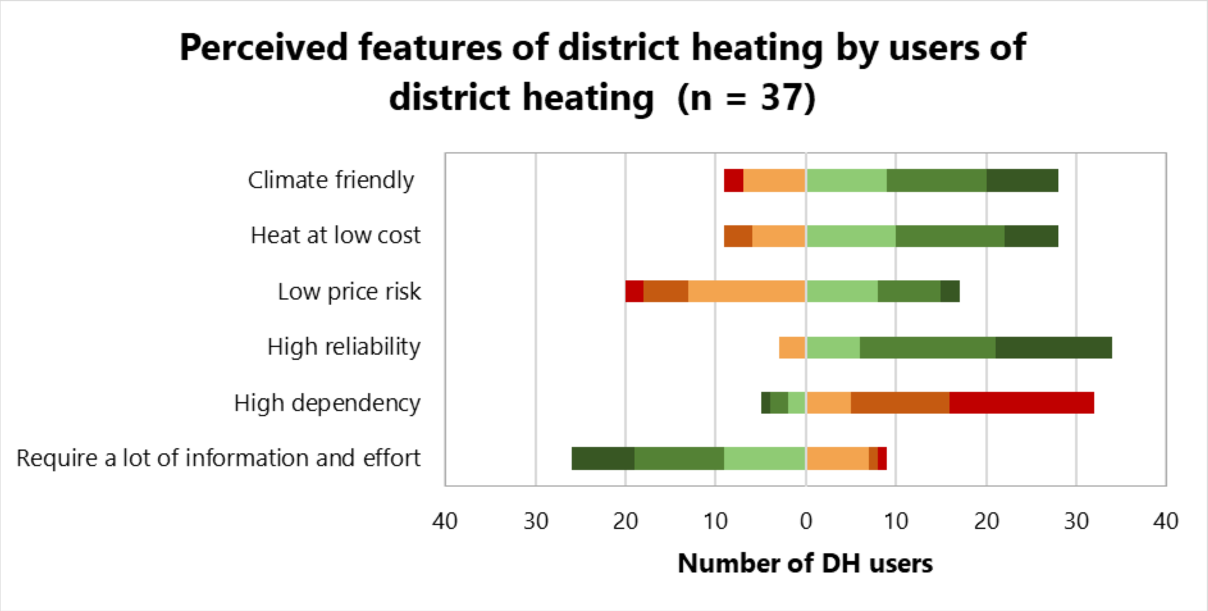


Figure 48: Perceived features of DH by DH users (industrial and public sector)

Both Figure 48 and Figure 49 reveal a similar perception pattern, i.e. the agreement levels are quite similar. The only difference is that DH users perceived the price risks as slightly higher than non-users.

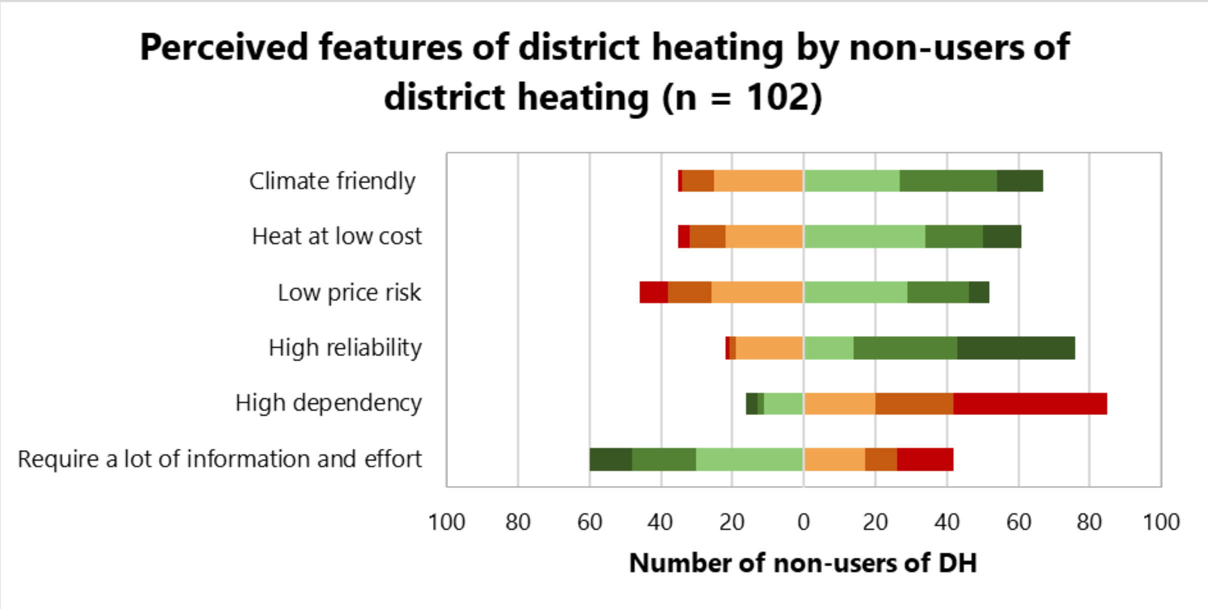


Figure 49: Perceived features of DH by non-users (industrial and public sector)

The following two figures (Figure 50 and Figure 51) illustrate how **HP users and non-users perceived the selected HP features**. Despite the differing numbers of users and non-users, there is some indication that the perceptions do not vary much. Apart from reliability, the pattern of agreement is relatively similar. Non-users seemed to evaluate the reliability of heat supply less positively, while the answers of users suggest that their experiences did not confirm the negative perception of non-users.

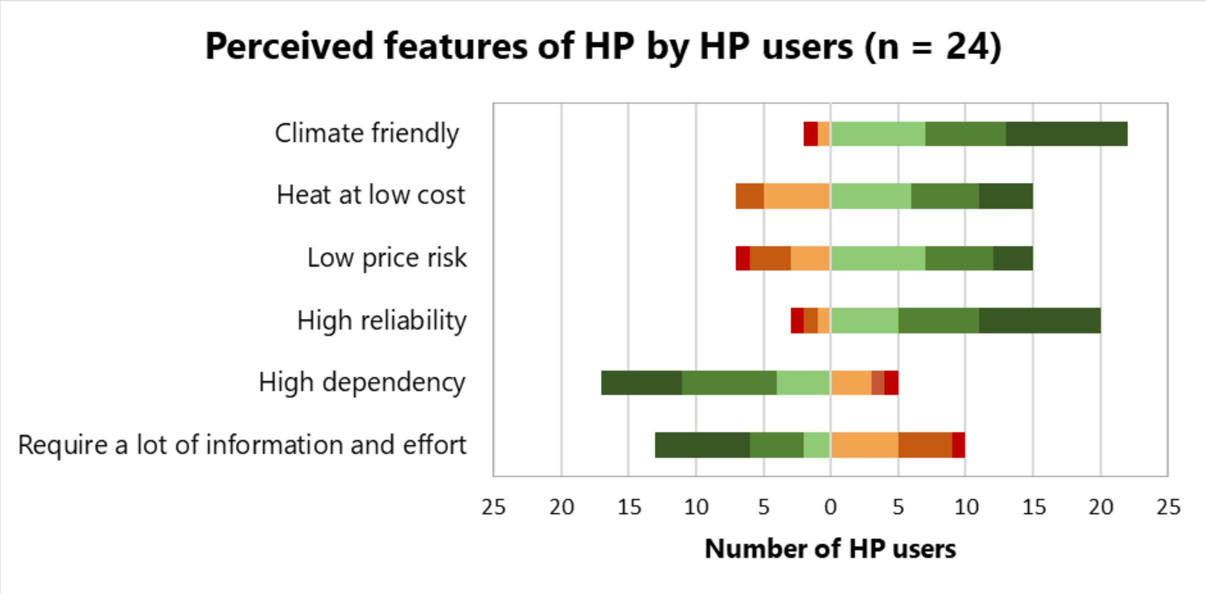


Figure 50: **Perceived features of HP by HP users (industrial and public sector)**

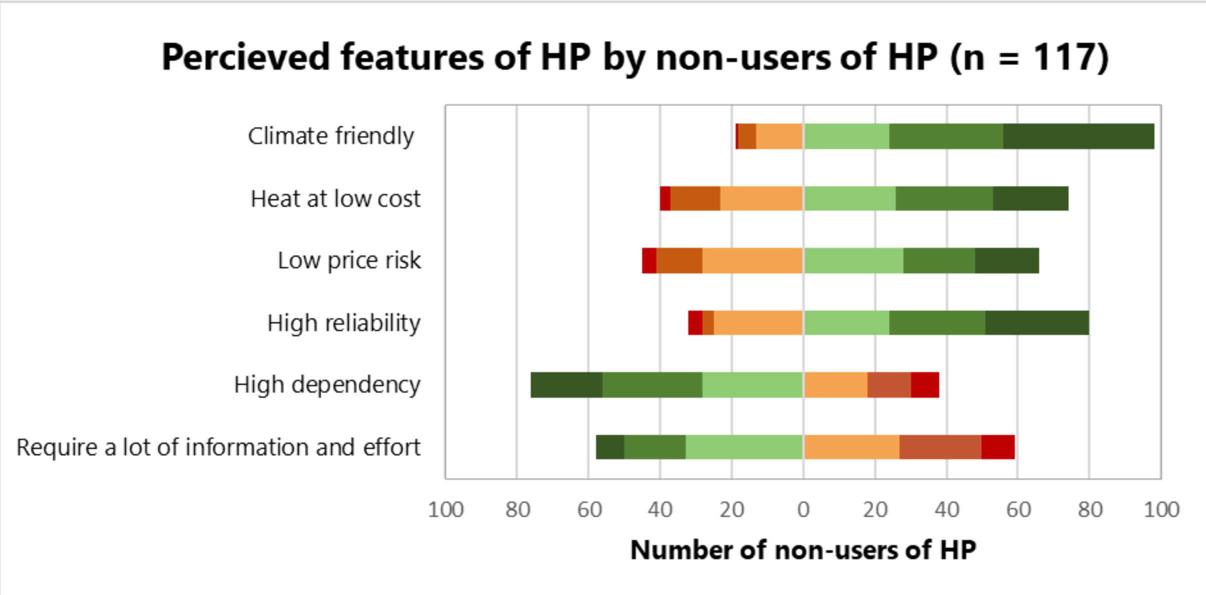


Figure 51: **Perceived features of HP by non-users of HP (industrial and public sector)**

Overall, the results are very much in line with findings from the literature review (Task 1). Non-users but also users of **DH** perceived the monopolistic nature of DH, i.e. the lack of competitors as a potential threat of becoming dependent on a single supplier. High costs and zero choices when prices are changing (price risks) were moderately pronounced, while the technical reliability, climate friendliness and simple use of the technology were clearly perceived and appreciated.

There was a different picture for **HP**. The perception of the features was less distinct, but still clear and positive: HP were considered a reliable, moderately costly and climate-friendly technology with a low price risk and a low risk of becoming dependent on one supplier, but one that requires information and work to adopt. There is still some potential to sharpen the profile of HP for users and non-users. The results indicate that non-users perceived HP as less reliable than users, which may be due to the fact that this technology is not yet widespread.

4.2.3 Interviews

Although a relatively large number of respondents in the survey signalled their interest in an interview, the actual interview appointments were low, ranging around 22 when including the case studies. About five interviewees were from the public sector, while the others were from industry. In addition, we included a few questions regarding the perception of DH and HP in interviews with representatives of associations or energy agencies conducted within the framework of another project[61]. Given the low number of interviews, we covered only a few European countries (UK, Czech Republic, Italy, Belgium, Germany, Austria, as well as Norway and Estonia), and had no regional coverage. In this section, we provide a brief summary of the main findings from interviews with representatives of industries, authorities, associations and agencies.

Regarding **experiences** with DH in the public sector and industry, the respondents were satisfied with the service of DH suppliers and had no difficulties or problems. HP were also considered a good sustainable heating option, if the existing buildings met the **technical requirements for HP,** for example, in terms of insulation and sufficiently large heat exchange surfaces. Some interview partners stated that initial problems experienced during the installation phase had been solved and they were very satisfied with the current operation of HP.

According to some interview partners, the perception of DH as a climate-friendly heating option **depends on the energy carrier used**. Similar to DH, they called HP a “clean” option if the electricity comes from climate-friendly, i.e. renewable sources. Biomass is sometimes used as an alternative to fossil fuels, but this was seen as a ”dusty” option in some cases.

A specific case in Norway indicated that the **availability of alternative energy sources frames the perception** of DH. As long as the alternatives are perceived as less environmentally-friendly, DH is seen as a sustainable energy source. For example, in Norway, heat from waste incineration was regarded as a sustainable energy source for DH as long as electricity from renewable sources such as hydro and wind power was not consciously available as a clean energy source for heating. With increasing shares of renewables in electricity and the emerging discussion on the energy transition, this perception has changed slightly, and heat from waste incineration has lost its clean image to a certain extent in favour of electric heating. The establishment of data centres near residential settlements, however, changed the perception of DH as a potential clean heating energy again, as the excess heat from cooling the data centres could be used for DH and is seen as a very sustainable way of heating.

The main **drivers of decisions** for heating options are financial in nature, such as profitability and total costs, but climate concerns and the pursuit of independency from fossil energy were mentioned as further drivers. Moreover, the simplicity of the system and past experience with other heating options are factors that affect decisions. However, since strict regulations apply with respect to efficiency standards in the building sector, **regulations were considered the primary driver**, as they set the framework within which decisions are taken (based on interviews in Germany). Financial criteria were cited by interview partners as the second main factor. Another interview showed that **building codes and energy labelling** affect the choice of energy carrier, as they define the metering and quantification of energy efficiency in buildings. For example, one interviewee explained that a regulation in Norway determines where the metering of a building’s energy consumption takes place (outside/inside the building). The regulation defines heat coming into the building as energy use, while electricity used for heating is not counted for the minimum energy efficiency standard in buildings. Under this regulation, buildings with a DH system are seen as less energy-efficient than buildings using electricity as a heating

[61] In the framework of the study on “Overview of District Heating and Cooling Markets and Regulatory Frameworks under the Revised Renewable Energy Directive (N°ENER/C1/2018-496)”.

source. In contrast to the case in Norway, in line with the Energy Performance of Buildings Directive (EPBD), the national regulations in Estonia **foster the use of RE**, in particular biomass, in DH and impede the use of HP. In Estonia, a large number of households are connected to DH. To achieve the targets and meet the standards for a large share of buildings in Estonia, the primary energy consumption of buildings is improved by adding a high share of biomass in DH. Furthermore, sector coupling through HP is hindered due to the low contribution of electricity to the EPB indicator, which is worse than that of efficient DH. These insights of Estonia show that national contexts must be considered for an efficient and sustainable achievement of targets.

Some interviewees stated that when a new heating system had to be installed or an existing one replaced, any employee could **suggest** a **heating option** (in the framework of existing regulations). Moreover, they mentioned that the selection of the (suggested) heating options, and the elaboration and presentation of the suggestions to the decision body was in the hands of the "energy manager" of the entity. Subsequently, the different heating options were discussed in a team or group (decision or consultation body), and final **decisions** were taken by the respective director or decision body. However, the "energy manager" has a **huge influence** on the discussion of the options through his/her selection and presentation quality of options. In some cases, external experts advise the energy manager.

4.2.4 Case study in south-west Germany

The **city of Mannheim in south-west Germany** is located in the north-western part of the federal state of Baden-Württemberg at the confluence of the Rhine and Neckar rivers and near the city of Ludwigshafen, where BASF (chemical industry) has its main headquarters and production sites. Mannheim currently has a population of around 310,000 (Mannheim 2021a). As one of the largest cities in this region, Mannheim is the site of important technical inventions, such as the first electric lift by the Siemens company in 1880, and the first automobile by Carl Benz in 1886, including the first route driven by his wife Bertha Benz in 1888 (Mannheim 2021a). Due to its rise during industrialisation, the city is still strongly influenced by local industries. Currently, a wide range of well-known companies and industries are located in the former port city, including the automobile, paper and pharma industries (Mannheim 2021b). The industrial sector accounted for 50.1 % of the total final energy consumption and 48.8 % of the total CO_2-emissions in Mannheim in 2018 (Hertle 2020). In terms of energy sources, electricity (22.3%), fossil fuels for transport (20.2%), natural gas (22.1%) and DH (19.9%) dominated the final energy consumption in Mannheim for all sectors in 2018. The energy supply of industry comprised about one third electricity, one third fossil fuels (mainly natural gas), one quarter renewables, with the remaining share assigned to DH (Hertle 2020[62]).

The local DH system is managed by a company named MVV Energie AG, which has a long history as a local and regional energy supplier for the city of Mannheim and the entire Rhine-Neckar metropolitan region (MVV 2022). Heat for the local DH network is predominantly supplied by four large coal-fired combined heat and power plants (CHP) at the Grosskraftwerk Mannheim (GKM 2021), with an overall capacity of 2150 MW. Heat from hard coal has a long tradition in Mannheim, as the first plant was established in 1921 (GKM 2021). Through the additional use of biomass and settlement waste at the local waste-to-energy-plant (MHKW) on the Friesenheimer Insel, the primary energy factor of Mannheim´s DH is currently 0.42 f_P (MVV 2021a; MVV 2021b). The DH supply in Mannheim is estimated to be made up of 70% from hard coal in the CHPs, 14% from biogenic residual waste, 13% from fossil residual waste in the MHKW and others, including a small proportion of industrial waste heat (von

62 Similar to DH, HP is called a "clean" option if the electricity comes from climate-friendly, i.e. renewable sources. Biomass is partly used as an alternative to fossil fuels, but this is seen as a "dusty" option in some cases.

Oehsen 2021[63]; Figure 52). Due to the very high proportion of fossil fuels still used for heat generation, local citizens' initiatives are striving for a more sustainable and environmentally-friendly supply in order to be able to comply with the 1.5-degree climate target. To strengthen their arguments, they supported a study that provides a scientific rationale for the sustainable restructuring of energy sources in Mannheim (see von Oehsen 2021).

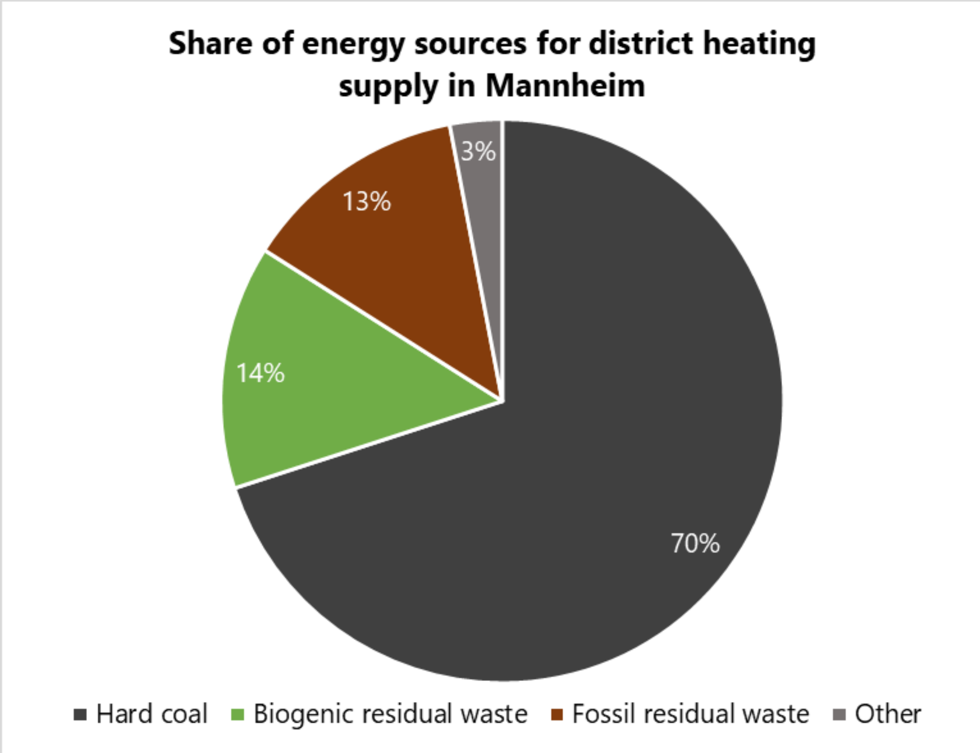


Figure 52: Share of energy sources for DH supply in Mannheim

The regulatory reason for a sustainable restructuring of heat generation in Mannheim (and Germany) is the Coal Phase-Out Act (KVBG), which stipulates that coal-fired units must be decommissioned by 2032 at the latest, which means that the energy generation of the GKM's coal-fired units must also be discontinued. In order to formulate the initial framework conditions and possible courses of action for a climate-neutral development of the city, MVV Energie AG, in coordination with the City of Mannheim, commissioned the Wuppertal Institute to conduct the energy framework study "Pathways to Climate Neutrality" (Arnold et al. 2021), which was published in March 2021. This study examined how the city can become climate-neutral by 2050, taking into account the resolutions of the German government and the EU in connection with the Paris Climate Agreement. It should be noted that the energy sources currently used in Mannheim for DH do not meet the sustainable standards needed to achieve the 1.5-degree climate target (von Oehsen 2021).

The local DH network was first established in the year 1959 and supplies not only households but also businesses with offices, warehouses, production halls as well as some industries with high-temperature process heat. Currently, the approx. 800 km long DH network operates with heat-flow temperatures of 83 °C to 130 °C, mostly used for space heating, but it also provides high-temperature steam of 385 °C to 430 °C for industrial processes (Agora Energiewende 2019, p. 18; MVV 2021a). There is currently no district cooling system in Mannheim.

In our case study, twelve interviews were conducted with major decision-makers in industry who are responsible for dealing with heating issues in their respective companies. The companies offer services

[63] https://hd-kohlefrei.de

(offices, 5), or have production sites (offices and production, 3) or operate process heat facilities (offices, production, process heat, 4) in Mannheim. The interviewees indicated that different heating options are used, whereby the combination of DH with an additional fossil fuel heating option was common to two large industries. The use of different heat options is related to the total heat consumption in MWh per year (see Figure 53). In several cases, more than one heating technology is used to cover the different heating demands. According to the interviewed decision-makers, **reasons for technology combinations** include the differing and high-temperature processes, the need for back-up options to cover peak demands, the general security of supply and the possible usage of small-scale renewable heating options (such as individual solar or geothermal applications[64]) and waste heat.

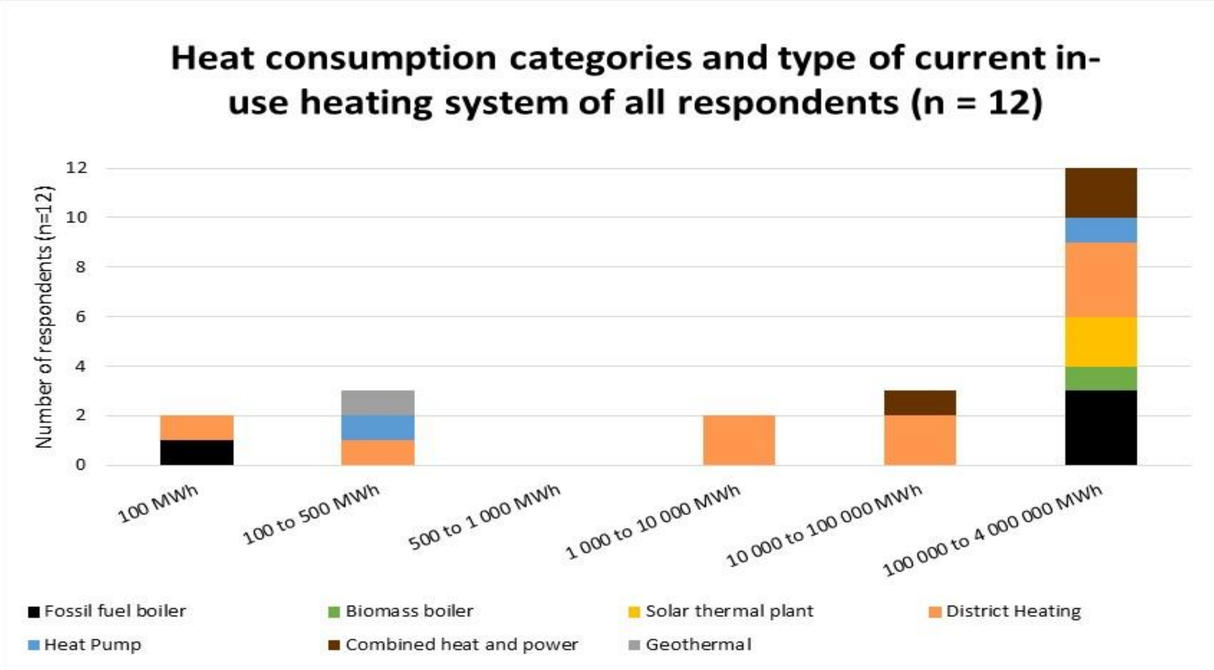


Figure 53: Type of heating system in use by annual heat consumption

The **position of the responsible decision-maker** dealing with energy and heating issues in the company ranged from HSE manager, energy manager, CEO to technical or operational manager. Therefore, the interviewees had different positions, and in each company, the "decision responsibility" is located in different departments, at different levels and/or positions.

From the case study, we concluded that the **decision-making process** with respect to heating decisions depends on the size of the company and its market coverage (competition local, national, international), and hence on the organisation's structure. The number of people involved in the decision-making process, and the number and type of departments responsible for heating issues depend on the regional or global reach of the company (regional, international, global competition) and thus on the organisational structure and position or status of the local entity (headquarters, holding company, etc.). In the case of **locally or nationally active companies** without an international presence, the decision about the appropriate energy and heat supply is made directly on site. In several cases, decisions are based on suggestions by the energy manager, which are discussed by a team with high expertise and knowledge of local requirements. No external consultants have been hired so far. The final decision rests with the CEO. In the case of **international (or global) operating companies** with a corporate identity, sustainability goals, or strategies, the subsidiaries in Mannheim must comply with the standards of the parent company and have only limited individual decision rights. When deciding on the appropriate heat

[64] Https://www.bau-mannheim.de

supply, several different departments are involved, such as the purchasing department, building technology, environmental, energy department, etc.. In addition to national or EU regulations, corporate sustainability standards, energy efficiency targets, and certification schemes are considered in the decision-making process. The elaboration of concepts takes place in coordination with all responsible departments. In some cases, external experts are involved to prepare a proposal including all the information needed on the heating technology options. The elaborated proposal is presented to the parent company or a decision body within the company. The final decision is made either locally or by the parent company, usually depending on the investment volume involved. Accordingly, there is limited individual freedom of choice on site (see Figure 54).

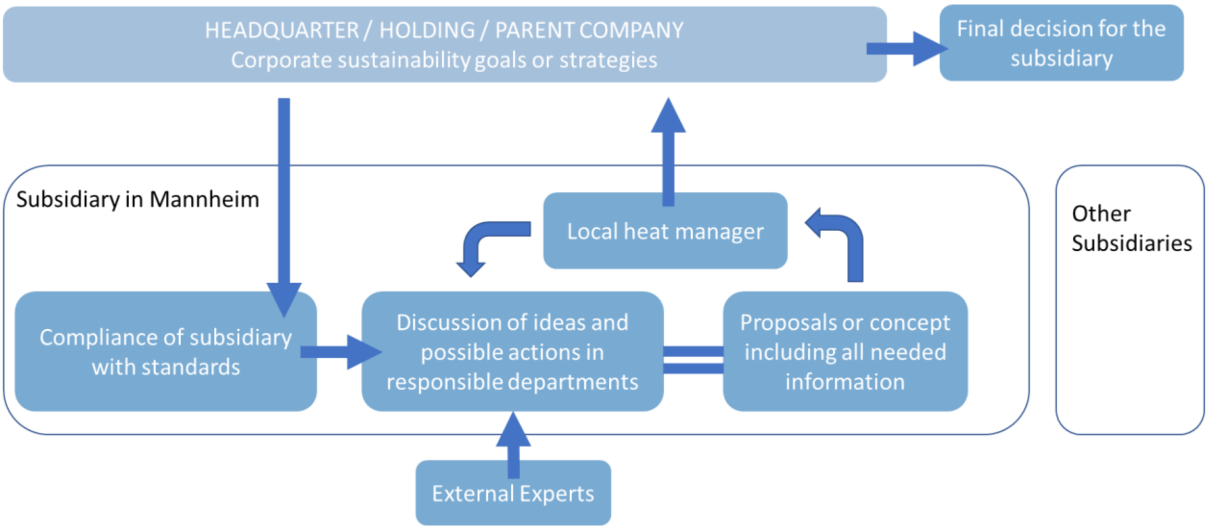


Figure 54: Decision process in companies

The interviewed actors emphasised that they feel a certain public and corporate **pressure to use clean energy options**. They perceive sustainable energy and decarbonisation as a mega trend.

- The perceived pressure comes from the government, shareholders, and customers as well as local citizens. The pressure from the government originates from the communication and commitment of the German government to the German coal-phase-out, renewable energy targets, legal restrictions, obligations, and required standards. The formal laws and stipulations of the federal government push companies towards sustainable and, if possible, climate-neutral corporate development. The EU, and national policy makers have clearly signalled to decision-makers in industry, which direction the desired "development path" should take. However, decision-makers face uncertainties regarding the further procedure and implementation, especially regarding alternative energy carriers and their costs. In addition, there are regional challenges associated with decarbonisation, and uncertainties about how quickly the hard coal currently used in the GKM to supply DH in Mannheim will have to be substituted.
- Furthermore, there is pressure from shareholders, especially for large corporations, as the CO_2-balance has become part of the annual report and, thus, affects the value of the company. Shareholders are increasingly demanding company compliance with politically formulated climate targets.
- Beyond shareholders, customers also exert pressure due to their growing preference and demand for climate-neutral and sustainable products.
- Finally, there is pressure from local, public media outlets, a) to mitigate climate change and prevent further local environmental crises, and b) to shift from fossil hard coal in the CHP in Mannheim to sustainable energy sources.

Drivers of DH and HP in Mannheim

For the private organisations in Mannheim, the main **drivers** for changing heating systems are economic issues, the simplicity of the information needed to implement the system, and the know-how of the decision-maker as well as existing relationship networks. The economic issues refer to the return on investment, financial support, reduced exemption or profitability. Further drivers include the potential for energy savings, shareholders (equity) and customers (sales) calling for climate-neutral production, and the sustainability target and strategy of the global parent company.

HP were seen as more climate-neutral than DH in the city, if the electricity used to power them is green. The main drivers of heat pumps were knowledge about heat pump technology and existing qualified staff for construction and maintenance. However, **DH** is simpler to implement, according to the interviewees. The DH in Mannheim is comparatively inexpensive for companies due to the subsidy for the initial DH connection on the one hand, and special tariffs that the companies can negotiate with the local energy supplier on the other hand. The local energy supplier MVV Energie AG thus offers companies both short-term (e.g. one-off subsidy) and long-term (e.g. secure and competitive tariffs, long contract terms) economic advantages if they connect to the local DH system. No technical know-how and hardly any human resources are needed to install DH, as all services are provided by the local DH supplier. Furthermore, the DH supplier can guarantee a stable, reliable supply of heat, which was perceived as very positive from the interviewees' perspective. The DH supply in Mannheim is not seen as a climate-neutral option due to its use of coal, but it is partly perceived as sustainable because waste heat is used as well. Interviewees rated the very high technical reliability, the associated security of supply and the flexibly adjustable temperature level of Mannheim's DH very positively. The existing social (corporate) networks provide decision-making certainty and are the main decision-makers with regard to a DH supply. In summary, economic advantages (subsidy, competitive prices, cost savings), easily accessible and available information (advice, contract renewal, convenient use) and existing relationship networks (trust, legitimacy, locational ties, tradition) emerged as the determinants supporting the use of DH.

Beyond this, the existing relationship with the energy supplier turned out to be a dominant factor, as both parties' benefit from such a good business relationship: a) easy and quick (informal) access to information and b) trust in relationships through strong local network affiliations. Accordingly, the decision regarding the heat supply is strongly characterized by the respective company's integration into existing networks and the trustworthy perception of the energy supplier.

DH and HP barriers and challenges in Mannheim

HP were associated with high investments and additional economic issues due to frequent servicing. Current users mentioned the scarcity of professional service and installation experts. The complexity of information due to the wide variety of heat pumps on the market (e.g. ground source, air or high-temperature heat pumps) as well as the large amount of legislation and support measures make it difficult to select the appropriate heat pump and fully understand the advantages of heat pumps. Most interviewees said that they would need an energy consultant.

DH was not perceived as climate-friendly in Mannheim, because predominantly fossil resources are used to supply heat. Furthermore, there was a very high perceived risk of prices increasing in the long term. On the one hand, this can be explained by the price adjustment clause in most energy contracts and, on the other hand, by the potential cost increase of DH should the local energy supplier switch to renewable sources. Current uncertainty regarding fossil fuel price development and supply security due to public debates on climate protection and the German planned coal phase-out are reinforcing the perceived price risk for DH. Despite the above-mentioned price adjustment clause in the DH contract, some companies that have been operating for a very long time in the citiy, agree to long-term contracts in order to ensure a degree of price stability and obtain more favourable prices, especially when they agree to purchase large amounts of heat. Thus, they have established a business relationship of bilateral dependency. In some cases, high process temperature is needed in Mannheim, which cannot be achieved by DH nor direct renewable heating options in several cases. Here, other technologies, like small fossil fuels-based heating or CHP are currently the only options. However, these might be replaced by hydrogen boilers or furnaces in the future.

There is an interplay of various factors when deciding on an appropriate heating system: **costs** (subsidy, competitive prices, cost savings)**, information availability** (which is linked to the know-how of the decision-maker; advice, contact renewal and convenient usage), **and existing relationship networks** (trust, legitimacy, location, tradition). Previously good experiences and personal trust, which usually result from a positive long-term business relationship with the local energy supplier, seem to be especially important factors in Mannheim that might compensate concerns about dependency and market power.

4.3 Conclusions for Industry and the Public Sector

This study investigated how representatives of industry and the public sector perceived the two heating options DH and HP, i.e. which were the perceived attributes and characteristics of DH and HP. An additional focus was on the factors governing decisions with respect to H&C options in these sectors. Overall, the aim was to understand how decisions about H&C options are made in industries and public institutions. We applied a multi-method approach. The first step was a literature review, which determined the drivers of using DH and HP as a heating option (see section 4.2.1 and Task 1). Secondly, a brief online survey was conducted to shed light onto the perceived characteristics of different heating options (see section 4.2.2). Interviews and a case study complemented the findings and provided additional insights into key drivers and decision structures of energy investment or service options (see section 4.2.3 and 4.2.4). The case study also examined the regional context, i.e. it included the meso level.

Based on Breitschopf and Billerbeck (2021) and on Matuso and Schmidt (2019), we differentiated the **factors governing decisions** about H&C into three levels. Since our focus is on HP and DH, we considered factors at three different levels: i) a high level of abstraction (macro level) for HP and DH, such as general resource and energy efficiency regulations, economics and financial requirements or public pressure to decarbonise production; ii) the program level of operationalisation (meso level), such as infrastructures, DH market designs, relationships or networks, specific regulations, and standards regarding DH or HP; iii) specific factors of individuals and specific firms (micro level), such as existing experiences, knowledge and affinity to DH or HP, technical requirements, specific costs, and required on-site resources. The findings from the interviews and the case study indicate the key drivers and barriers for using DH or HP as a heating option in industries and public institutions at these three levels. In particular, the case study included the regional context in which decision-makers operate with respect to energy investments and services. The key drivers and barriers are outlined in Table 9.

Table 9: Overview of factors affecting investment or supply decisions about DH or HP

Level	Industrial sector	Public sector
High abstraction level (macro)	Pressure from policy makers due to targets for CO_2 emissions, energy consumption and renewable energy	
	Regulations and standards regarding emissions, energy efficiency and renewable energy (i.e. quotas)	
	General economic and financial efficiency requirements of investment decisions, i.e. select low-cost or most profitable option (under the given climate and energy regulations)	
	Pressure from shareholders to produce sustainable products	
	Pressure from clients to provide green products	
Operationalisation, energy generation, supply and consumption (meso)	Local infrastructure, existing connections or pipelines (e.g. DH pipes)	
	Relationship to the local energy supplier that is based on a long and good history, leading to trust, providing advice and support when needed	
	Strong local networks such as energy suppliers, policy makers, industrial energy consumers and households pursuing sustainable energy supply and leading to peer pressure with regard to decarbonisation	
	Access to information, technology know-how, consultancy and technical support	
Specific factors (micro)	On-site, technical know-how, technical requirements and technical feasibility	
	Costs and returns on investment, i.e. selection of the least costly option that meets climate and energy requirements	
	Existing experience with heating technologies	
	Access to technical expertise, qualified installers	
	Available clean technology options or energy sources	Power of persuasion of the person that selects energy options and presents them to the decision body

In conclusion, the empirical case study clearly showed that any decision about heat supply in Mannheim is strongly influenced by the currently perceived social and political pressure to act and adapt, the high investment volume and the long-term impacts of heat supply technologies. Furthermore, the existing relationship network of policy makers (city), industries, energy supplier and citizens, all striving for a clean energy supply in Mannheim, is another factor that puts pressure on individual industries and the public sector to support this goal. The traditional relationships and experiences of industry with the energy supplier in Mannheim entails trust and commitment on both sides and compensates concerns about unilateral dependency and exposure to the market power of industrial consumers.

Overall, the study reveals that: (1) a large amount of technical information seems to be needed when using new technologies (DH and HP); (2) an enormous investment volume is required to switch to a clean energy supply; (3) technological reliability as well as a high level of trust in the energy supplier and contractual agreements are important for industries to balance market power; (4) uncertainties concerning the future development of fossil energy sources need to be reduced through a strong commitment by politics, society and utilities to jointly find acceptable solutions. However, in industry, heating option decisions are purely business cases, and the best one (i.e. the most economic) will be selected, assuming all other conditions are fulfilled. In the event that corporate sustainability goals can be achieved through other measures that are cheaper than sustainable heating, sustainable heating will no longer constitute a business case and, thus, will not be realised. Therefore, regulations are key, but these need to be accompanied by local networks that represent a kind of social environment for sharing common interests, norms and beliefs and thus contribute to a trustworthy environment.

Strict budget requirements apply to energy investment and service decisions in the public sector. This means that energy efficiency and emission standards have to be met first, then the decision body has to select the lowest-cost heating option. However, there is some scope for other options if they are known and well presented to the decision body. Thus, technical expertise and advice are key in this sector as well.

Regarding the **perceived characteristics** of heating options, the respondents of the survey showed a differentiated perception of the examined technologies (fossil fuel boiler, solar thermal, HP, biomass boiler, CHP, and DH). The characteristics focused on climate friendliness, price risks, low costs, dependency on supplier, reliability of technology or supply, and the efforts to adopt or adapt an option.

The empirical evidence shows a perceived risk of dependency on the **DH** supplier that is also expressed in how price risks were rated. The exposure to volatile and increasing prices was perceived as the highest risk for fossil fuel boilers. Technical reliability was highest for DH, but lowest for solar thermal plants due to the fluctuating solar radiation. Moreover, efforts to adopt or adapt to a new heating option were considered low for fossil fuel boilers, as these are well-known, and second lowest for DH. Thus, the risk of dependency on a supplier was able to be compensated by the technical reliability and low efforts attributed to adopting this technology. To further reduce the perceived exposure to dependency on the DH supplier, price control, price regulations, and transparency requirements are additional options.

A slightly different picture was obtained for **HP**. The perception of the features was less distinct than for DH, but still clear and positive: HP were considered a reliable, moderately costly and climate-friendly technology with a low price risk and a low risk of becoming dependent on one supplier, but one which requires a significant amount of information and effort to adopt. There is still some potential to sharpen the profile of HP for users and non-users alike. Nevertheless, the results show that experience with HP matters: HP users considered the technology to be more reliable than non-users did. Thus, information and exchange platforms might help to overcome any perception bias resulting from the still low share of HP in heating and cooling.

5 Summary and Conclusions

The objective of this study was to better understand how the features and characteristics of renewable and energy-efficient H&C technologies are perceived in industry and the residential, and public sectors, with a special focus on HP and DH.

For the **residential sector** (Task 2.1), an online survey was conducted. A market research company did the recruiting and the survey was split into a general part and specific sections for HP and DH, respectively. It took up to 15 minutes to answer the survey, which included the same questions as the survey targeting industry and several additional questions. Almost 8000 respondents completed the survey, which was a representative sample in terms of education, household size, ownership of housing, DH and HP. The survey took place during the ongoing Russian-Ukrainian war (June to August 2022).

For **industry and the public sector** (Task 2.2), we conducted a very short online survey. Potential participants were identified using company databases and contacted via email. The online survey focused on the main features of heating options and took about 5 minutes to answer. The resulting sample was not representative and comprised about 140 respondents. To complement the survey, brief interviews and a case study were conducted on the decision structures and factors involved in decisions about heating options. The survey, interview and case study took place between January 2021 and February 2022, i.e. prior to the Russian-Ukrainian war.

The findings for all the sectors – **residential sector, industry and the public sector** – were similar, but also revealed some differences in the perceived features:

- Fossil fuels were perceived as the least climate-friendly heating option in industry and the public sector, and the ranking of heating options was the same in both sectors. Furthermore, both sectors considered HP to be more climate-friendly than DH.
- Industry and the public sector considered the costs of the different heating options to be similarly high, while the residential sector rated the fossil fuel option as the most costly, and solar thermal as the cheapest solution. These differences are certainly the result of the current strong increase in (global) prices of fossil energy sources (due to the Russian-Ukrainian war).
- Regarding price risks, the ratings were very similar: solar thermal was assigned the lowest price risks, and fossil fuels the highest with HP and DH in-between.
- Due to the energy crisis, the meaning of the term reliability seems to have changed in citizens' perceptions and now includes aspects of the security of energy supply as well. While industry and the public sector rated fossil fuels as very reliable, the residential sector rated them as the least reliable heating option. This discrepancy in assessment might be explained by the current energy crisis as well.
- Dependency on an energy supplier was rated high for DH in all sectors, but the residential sector considered the risk of dependency on fossil fuel suppliers to be higher than the risk concerning dependency on DH suppliers. This assessment reflects the impacts of the Russian-Ukrainian war on the global energy market as well.
- Finally, the efforts needed to adapt or adopt a new heating option were rated the lowest for fossil fuel boilers by industry and the public sector, but the highest by the residential sector, which is likely to be a result of the energy crisis. Otherwise, the rating order was the same, but residents associated greater efforts with adoption in general.

Furthermore, **specific questions** focusing on DH and HP in the survey of the residential sector revealed a rather positive image of these technologies:

- The majority of the respondents rated DH and HP positively or even very positively. The perceived features and characteristics across countries differed, but the overall perception of the two technologies in the surveyed countries was positive.
- The general image and specific rating of selected characteristics or features of DH was below average in Lithuania, Spain, the Netherlands and the Czech Republic, while it was above average in Sweden and Denmark.
- Citizens in some countries rated the general image or specific features of HP lower than in other countries, e.g. in the Netherlands, but they rated other perceived features or satisfaction higher than others. Thus, the general or specific perception of features or characteristics of HP was not consistently negative in any country. In contrast, Polish citizens clearly had the most positive image of HP.

The drivers of decisions in industry and the public sector are different from those in the residential sector. Industry and the public sector focus primarily on economic issues or costs that are minimised under the given constraints – in economic terms. These constraints, which are pushing the use of sustainable energy supply and use, are set at the macro level through society, at the meso level through energy-related regulations and policies and at the micro level (company level). They encompass:

- Public pressure to produce and supply sustainable products is resulting in the establishment of green labels in industries that entail sustainability standards at company level. Large companies, in particular, have established such standards to meet the expectations of their stakeholders, but also to provide the product characteristics demanded by their customers.
- However, the regulations and standards set by government concerning emissions of greenhouse gases and air pollutants, and energy efficiency in production and energy consumption represent stronger drivers. If all industries have to comply with these regulations equally, there will be no distortion of competition.
- Finally, at the micro level, committed individuals in companies can drive sustainable energy use through their preparation of documents for energy-related decisions. This can be facilitated by membership in a network that pursues climate-friendly and sustainable energy use and may consist of representatives of industries, politics and society as outlined in the case study.

Several **factors** seem to **affect** the perception and image of DH and HP in the **residential sector**. In line with the results of Task 1, we divided these factors into three levels. The macro level entails external aspects that are not directly related to energy supply and consumption, but that have an impact on energy issues. The meso level comprises energy-related issues such as energy policies and regulations, energy culture and peer behaviour. The micro level addresses factors such as socio-economic and socio-demographic factors and behavioural aspects including the attitudes and habits of individuals. The following conclusions were derived from the survey in the residential sector:

- The impact of socio-demographic factors is very small and influencing them requires a long-term approach, if indeed they can be changed at all.
- In contrast, attitudes such as interest and knowledge, technology affinity and environmental awareness have a stronger influence than socio-demographic factors on the perception of DH and HP. Changing attitudes is also a long-term process that can be affected and accelerated by external factors such as the current energy crisis (macro level), but also by changes in the energy environment caused by policies, peers, etc., and through changes in socio-economic factors of individuals such as education and prosperity (see Task 1, Breitschopf and Billerbeck 2021).

- Energy policies and regulations can affect or even determine the behaviour of peers, the actions and energy behaviour of municipalities, and the energy culture and environment. They are all important factors shaping individuals' perceptions.
- Finally, the results show that the perceived features of DH and HP (e.g. climate friendliness, low cost, low price risk, high reliability, dependency on one energy supplier and efforts to adopt) are driving the general image and perception of DH and HP. In particular, climate friendliness, reliability, and low cost are key drivers that could be addressed by policy makers.

Given this broad view of sectors, the variety of actors and countries, our recommendations for policy makers are based on the key findings of this study. We suggest focusing on specific points that refer to either information or regulation measures:

Regulations in all sectors and accompanying financial instruments were identified as instruments to further promote the use of renewable and energy-efficient technologies in the H&C sector:

- In the case of general compliance, i.e. all industries and citizens have to comply; regulations and standards are considered a very appropriate means to achieve sustainability targets. The following regulations could be addressed:
  - Energy efficiency and sustainable energy standards in new buildings, the existing building stock and industrial processes.
  - Ban on fossil fuel heating and/or obligations to use HP or renewables in decentralised and/or central heating systems.
  - Obligations for municipalities to plan a local heat strategy, i.e. screening of areas that are suitable for DH, provision of public areas for DH, spatial zoning and planning with mandatory connection to DH (as the survey did not indicate any negative impact of connection obligations for consumers).
  - Obligation to publish prices and price components of heat by DH suppliers to increase transparency and thus market functioning (as the survey showed a strong preference of citizens for this approach).
- Since the low cost of heating options is important for their image, financial support instruments (e.g. for DH connection, HP investment) might have a positive effect.

Information is a key factor that could push sustainable energy use at different levels and in different areas:

- Since knowledge can improve environmental awareness, which in turn affects the perception of DH and HP, energy agencies (authorities) should provide detailed, trustworthy but understandable information on DH and HP technologies. Further, to improve knowledge or access to knowledge on DH and HP, policy makers could promote information exchange between users and non-users by providing discussion platforms, discussion rounds in public media, podcasts, etc.
- To improve the climate friendliness of heating options, it is important to not only establish and communicate standards for energy efficiency and the share of renewables in heating systems (e.g. labelling, easy access to lifetime energy use), but to accompany these by an intensive public media information campaign (increase in transparency).
- The findings reveal that well-established heating options are associated with lower adoption efforts. Thus, to reduce the efforts deemed necessary for the adoption or adaptation of new heating options, understanding of and familiarity with these technologies need to be improved through information campaigns, as do the availability and access to energy consulting through energy agencies.
- Overall, increasing the awareness of sustainable energy systems in society will (slowly) translate into pressure on industries to become more sustainable. Thus, raising awareness of sustainable energy use is a key issue and long-term task that should be pursued over the long term.

- To improve knowledge about heating technologies and to provide sufficient energy advice/services (e.g. by energy agencies), additional qualifications and training on the job for energy managers/technicians as well as more installers, engineers, etc. are urgently needed. Otherwise, the understanding and knowledge of sustainable heating options and consequently their diffusion will remain limited.

Overall, this study outlined how citizens, industries, and the public sector perceived selected heating options, identified the drivers of these perceptions in the EU Member States, and how these can be addressed by policy makers. There are still numerous gaps in our knowledge and understanding. Therefore, further research on this topic is recommended, especially on the role of policy and regulation for the perception and acceptance of DH and HP.

6 List of figures

7 List of tables

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A.1 Online survey in the residential sector

Dear participant,

In this survey, we would like to know your first impressions of different heating technologies that could bring important changes to the European energy sector.

During the course of the survey - which should not take longer than 10 minutes - we will ask some questions about your opinion on heating technologies. Although the topic might seem complex, we just want to know your personal view. No prior experience in the topic is necessary and there are no “correct” or “incorrect” responses.

OVERVIEW OF HEATING AND COOLING
PERCEPTIONS, MARKETS AND REGULATORY FRAMEWORKS FOR DECARBONISATION

The survey is completely anonymous and no one will be able to link your answers back to you. Your answers will be used exclusively for research purposes. You may withdraw from your participation at any time before completing the survey.

Your participation is much appreciated and will help to tackle climate change. Thank you in advance!

The research team from Fraunhofer ISI

Sociodemographic characteristics

Are you the decision-maker in energy matters (especially regarding heating) in your household?
Yes
No, another person is in charge of the energy decisions
If "No": Please notify the person who is the decision-maker regarding energy matters (especially regarding heating) in your household and ask them to complete the survey. You can also forward them survey link. If this has happened, this person can continue the survey by answering: Are you the decision-maker in energy matters (especially regarding heating) in your household? (see answers on the right). If the answer is again "No", the questionnaire ends: This survey is aimed at people who are in charge of the household's energy matters, more specifically who are in charge of heating. You have indicated that you are not the person in charge of energy matters; thus, unfortunately, this survey ends here. Nevertheless, we thank you for your interest!

Please indicate your gender.
Female
Male
Genderqueer/non-binary
I prefer not to answer

How old are you?
____ years

Which is the highest level of education that you have completed?
Primary level
Secondary level (collage, high school, middle school)
Vocational/technical training or education
Academic degree (Bachelor and Master degree or PhD)

In which country do you live?
Selection from: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom, Iceland, Norway, Switzerland

Where do you live?
Village (< 2000 inhabitants)
City with 2000-20000 inhabitants
City with 20001-199000 inhabitants
City 199001-1000000 inhabitants
City with > 1000000 inhabitants

How many people (incl. yourself) live in your household?
____people (incl. myself)

Do you own the house or apartment you are living in?
Yes, I own the house
Yes, I own the apartment
No, I rent the house
No, I rent the apartment

How many apartments are in the house you are living in?
Only 1
Two to 5
6 to 12
More than 12

When was the building constructed? If you do not know the exact year, please estimate it roughly.
In ____
Before the end of 2010
After 2010
I do not know at all

Has the building undergone major renovations during the last 10 years? Here, multiple answers are possible.
Yes, major renovation including insulation and heating system
Yes, insulation/retrofitting
Yes, replacement of heating system
Yes, new windows
No, nothing was renovated
I do not know
Yes, other, please specify ____

Current heating system and factors influencing decisions in H&C

What heating system do you currently use in your home, i.e. how do you heat your rooms?
Oil boiler
Gas boiler
District heating
Heat pump
Electric heater or boiler
Solar thermal plant
Biomass boiler or heater or stove
I do not know
Other, please specify ____________

How satisfied are you with your current heating system?
Very dissatisfied
Rather dissatisfied
Neutral
Rather satisfied
Very satisfied

Imagine your current heating system broke down and you have to install a new heating system. In the following you are asked to indicate which aspects are more or less important for you when you choose a new heating system.

(A) Which factors are very important, less important or unimportant for you when choosing a new heating system? (Selection 1-5; not important at all - very important):

- Efforts needed to adopt the new system should be low (e.g. no additional constructions or extensive paperwork)
- Novelty of the heating technology and acceptance by friends
- Low investment expenditures and low operating expenditures
- High autonomy and independency of supplier, e.g. from fuel supplier or service supplier
- No or minor changes e.g. in the heating technology, energy supplier, system control
- High comfort of the heating system (i.e. pleasant space heat and hot water, and convenient handling, low maintenance)
- Secure supply of heat and certain energy prices for many years
- Clean and environmentally friendly heat e.g. low emission of CO_2, low air pollutants
- Support of national employment when deciding for a locally produced heating technology

(B) Please select one of the two groups that include in your view the most decisive topics when choosing a new heating system.
Group 1:

- Low total expenditures of the heating system (incl. funding opportunities)
- Availability of money to pay for the heating system
- Appropriate technical features of the building or grid connection required for the new heating system
- Qualified and reliable information or recommendation about the heating technology e.g. from experts (professionals)

Group 2:

- High heating comfort that the system provides
- High degree of autonomy I get with this heating technology
- Low emissions of air pollutants, particles and CO_2
- Low effort and work needed to install the new heating system

-

(C) Which of these aspects do you consider as the most important and the least important when choosing a new heating system? Please select the least and the most important aspect.

- My specific needs comprising comfort, heating needs, the technical features of my housing, expenditures for heating, heating technology, autonomy in heating
- The heating systems most often used in my community or neighbourhood or promoted by the local municipality
- Impacts that my purchase decision has on economic growth, employment, national income distribution, global environment and climate change
- That there are mechanisms in place that ensure fair pricing of my heat, e.g. price controls, obligation to publish prices or costs

<u>Values and individual preferences</u>

In my view, climate change is...
1 ...not a problem
2 ...a mild problem
3 ...a moderate problem
4 ...a severe problem
5 ...a very severe problem

To what extent do you agree or disagree with the following statements? (Agreement 1-5)

- Acting environmentally-friendly is an important part of who I am
- I am the type of person who acts environmentally-friendly.
- I see myself as an environmentally-friendly person.
- I am very interested in the latest technology developments.
- It does not take me long to like new technology developments.
- I am always keen to use the latest technological devices.

<u>DH Survey - Perception DH (non-users)</u>

To tackle climate change, governments and companies are promoting various mitigation options (such as renewable energies or retrofitting buildings to make them more energy efficient). Among the options to mitigate climate change regarding heating, the heating technology **district heating** could be used.

With a district heating system, heat is generated and distributed in a centralised way. A district heating network allows a large number of individual consumers to access heat that has been produced from a number of sources such as: combined heat and power plants, biomass boilers, geothermal plants, solar thermal plants, municipal waste incineration or industrial waste heat recovery. Consequently, district heating can include large shares of renewable heat as well as heat that is produced anyway. Thus, district heating can have a lower carbon footprint than other heating options.

With the following questions, we would like to know your view on district heating. There are no correct or incorrect responses, only your personal opinion matters.

Have you ever heard of district heating before this survey?
No, I have never heard of it and I have absolutely no idea what it is.
Yes, I have heard of it but I do not know what it is
Yes, I have heard of it but I have only a vague idea what it is
Yes, I have heard of it and know what it is.
Yes, I have heard of it and I can explain it in detail.
Is there a district heating network in your area that you could connect to?
Yes

No
I do not know

If Yes: Have you ever considered to use district heating?
Yes, but I have decided against it
Yes, but I could not get connected (e.g. for technical reasons)
Yes, but I have not had to make a decision yet
No, I have not considered it so far
Other, please specify ____________

Overall, how do you rate district heating for heating?
(Selection 1-5; very negative - very positive)

How acceptable do you consider the use of district heating?
(Selection 1-5; totally unacceptable - totally acceptable)

How do you consider district heating?
(Selection 1-5)
interesting – uninteresting
conventional – innovative
expensive – economical/cheap
dangerous – safe
unreliable – reliable
leading to dependency (from others, e.g. fuel supplier) – leading to independency
inconvenient – convenient
uncomfortable – comfortable
controllable - uncontrollable (i.e. control of temperature)
bad for the environment – good for the environment
a lot of effort needed to adopt to – easy to adopt to
worse than my current heating system – better than my current heating system

Imagine you have to install a new heating system: How likely is it that you would choose district heating as new heating system?
(Selection 1-5; very unlikely - very likely)

DH Survey - Perception DH (users)

With the following questions, we would like to know your view on district heating. There are no correct or incorrect responses, only your personal opinion matters.

Were you obliged to connect to the district heating network or were you free to choose, i.e. was there a mandatory connection?
Yes
No
I do not know

Did you pay a fee for the connection to the district heating network?
Yes, I have paid (around) _____ (amount) _____ (currency)
No
I do not know
Did you receive some support/funding or discount (from the provider or municipality) for connecting to the network?

Yes, I received (around) ______ (amount) __________ (currency)
No
I do not know

How would you rate the connection process?
(Selection 1-5; very negative - very positive)

How would you describe your price for heating with district heating (in comparison with your income)?
(Selection 1-5; very high - very low)

Overall, how do you rate district heating for heating?
(Selection 1-5; very negative - very positive)

How acceptable do you consider the use of district heating?
(Selection 1-5; totally unacceptable - totally acceptable)

How do you consider district heating?
(Selection 1-5)
interesting – uninteresting
conventional – innovative
expensive – economical/cheap
dangerous – safe
unreliable – reliable
leading to dependency (from others, e.g. fuel supplier) – leading to independency
inconvenient – convenient
uncomfortable – comfortable
controllable - uncontrollable (i.e. control of temperature)
bad for the environment – good for the environment
a lot of effort needed to adopt to – easy to adopt to

<u>HP Survey - Perception HP (non-user)</u>

To tackle climate change, governments and companies are promoting various mitigation options (such as renewable energies or retrofitting buildings to make them more energy efficient). Among the options to mitigate climate change regarding heating, the heating technology **heat pumps** could be used.

A heat pump is a device that absorbs heat from the environment (air, ground, water) and releases it in the house by compressing and decompressing air. For this compressing and decompressing, the heat pump uses electricity. A heat pumps allows you to use renewable electricity produces e.g. by wind and solar energy to generate heat. Thus, a heat pump can have a lower carbon footprint than other heating options.

With the following questions, we would like to know your view on heat pumps. There are no correct or incorrect responses, only your personal opinion matters.

Have you ever heard of heat pumps before this survey?
No, I have never heard of it and I have absolutely no idea what it is.
Yes, I have heard of it but I do not know what it is
Yes, I have heard of it but I have only a vague idea what it is
Yes, I have heard of it and know what it is.

Yes, I have heard of it and I can explain it in detail.

How do you rate heat pumps for heating?
(Selection 1-5; very negative - very positive)

How acceptable do you consider the use of heat pumps?
(Selection 1-5; totally unacceptable - totally acceptable)

How do you consider heat pumps?
(Selection 1-5)
conventional – innovative
expensive – economical
dangerous – safe
unreliable – reliable
leading to dependency (from others, e.g. fuel supplier) – leading to independency
inconvenient – convenient
uncomfortable – comfortable
bad for the environment – good for the environment
a lot of effort needed to adopt to – easy to adopt to
worse than my current heating system – better than my current heating system

Imagine you have to install a new heating system: How likely is it that you would choose a heat pump as new heating system?
(Selection 1-5; very unlikely - very likely)

<u>**HP Survey - Perception HP (user)**</u>

With the following questions, we would like to know your view on heat pumps. There are no correct or incorrect responses, only your personal opinion matters.

Did you receive some support/funding or discount for the installation of the heat pump?
Yes, I received ______ (amount) __________ (currency)
No
I don't know

How would you rate the installation process?
(Selection 1-5; very negative - very positive)

How would you describe your price for heating with a heat pump (in comparison with your income)? (Selection 1-5; very high - very low)

How do you rate heat pumps for heating?
(Selection 1-5; very negative - very positive)

How acceptable do you consider the use of heat pumps?
(Selection 1-5; totally unacceptable - totally acceptable)

How do you consider heat pumps?
(Selection 1-5)
conventional – innovative
expensive – economical
dangerous – safe

unreliable – reliable
leading to dependency (from others, e.g. fuel supplier) – leading to independency
inconvenient – convenient
uncomfortable – comfortable
bad for the environment – good for the environment
a lot of effort needed to adopt to – easy to adopt to

<u>Trust in promoters and other aspects</u>

How many people do you think use district heating/heat pumps in the village/city you live in?
Almost everyone in my village/city
Around half of the people in my village/city
Around one quarter of the people in my village/city
Almost nobody in my village/city
Nobody in my village/city
I do not know
Other, please specify __________

What district heating network would you choose? (only DH survey)
District heating with a high share of renewables – district heating with a lower price
District heating in municipal/community ownership – district heating owned by a big, private energy supplier (Selection 1-5 semantic differential)

Which pricing regulation for district heating networks do you like best? Please select up to 3 options. (only DH survey)
Price should be set by authorities/regulators/government
Heat suppliers have to publish their price calculations
A price cap (maximum price) for heat based on an indicator (e.g. electricity or gas price)
Mandatory price controls by an authority to avoid excessive pricing
Price controls by authorities on request
Ownership of district heat networks are only allowed for municipality/community or cooperatives
Ownership of district heat networks are only allowed for private cooperatives
No price regulations or control at all
Other: ___________
I do not know/I have no opinion

How much do you trust the following actors in your country to make good decisions regarding district heating? (Selection 1-5; not at all - completely)
Energy providers / companies
Regional government
National government
European commission
If you are a tenant: landlord / house owner
Industry (near-by heat providers)
Your neighbours

After your reflection on the questions above, we would like to get your final impression.
With these last questions, we would like to know your view on different heating technologies. There are no correct or incorrect responses, only your personal opinion matters. Please answer the following questions by choosing 'I agree' or 'I disagree' or an answer in-between.

(Selection 1-5; I disagree - I agree, I do not know; technologies: fossil fuel boiler, biomass boiler or heater, solar thermal plant, district heating, heat pump)

- The following technologies can be used for climate-friendly heat.
- The following technologies entail low price risks (regarding long-term price development).
- The following technologies entail a high reliability (of supply, heat quality, temperature level, technical issues etc.).
- The following technologies entail a high dependency on one energy supplier (regarding pricing, metering, billing etc.).
- The following technologies require a lot of information and efforts to adopt (regarding technical and administrative issues).

A.2 Differences in perceived features of heating options by countries

The following tables show the mean sample size (N) per country (v_7) and the mean of the (dis)agreement. The (dis)agreement is indicated along a 5-point Likert scale and ranges from 1 == "I strongly agree" to 5 == "I strongly disagree". The value 3 reflects a neutral position, i.e. neither disagreement nor agreement. Thus, all mean values >3 indicate disagreement, and values < 3 agreement.

A.2.1 The following technologies provide climate-friendly heat

(1: strongly agree – 5: strongly disagree)

Fossil fuels

v_7	N	mean
Czech Republic	415	3.325301
Denmark	792	3.857323
France	431	3.658933
Germany	870	3.552874
Italy	893	3.549832
Lithuania	599	3.260434
Netherlands	756	3.65873
Poland	877	3.019384
Slovakia	754	3.307692
Spain	407	3.479115
Sweden	432	3.979167
Total	7226	3.496955

biomass

v_7	N	mean
Czech Republic	418	2.528708
Denmark	754	2.562334
France	400	2.42
Germany	832	2.347356
Italy	838	2.602625
Lithuania	594	2.494949
Netherlands	720	3.158333
Poland	849	2.559482
Slovakia	756	2.506614
Spain	384	2.309896
Sweden	414	2.724638
Total	6959	2.57652

Solar thermal

v_7	N
Czech Republic	431
Denmark	835
France	430
Germany	872
Italy	930
Lithuania	620
Netherlands	775
Poland	884
Slovakia	782
Spain	411
Sweden	456
Total	7426

DH

v_7	N	mean
Czech Republic	420	2.580952
Denmark	825	2.304242
France	438	2.56621
Germany	849	2.448763
Italy	848	2.317217
Lithuania	605	2.971901
Netherlands	745	2.830872
Poland	882	2.511338
Slovakia	744	2.572581
Spain	355	2.850704
Sweden	441	2.294785
Total	7152	2.54656

HP

v_7	N	mean
Czech Republic	427	2.067916
Denmark	815	2.096933
France	431	2.194896
Germany	856	2.01986
Italy	893	2.432251
Lithuania	585	2.276923
Netherlands	763	2.207077
Poland	878	2.006834
Slovakia	763	2.199214
Spain	398	2.376884
Sweden	427	2.227166
Total	7236	2.182421

A.2.2 The following technologies provide heat at low costs

(1: strongly agree – 5: strongly disagree)

Fossil fuels

v_7	N	mean
Czech Republic	398	3.075377
Denmark	715	3.623776
France	418	3.425837
Germany	834	3.426859
Italy	865	3.357225
Lithuania	573	3.150087
Netherlands	713	3.290323
Poland	845	2.957396
Slovakia	733	3.036835
Spain	397	3.299748
Sweden	389	3.624679
Total	6880	3.28561

biomass

v_7	N	mean
Czech Republic	397	2.798489
Denmark	656	2.891768
France	369	2.647696
Germany	767	2.805737
Italy	792	2.766414
Lithuania	576	2.769097
Netherlands	660	3.121212
Poland	815	2.720245
Slovakia	732	2.70082
Spain	370	2.645946
Sweden	361	2.958449
Total	6495	2.805851

Solar thermal

v_7	N	mean
Czech Republic	414	2.316425
Denmark	773	2.148771
France	395	2.410127
Germany	810	2.271605
Italy	885	2.167232
Lithuania	604	2.099338
Netherlands	738	2.226287
Poland	853	2.381008
Slovakia	758	2.233509
Spain	388	2.219072
Sweden	432	2.178241
Total	7050	2.236454

DH

v_7	N	mean
Czech Republic	405	2.916049
Denmark	775	2.467097
France	421	2.610451
Germany	792	2.693182
Italy	811	2.53021
Lithuania	593	3.209106
Netherlands	697	2.909613
Poland	848	2.557783
Slovakia	709	2.726375
Spain	351	2.837607
Sweden	403	2.466501
Total	6805	2.703894

HP

v_7	N	mean
Czech Republic	406	2.362069
Denmark	744	2.369624
France	410	2.431707
Germany	796	2.355528
Italy	856	2.679907
Lithuania	559	2.556351
Netherlands	713	2.527349
Poland	842	2.30285
Slovakia	724	2.486188
Spain	385	2.615584
Sweden	404	2.304455
Total	6839	2.455915

A.2.3 The following heating technologies have a low long-term price risk

(1: strongly agree – 5: strongly disagree)

Fossil fuels

v_7	N	mean
Czech Republic	395	3.288608
Denmark	696	3.853448
France	410	3.682927
Germany	826	3.882567
Italy	813	3.322263
Lithuania	554	3.122744
Netherlands	698	3.454155
Poland	837	3.126643
Slovakia	715	3.167832
Spain	390	3.525641
Sweden	377	3.761273
Total	6711	3.459246

biomass

v_7	N	mean
Czech Republic	387	2.922481
Denmark	634	3.041009
France	366	2.775956
Germany	741	2.878543
Italy	752	2.893617
Lithuania	555	2.926126
Netherlands	648	3.169753
Poland	805	2.848447
Slovakia	704	2.848011
Spain	370	2.856757
Sweden	350	3.04
Total	6312	2.927915

Solar thermal

v_7	N	mean
Czech Republic	399	2.466165
Denmark	730	2.282192
France	388	2.463918
Germany	798	2.349624
Italy	804	2.426617
Lithuania	573	2.404887
Netherlands	702	2.381766
Poland	842	2.450119
Slovakia	733	2.45839
Spain	385	2.405195
Sweden	417	2.280576
Total	6771	2.396101

DH

v_7	N	mean
Czech Republic	395	3.048101
Denmark	732	2.677596
France	401	2.805486
Germany	771	2.885863
Italy	755	2.703311
Lithuania	565	3.143363
Netherlands	671	2.988077
Poland	840	2.803571
Slovakia	691	2.914616
Spain	355	2.991549
Sweden	389	2.655527
Total	6565	2.863671

HP

v_7	N	mean
Czech Republic	402	2.577114
Denmark	711	2.485232
France	400	2.6
Germany	775	2.486452
Italy	778	2.754499
Lithuania	545	2.721101
Netherlands	682	2.555718
Poland	828	2.422705
Slovakia	706	2.600567
Spain	372	2.752688
Sweden	378	2.510582
Total	6577	2.577771

A.2.4 The following technologies are very reliable in providing heat

(1: strongly agree – 5: strongly disagree)

Fossil fuels

v_7	N	mean
Czech Republic	400	2.7825
Denmark	705	3.167376
France	405	3.009877
Germany	824	2.815534
Italy	864	2.83912
Lithuania	543	2.88582
Netherlands	718	2.589136
Poland	836	2.715311
Slovakia	729	2.8107
Spain	399	2.669173
Sweden	372	2.895161
Total	6795	2.829286

biomass

v_7	N	mean
Czech Republic	389	2.670951
Denmark	652	2.763804
France	369	2.566396
Germany	755	2.635762
Italy	784	2.665816
Lithuania	545	2.67156
Netherlands	662	2.89577
Poland	801	2.660424
Slovakia	710	2.656338
Spain	371	2.544474
Sweden	357	2.638655
Total	6395	2.680844

Solar thermal

v_7	N	mean
Czech Republic	403	2.496278
Denmark	748	2.395722
France	380	2.486842
Germany	794	2.449622
Italy	875	2.261714
Lithuania	563	2.388988
Netherlands	715	2.430769
Poland	829	2.541616
Slovakia	733	2.428377
Spain	393	2.305344
Sweden	400	2.5875
Total	6833	2.426167

DH

v_7	N	mean
Czech Republic	405	2.592593
Denmark	762	2.221785
France	400	2.61
Germany	781	2.430218
Italy	805	2.478261
Lithuania	568	2.818662
Netherlands	693	2.738817
Poland	840	2.514286
Slovakia	700	2.622857
Spain	355	2.639437
Sweden	410	2.190244
Total	6719	2.524483

HP

v_7	N	mean
Czech Republic	401	2.286783
Denmark	737	2.261872
France	389	2.383033
Germany	779	2.314506
Italy	834	2.514388
Lithuania	530	2.469811
Netherlands	695	2.492086
Poland	824	2.412621
Slovakia	709	2.435825
Spain	384	2.421875
Sweden	386	2.266839
Total	6668	2.395321

A.2.5 The following heating technologies entail a high dependency on energy suppliers

(1: strongly agree – 5: strongly disagree)

Fossil fuels

v_7	N	mean
Czech Republic	404	2.346535
Denmark	724	2.208564
France	413	2.072639
Germany	849	1.784452
Italy	875	2.050286
Lithuania	580	2.22069
Netherlands	717	2.2106
Poland	850	2.234118
Slovakia	738	2.180217
Spain	401	1.990025
Sweden	390	2.207692
Total	6941	2.125342

biomass

v_7	N	mean
Czech Republic	398	2.68593
Denmark	679	2.493373
France	374	2.59893
Germany	771	2.536965
Italy	804	2.595771
Lithuania	577	2.530329
Netherlands	670	2.467164
Poland	829	2.525935
Slovakia	725	2.535172
Spain	380	2.631579
Sweden	374	2.548128
Total	6581	2.549005

Solar thermal

v_7	N	mean
Czech Republic	408	3.107843
Denmark	752	3.136968
France	393	2.959288
Germany	817	3.26071
Italy	872	3.231651
Lithuania	592	3.113176
Netherlands	701	3.168331
Poland	842	2.972684
Slovakia	738	3.191057
Spain	391	3.153453
Sweden	402	3.174129
Total	6908	3.14172

DH

v_7	N	mean
Czech Republic	404	2.314356
Denmark	754	2.5
France	407	2.523342
Germany	801	2.410737
Italy	793	2.725095
Lithuania	598	2.110368
Netherlands	697	2.500717
Poland	846	2.3487
Slovakia	705	2.462411
Spain	359	2.493036
Sweden	389	2.362468
Total	6753	2.440545

HP

v_7	N	mean
Czech Republic	405	3.024691
Denmark	735	3.008163
France	400	2.7725
Germany	797	3.148055
Italy	839	2.713945
Lithuania	552	2.826087
Netherlands	689	3.053701
Poland	835	2.948503
Slovakia	703	2.953058
Spain	387	2.728682
Sweden	380	2.902632
Total	6722	2.929485

A.2.6 The following technologies require much technical and administration, information or work

(1: strongly agree – 5: strongly disagree)

Fossil fuels

v_7	N	mean
Czech Republic	392	3.040816
Denmark	658	3.080547
France	403	3.066998
Germany	762	3.018373
Italy	843	3.022539
Lithuania	571	2.835377
Netherlands	693	3.378066
Poland	835	2.767665
Slovakia	700	2.922857
Spain	394	3.063452
Sweden	344	2.732558
Total	6595	2.997271

biomass

v_7	N	mean
Czech Republic	383	2.848564
Denmark	627	2.770335
France	382	2.562827
Germany	708	2.586158
Italy	788	2.653553
Lithuania	569	2.718805
Netherlands	657	2.824962
Poland	815	2.651534
Slovakia	694	2.708934
Spain	375	2.642667
Sweden	340	2.617647
Total	6338	2.690754

Solar thermal

v_7	N	mean
Czech Republic	403	2.419355
Denmark	723	2.816044
France	392	2.446429
Germany	755	2.598675
Italy	843	2.474496
Lithuania	584	2.217466
Netherlands	686	2.838192
Poland	830	2.501205
Slovakia	711	2.524613
Spain	390	2.497436
Sweden	381	2.419948
Total	6698	2.542102

DH

v_7	N	mean
Czech Republic	400	2.9025
Denmark	734	3.179837
France	401	2.685786
Germany	735	2.805442
Italy	784	2.577806
Lithuania	580	2.925862
Netherlands	667	2.827586
Poland	832	2.759615
Slovakia	697	2.721664
Spain	356	2.758427
Sweden	368	2.796196
Total	6554	2.813854

HP

v_7	N	mean
Czech Republic	404	2.522277
Denmark	716	3.002793
France	399	2.639098
Germany	742	2.568733
Italy	812	2.758621
Lithuania	559	2.422182
Netherlands	684	2.660819
Poland	827	2.587666
Slovakia	698	2.636103
Spain	384	2.809896
Sweden	376	2.848404
Total	6601	2.67717

A.3 Differences in perceived features by socio-demographic characteristics

The following tables show the mean sample size (N) per socio-demographic variable (v_8 == location, v_6 == education, v_10 == ownership) and the mean of the (dis)agreement. The (dis)agreement is indicated using a 5-point Likert scale and ranges from 1 == "I strongly agree" to 5 == "I strongly disagree". The value 3 reflects a neutral position, i.e. neither disagreement nor agreement. Thus, all mean values >3 indicate disagreement, and values < 3 agreement.

The test statistics shows whether respondents' answers differ significantly depending on their location, for example, whether respondents living in a city or a mega city have significantly different answers to those that live in towns or villages. All significant results of the non-parametric test [65]are presented by technology and perceived feature. It is to be noted that the test statistics only shows differences between locations.

A.3.1 Location

The variable location (v_8) is differentiated into 5 levels: villages with up to 1999 inhabitants, towns with 2000 – 19999 inhabitants, city with 20000-1999999 inhabitants, large city with 200000 -1 million inhabitants and mega city with >1 million inhabitants.

Climate-friendly heating option:

Fossil fuel boiler

v_8	N	mean
village 1999	1169	3.429427
town 19 999	1652	3.486683
city 199 999	2397	3.510221
large city 1 Mio	1284	3.509346
mega city	692	3.578035
Total	7194	3.498054

DH

v_8	N	mean
village 1999	1155	2.593074
town 19 999	1614	2.502478
city 199 999	2382	2.525189
large city 1 Mio	1285	2.612451
mega city	689	2.519594
Total	7125	2.546246

HP

v_8	N	mean
village 1999	1177	2.097706
town 19 999	1654	2.189843
city 199 999	2399	2.158399
large city 1 Mio	1280	2.235156
mega city	694	2.276657
Total	7204	2.180733

[65] Kruskal-Wallis test

Heat at low cost:

Fossil fuel boilers

v_8	N	mean
village 1999	1123	3.314337
town 19 999	1561	3.34337
city 199 999	2286	3.295276
large city 1 Mio	1220	3.230328
mega city	658	3.183891
Total	6848	3.287091

DH

v_8	N	mean
village 1999	1100	2.800909
town 19 999	1518	2.66996
city 199 999	2276	2.657293
large city 1 Mio	1228	2.780945
mega city	655	2.629008
Total	6777	2.703113

Heat at low price risk:

DH

v_8	N	mean
village 1999	1069	2.925164
town 19 999	1465	2.833447
city 199 999	2190	2.842009
large city 1 Mio	1169	2.922156
mega city	646	2.798762
Total	6539	2.863741

Reliability of heat supply:

DH

v_8	N	mean
village 1999	1077	2.612813
town 19 999	1515	2.533333
city 199 999	2254	2.490683
large city 1 Mio	1193	2.539816
mega city	652	2.441718
Total	6691	2.523987

v_8	N	mean
village 1999	1089	2.389348
town 19 999	1518	2.386034
city 199 999	2216	2.366426
large city 1 Mio	1169	2.456801
mega city	646	2.400929
Total	6638	2.393944

High effort needed when adopting or using this technology:

Fossil fuel boilers

v_8	N	mean
village 1999	1065	2.99061
town 19 999	1489	3.034923
city 199 999	2197	3.0132
large city 1 Mio	1182	2.979695
mega city	629	2.903021
Total	6562	2.997867

biomass

v_8	N	mean
village 1999	1032	2.733527
town 19 999	1431	2.725367
city 199 999	2112	2.682292
large city 1 Mio	1127	2.669033
mega city	606	2.607261
Total	6308	2.690869

Solar thermal

v_8	N	mean
village 1999	1081	2.557817
town 19 999	1516	2.60752
city 199 999	2231	2.557149
large city 1 Mio	1199	2.487073
mega city	638	2.418495
Total	6665	2.542836

DH

v_8	N	mean
village 1999	1064	2.733083
town 19 999	1461	2.793977
city 199 999	2190	2.869406
large city 1 Mio	1179	2.852417
mega city	630	2.739683
Total	6524	2.814684

HP

v_8	N	mean
village 1999	1093	2.688015
town 19 999	1495	2.743144
city 199 999	2180	2.671101
large city 1 Mio	1169	2.627032
mega city	633	2.619273
Total	6570	2.677473

A.3.2 Ownership

The variable ownership (v_10) is differentiated into 4 levels: ownership of house, ownership of apartment, tenant of house, tenant of apartment.

Climate-friendly heating option:

Fossil fuel boilers

v_10	N	mean
owner hous	3387	3.440213
owner appartment	1804	3.470067
tenant house	524	3.593511
tenant appartmen	1495	3.6301
Total	7210	3.498197

biomass

v_10	N	mean
owner hous	3270	2.576147
owner appartment	1747	2.57012
tenant house	494	2.718623
tenant appartmen	1433	2.534543
Total	6944	2.576181

DH

v_10	N	mean
owner hous	3319	2.567942
owner appartment	1796	2.561804
tenant house	514	2.540856
tenant appartmen	1507	2.484406
Total	7136	2.546805

HP

v_10	N	mean
owner hous	3390	2.125664
owner appartment	1799	2.23124
tenant house	537	2.22905
tenant appartmen	1494	2.237617
Total	7220	2.182825

Heat at low cost:

Fossil fuel boilers

v_10	N	mean
owner hous	3249	3.279163
owner appartment	1712	3.202103
tenant house	503	3.335984
tenant appartmen	1400	3.385714
Total	6864	3.285839

biomass

v_10	N	mean
owner hous	3086	2.792288
owner appartment	1636	2.766504
tenant house	463	2.920086
tenant appartmen	1294	2.847759
Total	6479	2.805989

DH

v_10	N	mean
owner hous	3181	2.72933
owner appartment	1712	2.719626
tenant house	488	2.684426
tenant appartmen	1408	2.629261
Total	6789	2.702902

HP

v_10	N	mean
owner hous	3264	2.434743
owner appartment	1690	2.468639
tenant house	506	2.474308
tenant appartmen	1363	2.482025
Total	6823	2.455518

Heat at low price risk:

Fossil fuel boilers

v_10	N	mean
owner hous	3185	3.459969
owner appartment	1664	3.344351
tenant house	482	3.406639
tenant appartmen	1366	3.615666
Total	6697	3.459161

Reliability of heat supply:

Fossil fuel boilers

v_10	N	mean
owner hous	3216	2.811256
owner appartment	1688	2.800948
tenant house	502	2.844622
tenant appartmen	1373	2.900947
Total	6779	2.829326

biomass

v_10	N	mean
owner hous	3053	2.64756
owner appartment	1599	2.686054
tenant house	461	2.791757
tenant appartmen	1266	2.71406
Total	6379	2.680828

Solar thermal

v_10	N	mean
owner hous	3220	2.393478
owner appartment	1714	2.461494
tenant house	506	2.347826
tenant appartmen	1377	2.488017
Total	6817	2.426287

DH

v_10	N	mean
owner hous	3153	2.551538
owner appartment	1698	2.534158
tenant house	484	2.545455
tenant appartmen	1368	2.442251
Total	6703	2.524392

HP

v_10	N	mean
owner hous	3190	2.363323
owner appartment	1642	2.442753
tenant house	490	2.408163
tenant appartmen	1330	2.406767
Total	6652	2.394919

High dependency on energy supplier:

Fossil fuel boiler

v_10	N	mean
owner hous	3289	2.105199
owner appartment	1729	2.175824
tenant house	501	2.103792
tenant appartmen	1407	2.115849
Total	6926	2.124892

biomass

v_10	N	mean
owner hous	3140	2.516879
owner appartment	1644	2.578467
tenant house	473	2.560254
tenant appartmen	1309	2.583652
Total	6566	2.548736

DH

v_10	N	mean
owner hous	3173	2.419792
owner appartment	1700	2.384706
tenant house	484	2.646694
tenant appartmen	1381	2.484432
Total	6738	2.440487

High effort needed when adopting or using this technology:

Biomass

v_10	N	mean
owner hous	3019	2.719775
owner appartment	1614	2.67596
tenant house	462	2.720779
tenant appartmen	1228	2.626221
Total	6323	2.690495

solar thermal

v_10	N	mean
owner hous	3182	2.547454
owner appartment	1680	2.447024
tenant house	494	2.67004
tenant appartmen	1327	2.596081
Total	6683	2.540925

DH

v_10	N	mean
owner hous	3106	2.745976
owner appartment	1654	2.855502
tenant house	472	2.862288
tenant appartmen	1307	2.901301
Total	6539	2.813121

HP

v_10	N	mean
owner hous	3185	2.673469
owner appartment	1632	2.623775
tenant house	488	2.733607
tenant appartmen	1281	2.730679
Total	6586	2.676739

A.3.3 Education

The variable education (v_6) is differentiated into 4 levels: primary school (4-6 years of school), secondary education (up to 13 years of school), professional training on the job, tertiary education comprising a PhD, Master or Bachelor degree.

Climate-friendly heating option:

Fossil fuel boilers

v_6	N	mean
primary	672	3.447917
secondary	2284	3.429947
training	1657	3.481593
tertiary	2584	3.579334
Total	7197	3.497152

solar thermal

v_6	N	mean
primary	694	1.868876
secondary	2364	1.834602
training	1709	1.834991
tertiary	2626	1.803884
Total	7393	1.826999

DH

v_6	N	mean
primary	657	2.421613
secondary	2254	2.533718
training	1653	2.525106
tertiary	2555	2.60274
Total	7119	2.546144

HP

v_6	N	mean
primary	678	2.221239
secondary	2305	2.21128
training	1672	2.163278
tertiary	2548	2.159341
Total	7203	2.182702

Heat at low cost:

Fossil fuel boilers

v_6	N	mean
primary	624	3.365385
secondary	2191	3.247376
training	1595	3.326019
tertiary	2439	3.278803
Total	6849	3.287633

DH

v_6	N	mean
primary	612	2.578431
secondary	2145	2.703963
training	1575	2.674286
tertiary	2437	2.753385
Total	6769	2.703501

HP

v_6	N	mean
primary	621	2.439614
secondary	2170	2.478341
training	1578	2.405577
tertiary	2437	2.473943
Total	6806	2.456362

Heat at low price risk:

Fossil fuel boilers

v_6	N	mean
primary	601	3.437604
secondary	2117	3.363722
training	1553	3.495815
tertiary	2408	3.524917
Total	6679	3.4592

biomass

v_6	N	mean
primary	556	2.910072
secondary	2001	2.895552
training	1454	2.916094
tertiary	2273	2.968764
Total	6284	2.928071

DH

v_6	N	mean
primary	591	2.736041
secondary	2052	2.843567
training	1507	2.833444
tertiary	2381	2.927341
Total	6531	2.862043

Reliability of heat supply:

Fossil fuel boilers

v_6	N	mean
primary	612	2.913399
secondary	2171	2.802395
training	1564	2.861893
tertiary	2414	2.814002
Total	6761	2.830351

solar thermal

v_6	N	mean
primary	621	2.359098
secondary	2179	2.417623
training	1566	2.39272
tertiary	2431	2.474702
Total	6797	2.426953

DH

v_6	N	mean
primary	597	2.390285
secondary	2120	2.559434
training	1552	2.514175
tertiary	2415	2.530021
Total	6684	2.52319

High dependency on energy supplier:

Fossil fuel boiler

v_6	N	mean
primary	619	2.211632
secondary	2216	2.16426
training	1592	2.067839
tertiary	2480	2.105645
Total	6907	2.125235

biomass

v_6	N	mean
primary	575	2.56
secondary	2095	2.591408
training	1503	2.487691
tertiary	2377	2.549432
Total	6550	2.549618

Solar thermal

v_6	N	mean
primary	623	3.016051
secondary	2198	3.170155
training	1580	3.055063
tertiary	2475	3.20404
Total	6876	3.141943

DH

v_6	N	mean
primary	607	2.53542
secondary	2114	2.483917
training	1561	2.403587
tertiary	2439	2.404264
Total	6721	2.441006

HP

v_6	N	mean
primary	611	2.823241
secondary	2134	2.88941
training	1548	2.916667
tertiary	2395	3.000418
Total	6688	2.929426

High effort needed when adopting or using this technology:

Fossil fuel boiler

v_6	N	mean
primary	575	2.972174
secondary	2099	2.939971
training	1507	2.951559
tertiary	2380	3.082353
Total	6561	2.997104

solar thermal

v_6	N	mean
primary	592	2.646959
secondary	2128	2.541353
training	1540	2.555844
tertiary	2404	2.50624
Total	6664	2.541417

DH

v_6	N	mean
primary	571	2.758319
secondary	2069	2.78202
training	1519	2.815668
tertiary	2361	2.857264
Total	6520	2.815031

HP

v_6	N	mean
primary	588	2.77551
secondary	2082	2.669549
training	1514	2.678336
tertiary	2383	2.656735
Total	6567	2.676412

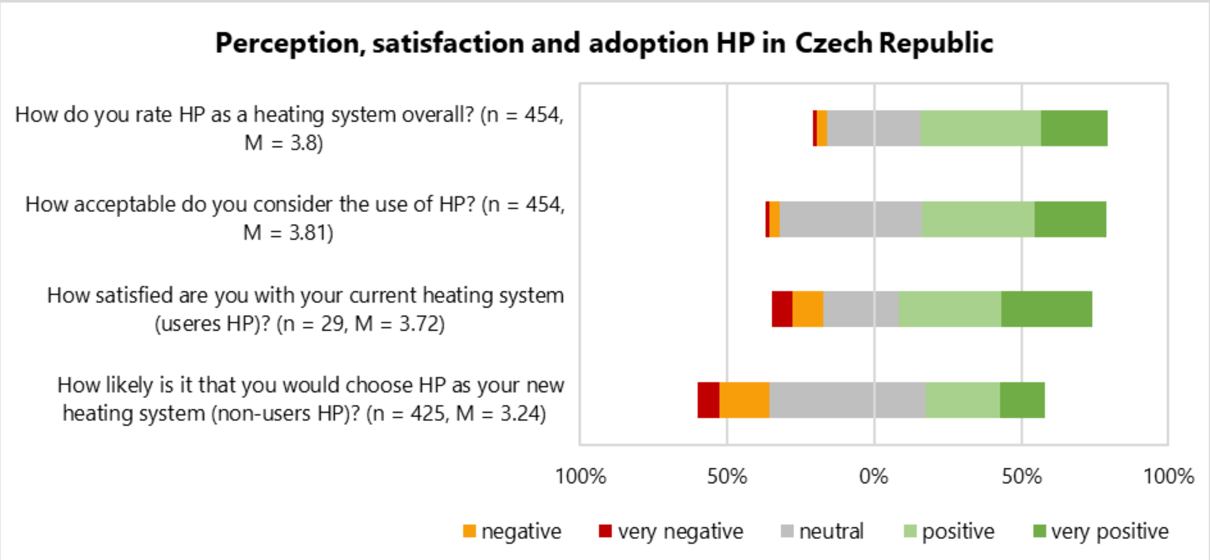
A.4 Country fact sheets of the survey in the residential sector

A.4.1 Czech Republic

For Czech Republic, data were collected for HP (n = 455).

Category	Country data	Sample HP
Socio-demographic characteristics		
Share of female	51%	54%
Median age	43	50
Share tertiary education	33%	39%
Size HH	2.3	2.4
Share home owners	79%	76%
Heating characteristics		
Share HP (market stock)	2%	6%
Share RES in electricity	14%	-

Sources: Country data for 2019/2020 based on Eurostat, RES'Observer 2021, Bacquet et al. 2022

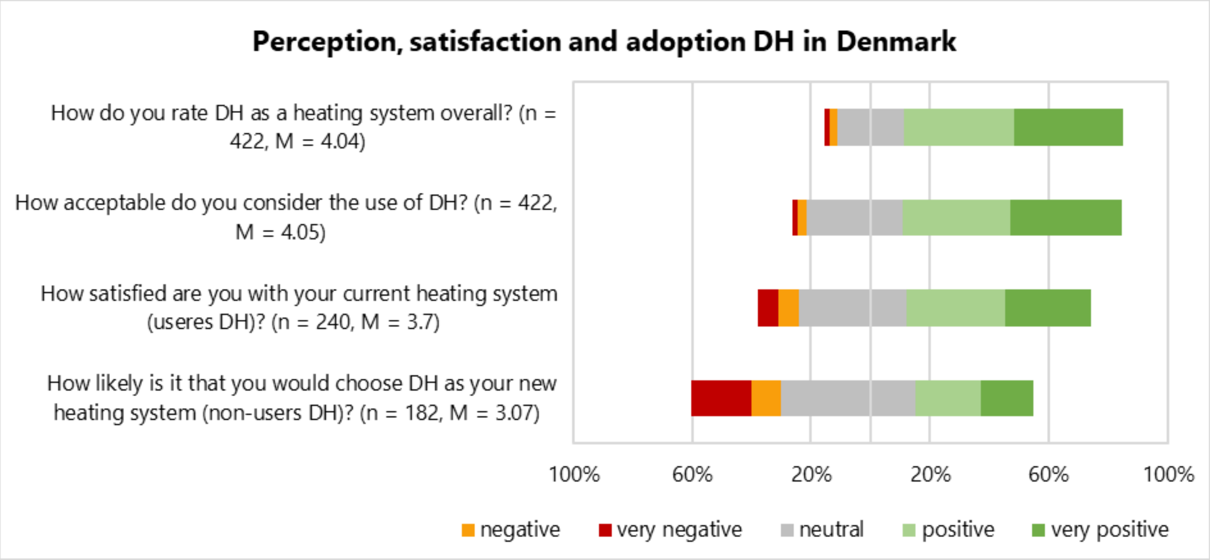


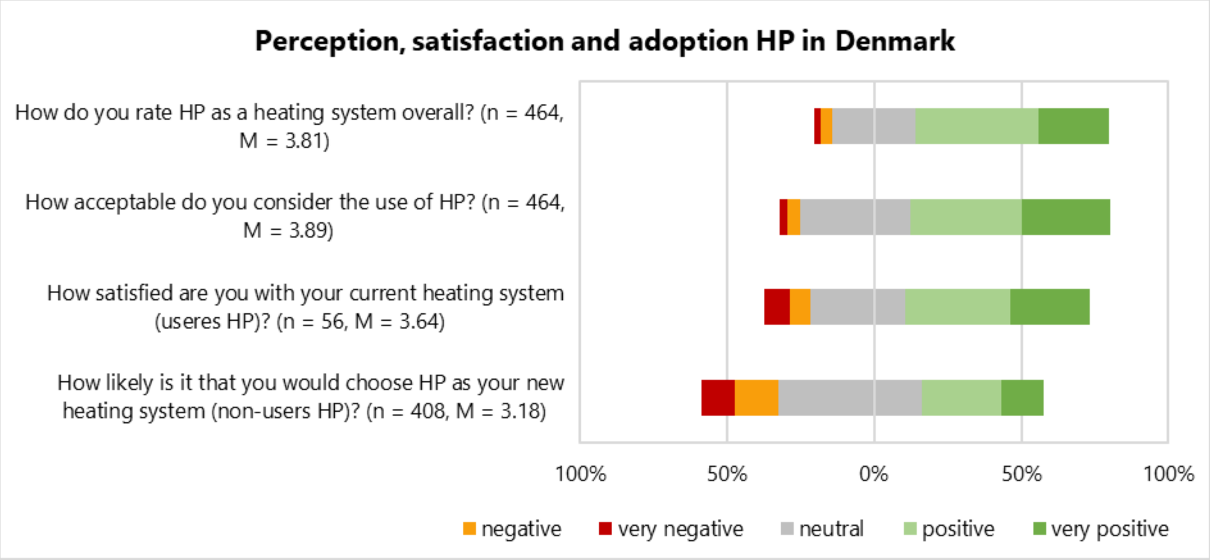
A.4.2 Denmark

For Denmark, data were collected for DH (n = 422) and HP (n = 464).

Category	Country data	Sample DH	Sample HP
Socio-demographic characteristics			
Share of female	50%	48%	50%
Median age	42	53	52
Share tertiary education	47%	70%	68%
Size HH	2.0	2.1	2.0
Share home owners	59%	64%	59%
Heating characteristics			
Share DH (citizens served)	65%	57%	-
Share HP (market stock)	13%	-	12%
Share RES in DH	62%	-	-
Share RES in electricity	65%	-	-

Sources: Country data for 2019/2020 based on Eurostat, RES'Observer 2021, Bacquet et al. 2022



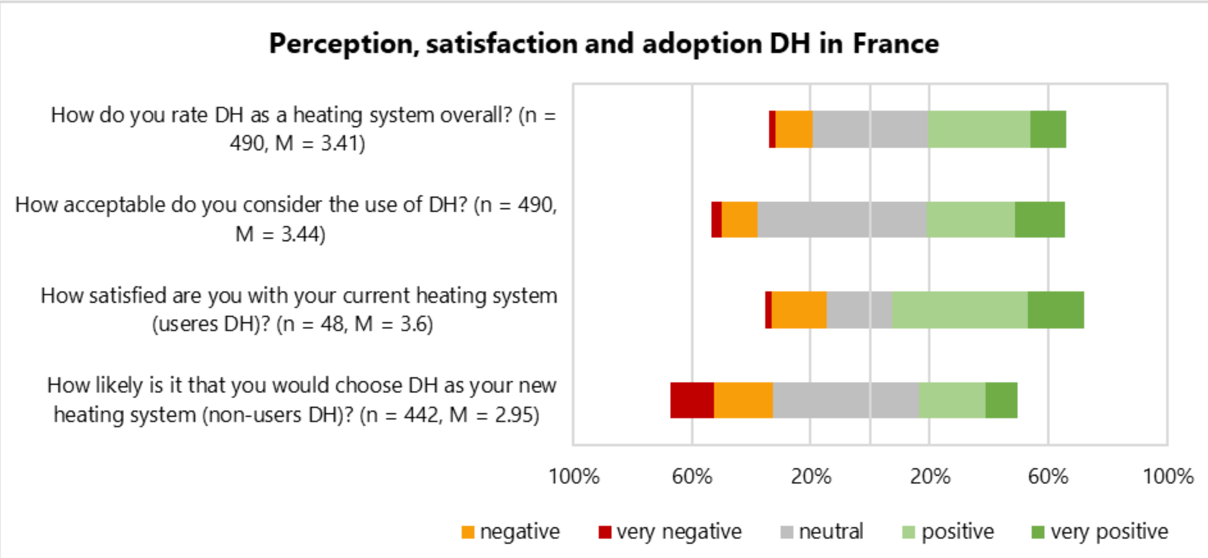


A.4.3 France

For France, data were collected for DH (n = 490).

Category	Country data	Sample DH
Socio-demographic characteristics		
Share of female	52%	50%
Median age	42	54
Share tertiary education	49%	59%
Size HH	2.3	2.2
Share home owners	64%	64%
Heating characteristics		
Share DH (citizens served)	8%	10%
Share RES in DH	56%	-

Sources: Country data for 2019/2020 based on Eurostat, RES'Observer 2021, Bacquet et al. 2022

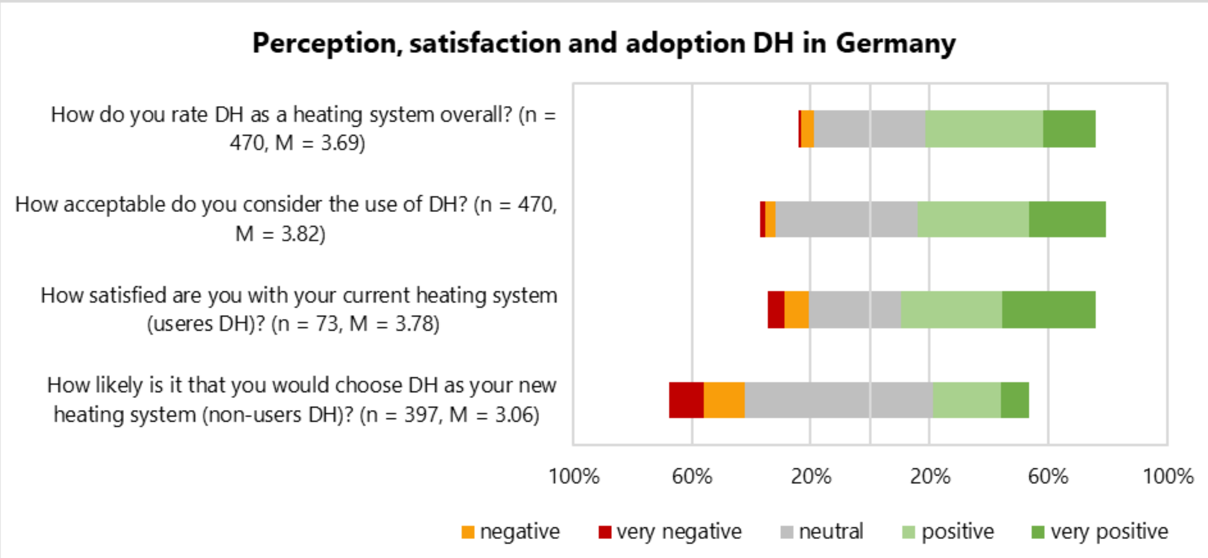


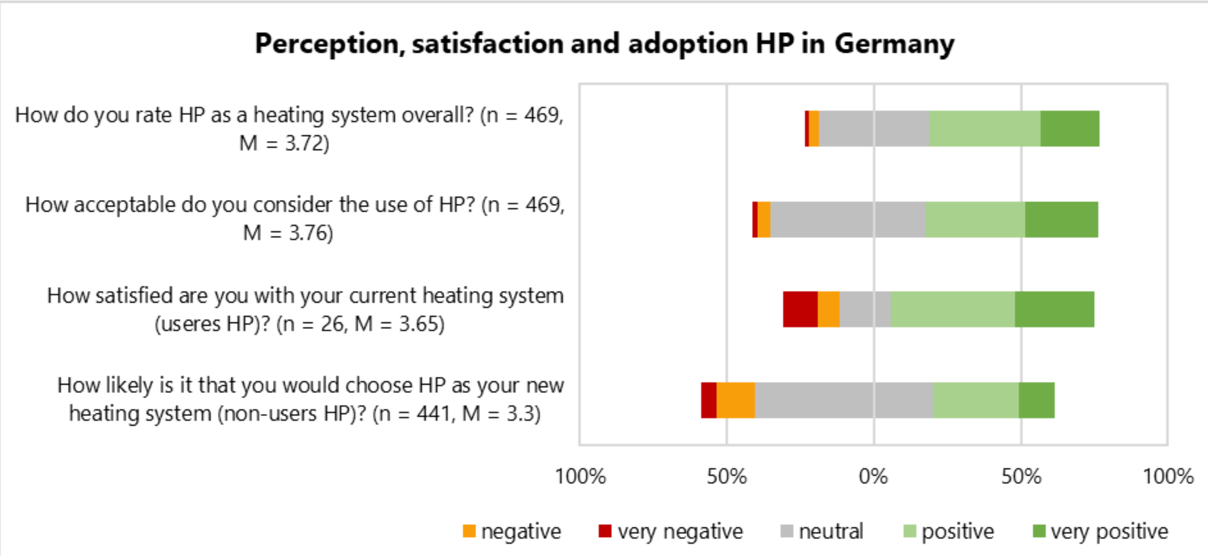
A.4.4 Germany

For Germany, data were collected for DH (n = 470) and HP (n = 469).

Category	Country data	Sample DH	Sample HP
Socio-demographic characteristics			
Share of female	51%	51%	49%
Median age	46	56	53
Share tertiary education	35%	69%	65%
Size HH	2.0	2.0	2.0
Share home owners	51%	47%	45%
Heating characteristics			
Share DH (citizens served)	15%	16%	-
Share HP (market stock)	6%	-	6%
Share RES in DH	22%	-	-
Share RES in electricity	41%	-	-

Sources: Country data for 2019/2020 based on Eurostat, RES'Observer 2021, Bacquet et al. 2022



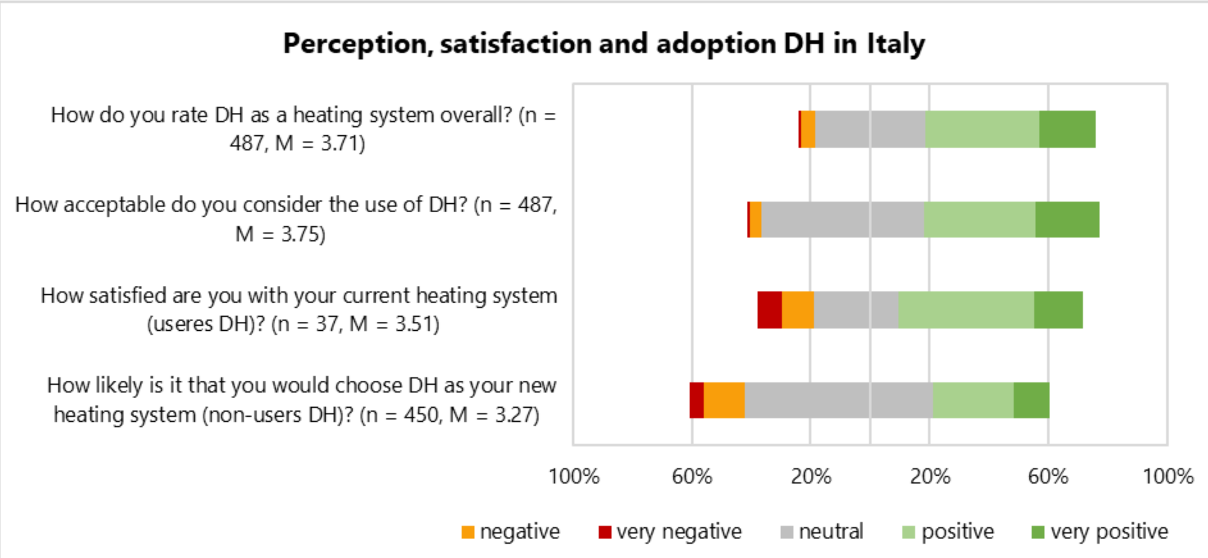


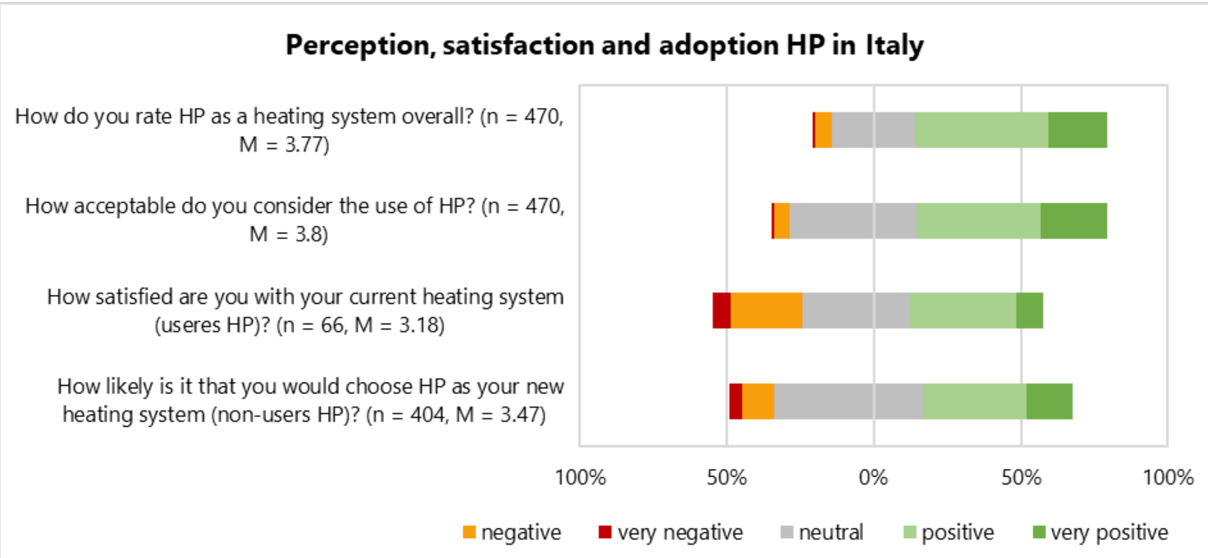
A.4.5 Italy

For Italy, data were collected for DH (n = 487) and HP (n = 470).

Category	Country data	Sample DH	Sample HP
Socio-demographic characteristics			
Share of female	51%	52%	53%
Median age	47	47	50
Share tertiary education	29%	37%	35%
Size HH	2.3	2.4	2.4
Share home owners	75%	72%	73%
Heating characteristics			
Share DH (citizens served)	6%	8%	-
Share HP (market stock)	7%	-	14%
Share RES in DH	12%	-	-
Share RES in electricity	35%	-	-

Sources: Country data for 2019/2020 based on Eurostat, RES'Observer 2021, Bacquet et al. 2022



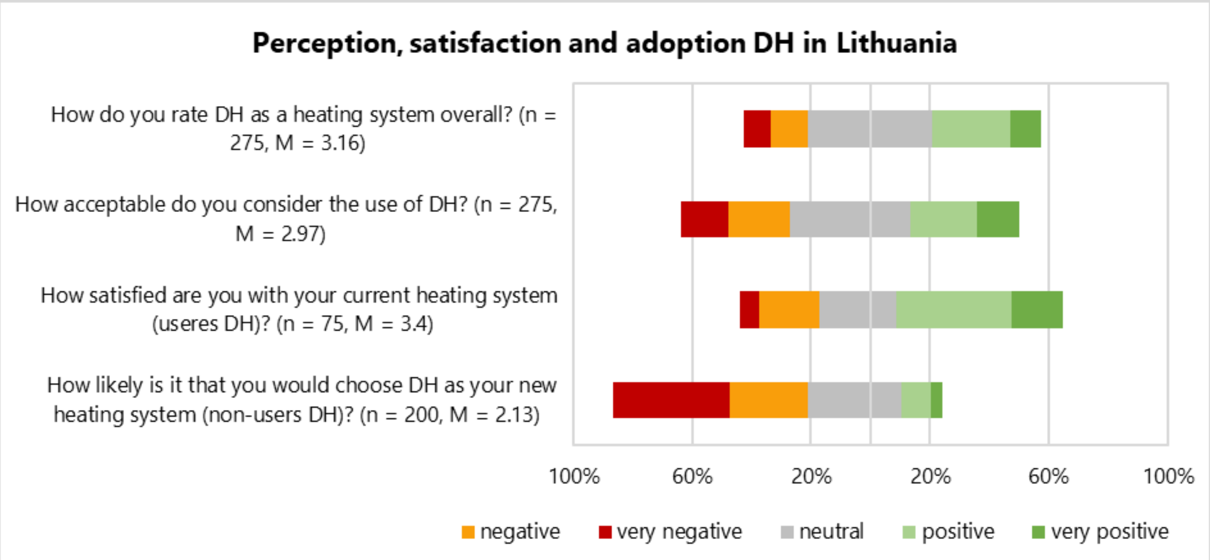


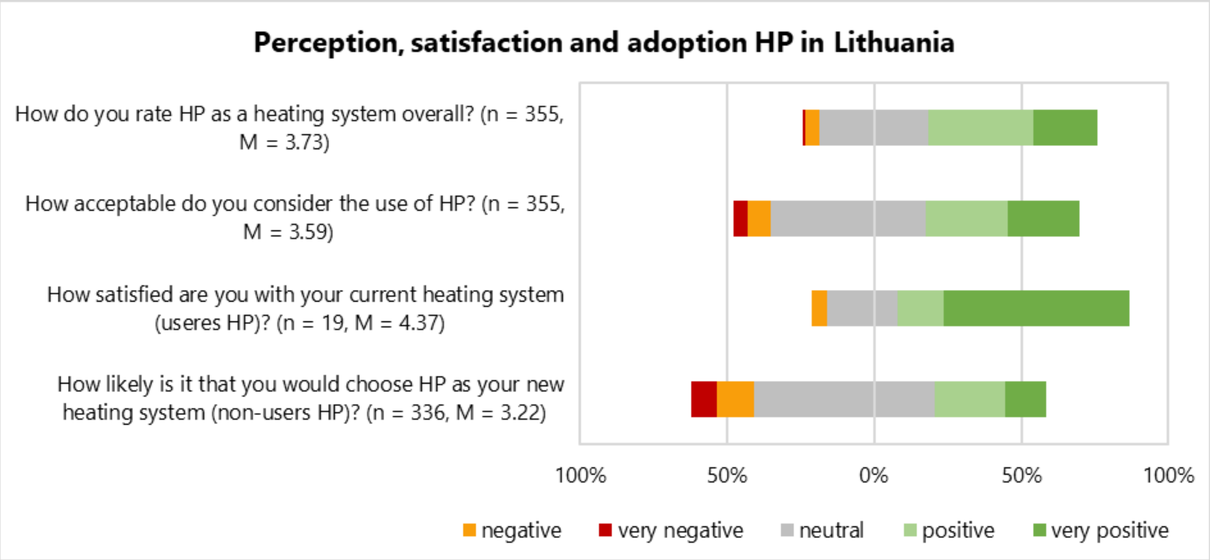
A.4.6 Lithuania

For Lithuania, data were collected for DH (n = 275) and HP (n = 355).

Category	Country data	Sample DH	Sample HP
Socio-demographic characteristics			
Share of female	53%	64%	62%
Median age	44	47	47
Share tertiary education	56%	90%	88%
Size HH	2.2	2.7	2.6
Share home owners	88.6	95%	91%
Heating characteristics			
Share DH (citizens served)	57%	27%	-
Share HP (market stock)	2%	-	5%
Share RES in DH	61%	-	-
Share RES in electricity	19%	-	-

Sources: Country data for 2019/2020 based on Eurostat, RES'Observer 2021, Bacquet et al. 2022



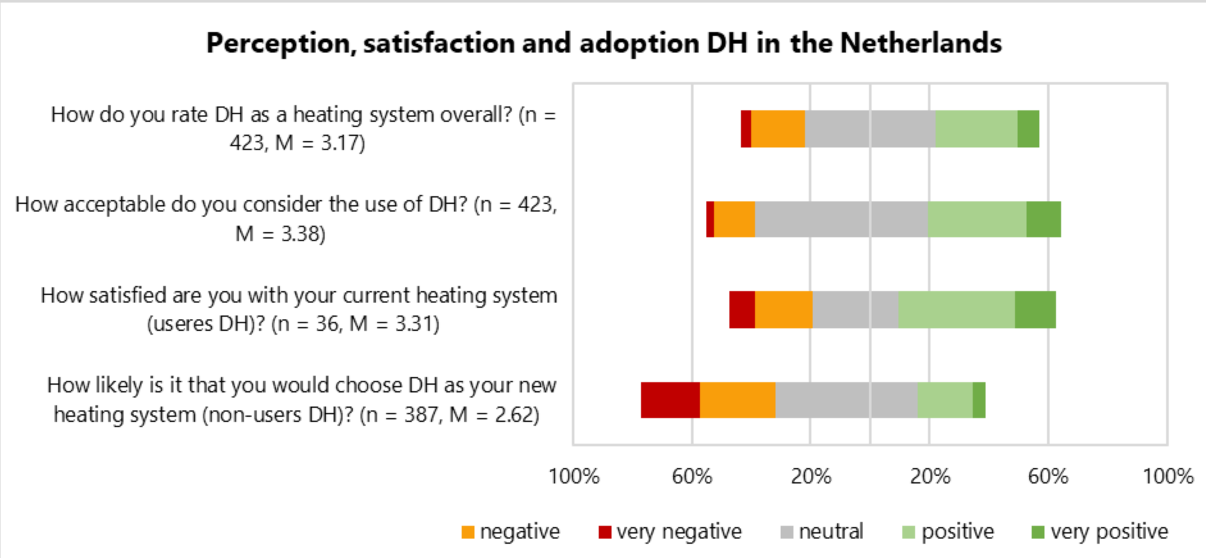


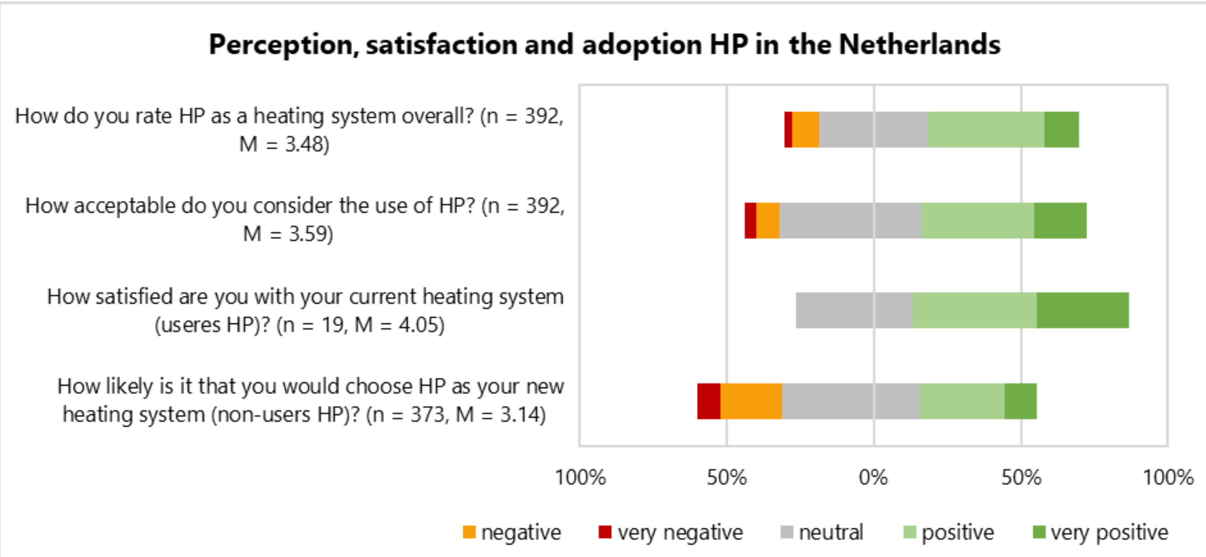
A.4.7 Netherlands

For the Netherlands, data were collected for DH (n = 423) and HP (n = 392).

Category	Country data	Sample DH	Sample HP
Socio-demographic characteristics			
Share of female	50%	53%	47%
Median age	43	52	56
Share tertiary education	52%	68%	66%
Size HH	2.1	2.2	2.1
Share home owners	69%	62%	61%
Heating characteristics			
Share DH (citizens served)	6%	9%	-
Share HP (market stock)	2%	-	5%
Share RES in DH	23%	-	-
Share RES in electricity	18%	-	-

Sources: Country data for 2019/2020 based on Eurostat, RES'Observer 2021, Bacquet et al. 2022



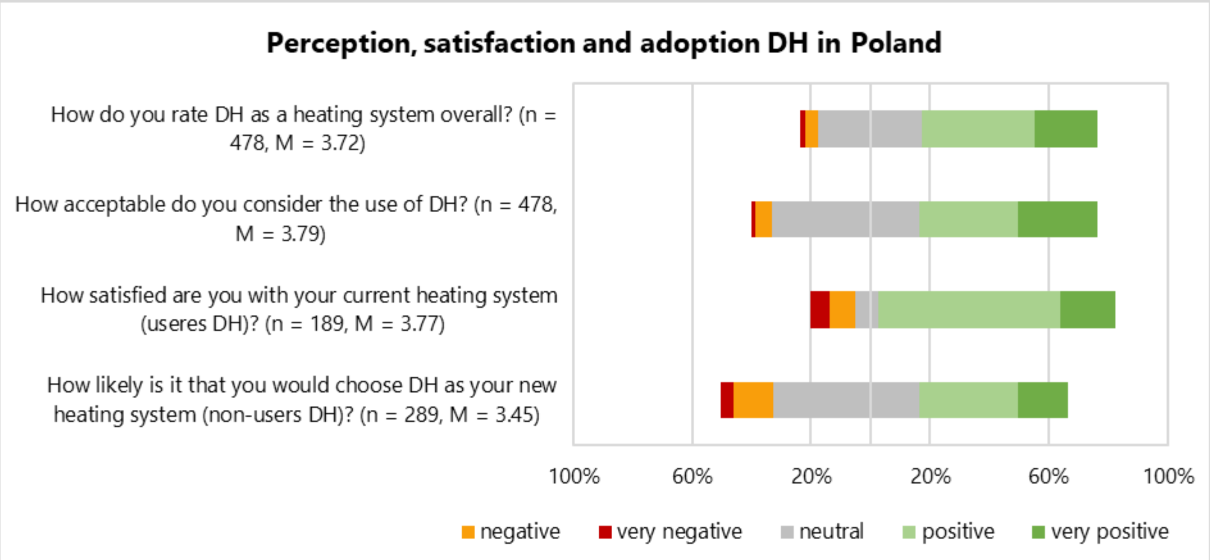


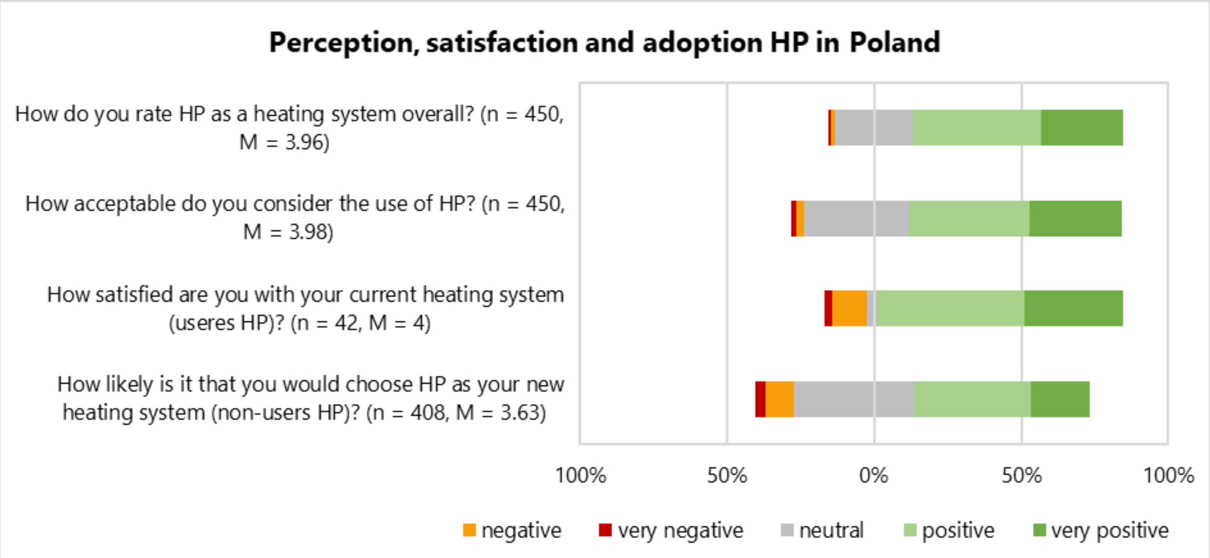
A.4.8 Poland

For Poland, data were collected for DH (n = 478) and HP (n = 450).

Category	Country data	Sample DH	Sample HP
Socio-demographic characteristics			
Share of female	52%	58%	55%
Median age	41	40	42
Share tertiary education	42%	55%	56%
Size HH	2.8	2.8	2.9
Share home owners	86%	83%	84%
Heating characteristics			
Share DH (citizens served)	43%	40%	-
Share HP (market stock)	1%	-	9%
Share RES in DH	9%	-	-
Share RES in electricity	14%	-	-

Sources: Country data for 2019/2020 based on Eurostat, RES'Observer 2021, Bacquet et al. 2022



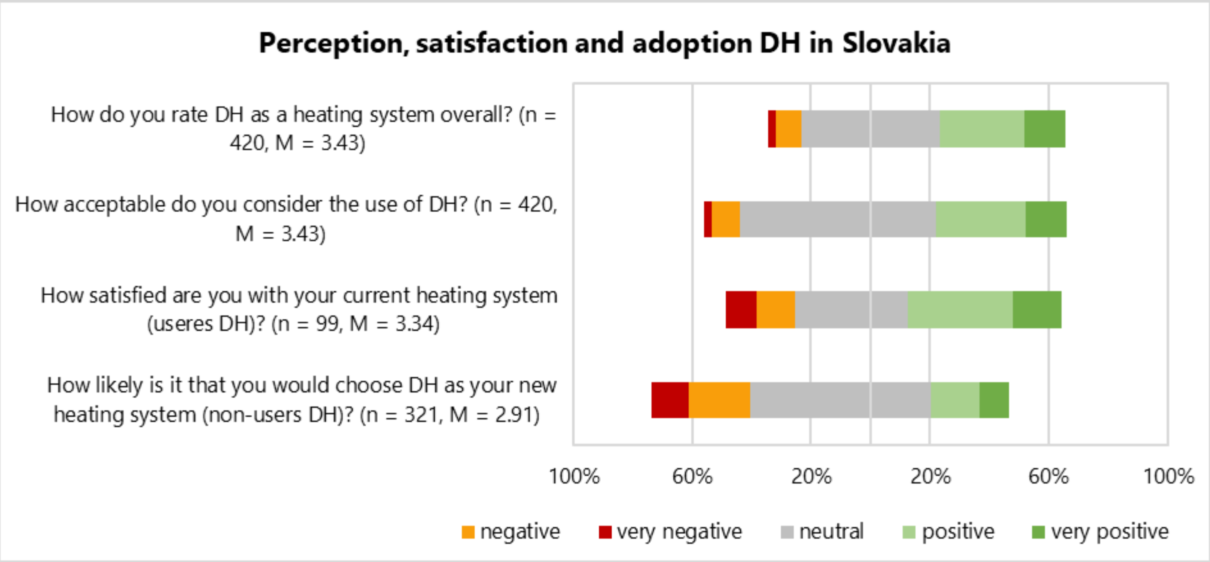


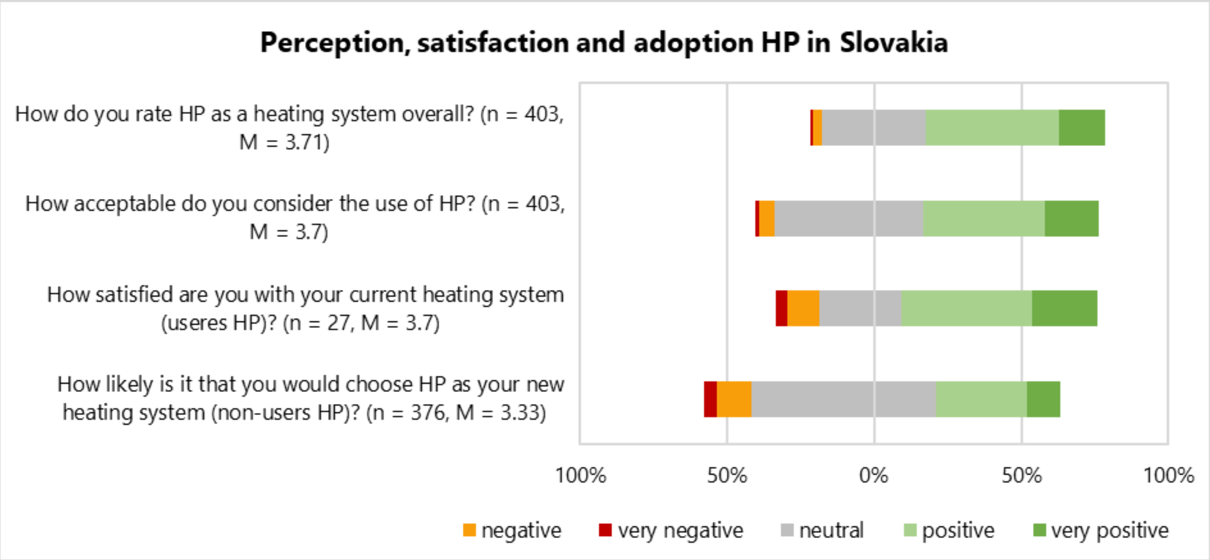
A.4.9 Slovakia

For Slovakia, data were collected for DH (n = 420) and HP (n = 403).

Category	Country data	Sample DH	Sample HP
Socio-demographic characteristics			
Share of female	51%	54%	53%
Median age	41	43	42
Share tertiary education	39%	36%	35%
Size HH	2.9	3.0	3.0
Share home owners	92%	89%	90%
Heating characteristics			
Share DH (citizens served)	34%	24%	-
Share HP (market stock)	1%	-	7%
Share RES in DH	9%	-	-
Share RES in electricity	14%	-	-

Sources: Country data for 2019/2020 based on Eurostat, RES'Observer 2021, Bacquet et al. 2022



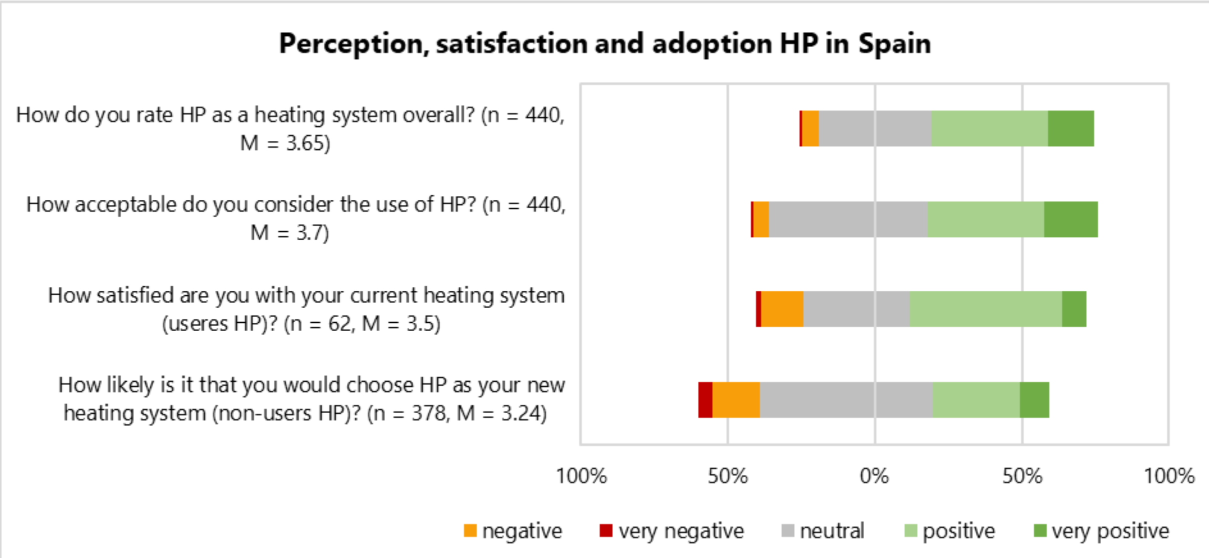


A.4.10 Spain

For Spain, data were collected for HP (n = 440).

Category	Country data	Sample HP
Socio-demographic characteristics		
Share of female	51%	45%
Median age	44	47
Share tertiary education	47%	66%
Size HH	2.5	2.6
Share home owners	75%	73%
Heating characteristics		
Share HP (market stock)	4%	14%
Share RES in electricity	37%	-

Sources: Country data for 2019/2020 based on Eurostat, RES'Observer 2021, Bacquet et al. 2022

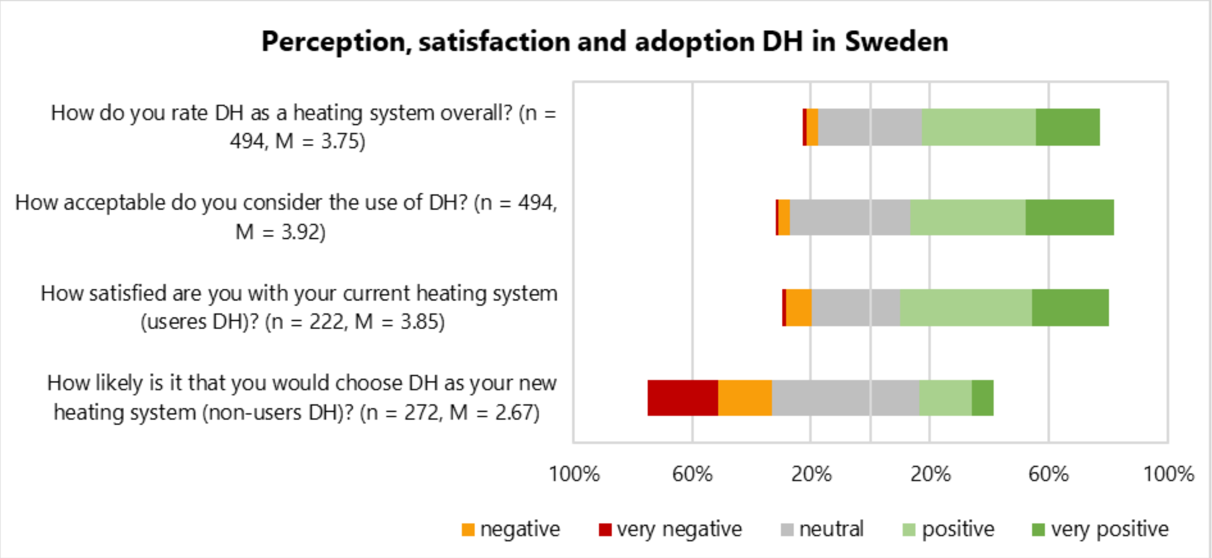


A.4.11 Sweden

For Sweden, data were collected for DH (n = 494).

Category	Country data	Sample DH
Socio-demographic characteristics		
Share of female	50%	52%
Median age	41	54
Share tertiary education	49%	56%
Size HH	2.0	2.0
Share home owners	65%	60%
Heating characteristics		
Share DH (citizens served)	50%	45%
Share RES in DH	58%	-

Sources: Country data for 2019/2020 based on Eurostat, RES'Observer 2021, Bacquet et al. 2022



A.5 Online survey in industry and the public sector

Welcome to our short online survey!

The survey will take you only **about 5 min**. It includes questions about your company's heating system as well as your perception of different heat technology options.

The survey is part of the project "Overview of Heating and Cooling: Perceptions, Markets and Regulatory Frameworks for Decarbonisation" performed for the European Commission. More information is available on the project website.

OVERVIEW OF HEATING AND COOLING
PERCEPTIONS, MARKETS AND REGULATORY FRAMEWORKS FOR DECARBONISATION

Thank you for your participation and support!

Please select your country:
[Selection from: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, United Kingdom, Iceland, Norway, Switzerland]

Please select your company's or your institution's activity / sector:

☐ Agriculture, forestry and fishing
☐ Mining and quarrying
☐ Manufacturing
☐ Construction
☐ Wholesale and retail trade or repair
☐ Social and health activities
☐ Education
☐ Leisure time
☐ Administration / public
☐ Other

Please specify your activities by naming a subcategory or subsector or briefly characterize the activity (e.g. textile manufacturing, building construction, hospital, swimming pool):
[Free text]

If available, please specify your annual heat consumption in MWh:

☐< 100 MWh
☐ 100 to 500 MWh
☐ 500 to 1 000 MWh
☐ 1 000 to 10 000 MWh
☐ 10 000 to 100 000 MWh
☐ 100 000 to 4 000 000 MWh
☐ > 4 000 000 MWh
☐ Not available

Please select your current heating system (multiple selection possible):

☐ Fossil fuel boiler
☐ Biomass boiler
☐ Solar thermal plant
☐ District heating

☐ Heat pump
☐ Combined heat and power plant
☐ Other [Free text]

With the following questions, we would like to know your view. There are no correct or incorrect responses - only your personal opinion matters. Please answer the following questions by choosing 'I agree' or 'I disagree' or an answer in-between.

The following technologies can be used for **climate-friendly** heat.

Fossil fuel boiler	I disagree	☐	☐	☐	☐	☐	☐	I agree
Biomass boiler	I disagree	☐	☐	☐	☐	☐	☐	I agree
Solar thermal plant	I disagree	☐	☐	☐	☐	☐	☐	I agree
District heating	I disagree	☐	☐	☐	☐	☐	☐	I agree
Heat pump	I disagree	☐	☐	☐	☐	☐	☐	I agree
Combined heat and power	I disagree	☐	☐	☐	☐	☐	☐	I agree

The following technologies can provide heat at **low costs** (i.e. levelised cost of heat).

Fossil fuel boiler	I disagree	☐	☐	☐	☐	☐	☐	I agree
Biomass boiler	I disagree	☐	☐	☐	☐	☐	☐	I agree
Solar thermal plant	I disagree	☐	☐	☐	☐	☐	☐	I agree
District heating	I disagree	☐	☐	☐	☐	☐	☐	I agree
Heat pump	I disagree	☐	☐	☐	☐	☐	☐	I agree
Combined heat and power	I disagree	☐	☐	☐	☐	☐	☐	I agree

The following technologies entail **low price risks** (regarding long-term price development).

Fossil fuel boiler	I disagree	☐	☐	☐	☐	☐	☐	I agree
Biomass boiler	I disagree	☐	☐	☐	☐	☐	☐	I agree
Solar thermal plant	I disagree	☐	☐	☐	☐	☐	☐	I agree
District heating	I disagree	☐	☐	☐	☐	☐	☐	I agree
Heat pump	I disagree	☐	☐	☐	☐	☐	☐	I agree
Combined heat and power	I disagree	☐	☐	☐	☐	☐	☐	I agree

The following technologies entail a **high reliability** (of supply, heat quality, temperature level, technical issues etc.).

Fossil fuel boiler	I disagree	☐	☐	☐	☐	☐	☐	I agree
Biomass boiler	I disagree	☐	☐	☐	☐	☐	☐	I agree
Solar thermal plant	I disagree	☐	☐	☐	☐	☐	☐	I agree
District heating	I disagree	☐	☐	☐	☐	☐	☐	I agree
Heat pump	I disagree	☐	☐	☐	☐	☐	☐	I agree
Combined heat and power	I disagree	☐	☐	☐	☐	☐	☐	I agree

The following technologies entail a **high dependency** on one energy supplier (regarding pricing, metering, billing etc.).

Fossil fuel boiler	I disagree	☐	☐	☐	☐	☐	☐	I agree
Biomass boiler	I disagree	☐	☐	☐	☐	☐	☐	I agree
Solar thermal plant	I disagree	☐	☐	☐	☐	☐	☐	I agree
District heating	I disagree	☐	☐	☐	☐	☐	☐	I agree
Heat pump	I disagree	☐	☐	☐	☐	☐	☐	I agree
Combined heat and power	I disagree	☐	☐	☐	☐	☐	☐	I agree

The following technologies require a **lot of information and efforts** to adopt (regarding technical and administrative issues).

Fossil fuel boiler	I disagree	☐	☐	☐	☐	☐	☐	I agree
Biomass boiler	I disagree	☐	☐	☐	☐	☐	☐	I agree
Solar thermal plant	I disagree	☐	☐	☐	☐	☐	☐	I agree
District heating	I disagree	☐	☐	☐	☐	☐	☐	I agree
Heat pump	I disagree	☐	☐	☐	☐	☐	☐	I agree
Combined heat and power	I disagree	☐	☐	☐	☐	☐	☐	I agree

Would you like to further exchange with us and have a short interview (approx. 20-30 min) about energy decisions? All input - from you and others - will be reported to the European Commission and might impact future policies. In addition, we will send you the final report of the project. If you are interested in an exchange, please provide your contact details:

Name:	[Free text]
Company/Institution:	[Free text]
E-Mail:	[Free text]
Phone:	[Free text]

A.6 Additional results of the survey in industry and the public sector

Table 10: General, total number of responses per country and per sector

Feature	#
Total number of responses	143
Geographical coverage	
Austria	14
Belgium	7
Czech Republic	1
Denmark	2
Estonia	1
Finland	2
France	2
Germany	67
Greece	2
Hungary	3
Ireland	1
Italy	4
Luxembourg	1
Netherlands	2
Slovakia	2
Slovenia	5
Spain	4
Sweden	7
United Kingdom	14
Norway	1
Switzerland	1
Sectoral coverage	
Agriculture, forestry and fishing	8
Wholesale and retail trade or repair	7
Manufacturing	68
Construction	8
Industries (total)	91
Education	10
Social health activities	5
Administration / public	9
Social services (total)	24
Other	28

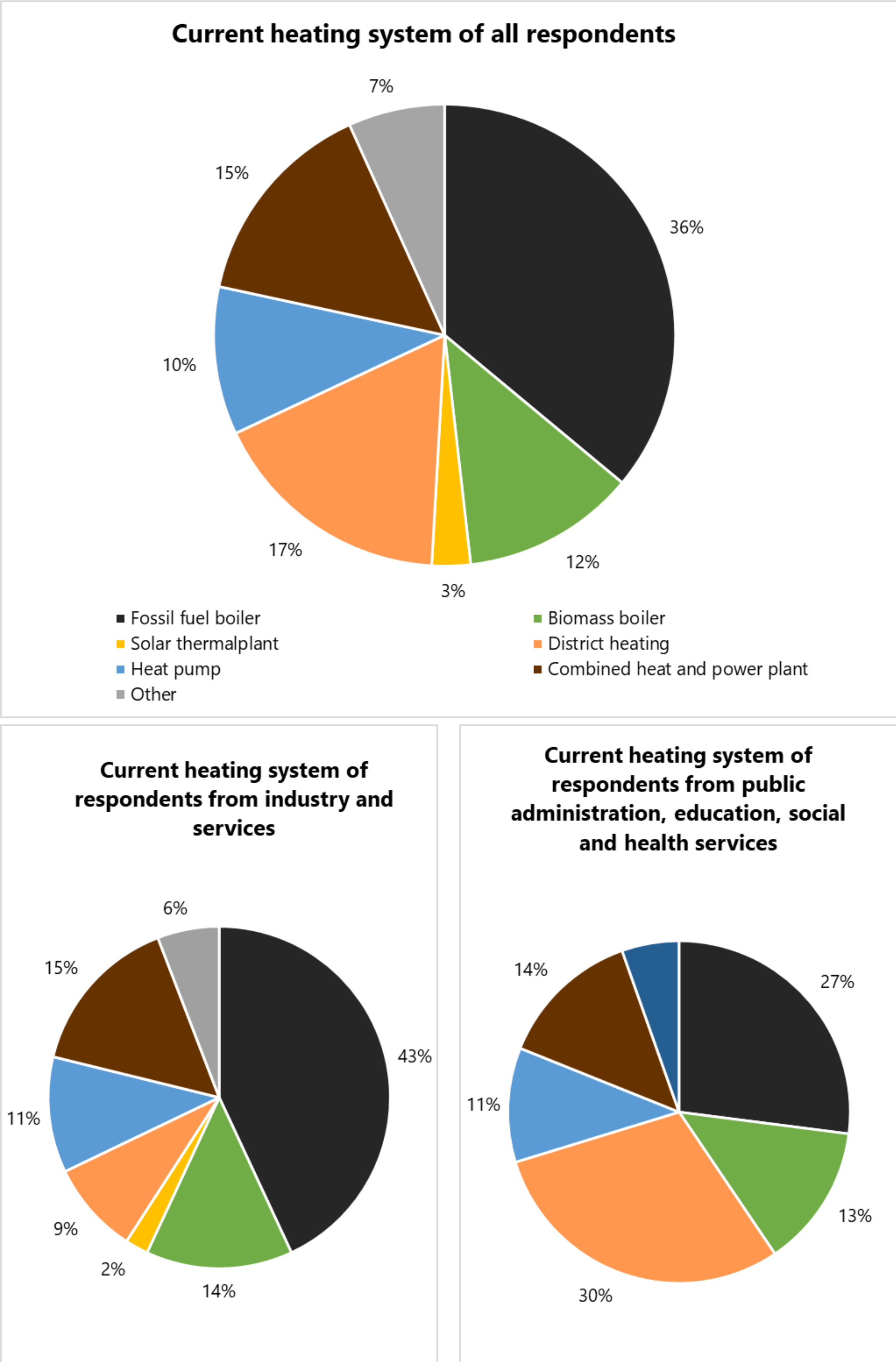


Figure 55: **Share of in-use heating systems of respondents and by sector (not representative)**

A.7 Interview guideline for the interview with representatives of industry and the public sector

Meta-data	ID Interviewee in online survey	
	Name interviewee	
	E-Mail interviewee	
	Company interviewee	
	Sector company interviewee	
	Heating system interviewee	
	Position of interviewee	
	Country interviewee	
	Date of interview	
	Interviewer ISI	
	Time of interview in min	
Organisational structure		
Decision making in organisations (all)	Who is responsible for decisions regarding your heating supply/system or technology?	One person
		Several levels
		Other or comment
	Who brings in new ideas and topics regarding energy services?	
	Other or comment	
	General notes or comments on decision making	
Governing factors (all)	Factors: Which 4 factors determine your decision for heating services the most? Profitability; investment costs; energy savings; perception of the organisation by potential customer, the public etc.; search for and commitment applying innovative solutions; climate/environmental concerns existing standards or regulations; commitment of the leader/responsible person; commitment of colleagues; expectations and values of society wrt RES and EE; other	
	Ranking: What is the most decisive factor?	
	General notes or comments on factors	
DH (only the ones who have DH)	How satisfied are you with your connection to the DH network?	
	Decision: Were there concerns and challenges when you chose DH?	
	Concerns or comments	
	Connection: Have there been any issues or challenges since your connection to DH?	
	Issues/challenges or comments	
HP (only the ones who have HP)	How satisfied are you with your HP?	
	Decision: Were there concerns and challenges when you choser HP?	
	Concerns or comments	
	Connection: Have there been any issues or challenges since you installed the HP?	
	Issues/challenges or comments	
General comments or notes from interviewer		

A.8 Semi-structured interview guideline for the in-depth interviews (case study)

Step 1: Position of the interviewee in the organisation and the decision process

1. Can you please introduce yourself briefly? What is your position in the organisation?
2. What is the heat supply currently on site?
3. How were decisions about investments in heat supply made? Were you involved in these decisions?

Step 2: Decision process within the organisation

4. What is your organisational structure within the company? (One person; leader/manager; separate person for energy decisions; committee, several levels etc.).
5. Who else is responsible for decisions on heat supply, who initiated this decision and who was involved?
6. Do you have a clear process before making energy decisions? What is your decision-making process regarding heat supplies?
7. Who brought the idea to you to take care of the district heating connection / the respective heat supply? How did you become aware of it? (Everyone in the organisation, responsible department/group, experts, media, public, city of Mannheim, etc.)

Step 3: Factors and challenges

8. What factors most determine your decision for a particular heat supply? What was the most dominant factor for you? (Profitability, investment costs, energy savings, perception of the organisation by potential customers or the public, climate and environmental conditions, existing standards and regulations, commitment of the manager, responsible person or colleague, society's expectations, and values regarding EE, looking for the use of innovative solutions).
9. What were the challenges in making the decision?

Step 4: Conclusion

10. Do you see an opportunity to do something for the environment/climate when connecting your company to the district heating system in Mannheim?
11. Are there any other topics regarding heating systems and your decision-making process that you would like to address? Do you have any further questions?

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