D3.2 - Customers' perspective on REWARDHeat solutions

Renewable and Waste Heat Recovery for Competitive District Heating and Cooling Networks

REWARDHeat

Project Title: Renewable and Waste Heat Recovery for Competitive District Heating and Cooling Networks

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1 Summary

In this deliverable, the customers' perspective on the REWARDHeat solutions is in focus. A survey was conducted with both professional customers and end-users in connection to the REWARDHeat demonstration sites in seven different countries (Denmark, Croatia, Germany, France, Italy, Sweden and Netherlands).

Customers comfort requirements, flexibility & temporality of the services, willingness to pay for green energy and other aspects for increased end-user engagement in the H&C solution have been addressed. The district heating addressed in the survey offers one or several of the following services: space heating, cooling and domestic hot water.

63 responses were collected, 25 from professional customers and 38 from end-users. Respondents think that temperature is the most important aspect of indoor climate. To 51% of respondents the most important indoor climate factor is indoor temperature and to another 25% an evenly distributed temperature is the most important. There is a flexibility in when the services in the district heating offer are more and less important during the day according to 84% of respondents. Only 16% of respondents consider all services to be equally important throughout the day. Domestic hot water is the service respondents are the least flexible about, hot water is considered to be equally important throughout the day according to 48% of respondents. There is further a flexibility in which rooms are more and less important to maintain a comfortable indoor climate. The most important rooms where a comfortable indoor climate must be maintained are the bathroom, dining room and living room. Less important rooms are the garage (71% of respondents answered that the room is less important) and the basement (65%), followed by the bedroom (41%). The next generation district energy solutions, such as the REWARDHeat solutions, have competitive advantages compared to other heating solutions in being able to match customers comfort requirements more closely. Increased control could for example enable different temperature levels in different rooms. Comparison of the customers comfort requirements with national legislation on indoor climate yields that all countries need improvement to avoid reducing the efficiency, health and comfort of occupants. Especially the customers' thermal comfort needs to be better guarded against high temperatures.

The cost of heating and cooling is important or very important to 89% of respondents and 94% want to be able to impact the cost. 81% of respondents perceive energy as a commodity and are prone to demand such pricing schemes. 75% of respondents prefer that someone else managed the maintenance of the H&C equipment. The main risk perceived by 32% of respondents towards increasing the level of servicification is a more expensive bill and foreseen benefits are increased comfort (17%) and a carefree contract (21%). 17% of respondents did not perceive any benefits and 27% did not know. Customers engagement in the energy solutions will require more information to create a pull from the market for increased servicification and for customers to develop towards becoming energy citizens. 56% of the respondents display a willingness to pay for a greener heat supply. 18% are willing to pay more than 6% more and 38% would be willing to pay a 1-5% higher price. For a more rapid energy transition, incentives for customers to actively choose green energy are needed.

2 Introduction

The REWARDHeat project demonstrates a new generation of low-temperature district heating and cooling networks (LTDHCN), able to recover low-grade renewable energy (RE) and waste heat (WH) available within the urban context. The REWARDHeat solutions are being piloted at eight demonstration sites around Europe where either third generation DHN are being retrofitted or new networks are being constructed.

This deliverable is part of work package 3 (WP3) of the REWARDHeat project. In WP3, the objective is to facilitate investments in DHC networks resorting to renewables and urban waste heat sources. This deliverable contributes to the WP3 objective by creating an understanding of comfort demands and requirements of the customers. It has a direct link to D3.4 (*Business models at REWARDHeat demonstrators*) where business models are drafted for the demonstrators and provides input to D3.1 (*REWARDHeat PESTLE* Analysis) where a PESTLE analysis is performed.

There is an ambition and potential in the EU to generate Energy Citizens that are actively engaged in making choices and impacting their energy demand and supply (Kampman, Blommerde, & Afman, 2016). However, most customers are still not involved, engaged or informed about energy and their usage thereof. One reason is that people's relationship with energy providers is the energy bill. Heating and cooling are present in the daily life as a comfort factor and people tend to only consider energy when it is not present, e.g. heat and cool are taken for granted just like light and sanitary water.

The focus in this deliverable is on the customers' perspective on the REWARDHeat solutions to understand customers comfort requirements, flexibility & temporality of heat demand, willingness to pay for green energy and other contractual desirables for increased end-user engagement in the H&C solution. If the customers can be engaged to care for their heating and cooling supply first steps are taken to facilitate the progression towards 2050 targets. The analysis assesses which comfort factors are more important to customers as well as if the comfort demand is flexible and has a temporality. Contractual desirables of customers are collected with special attention to customers attitude towards increased servicification and their willingness to pay for a greener H&C supply to increase end-user engagement. Findings in the survey are contrasted to the legal standards for buildings and indoor climate that exist in the countries of the REWARDHeat demo sites - namely: Denmark, Croatia, Germany, France, Italy, Sweden, Netherlands - and policy recommendations are derived.

A proximity to customers is achieved through a participative approach where customers in connection to the demo sites are respondents to the survey. The proximity to the solutions creates a living lab where customers experiencing the solutions are the providers of data. Results have been analysed on an aggregated level and on country-level (Annex: Country analysis).

2.1 Purpose & Research questions

The purpose of the deliverable is to understand the impact of comfort for end-users of heating and cooling. Data are collected by surveys to identify which factors of comfort are important for the customer. The temporality in energy demand, willingness to pay for green energy and impact from national legislations are explicitly addressed.

The deliverable is focused on the following research questions:

1. What comfort factors are most important for customers and are national requirements on indoor climate aligned?
2. Does the customers comfort demand reflect temporality?
3. How can customers be more engaged in the H&C solution?
4. Is there a willingness among customers to pay for a greener heat supply?

2.2 Indoor environmental quality (IEQ)

Indoor environmental quality (IEQ) focuses on the occupant's well-being and comfort. People spend approximately 80-90% of their time indoors and IEQ has a large impact on the well-being of people. Buildings are not one-sidedly determining the IEQ, the occupants have both an active and passive impact.

A building is a supportive structure meant to support and protect human activity at a reasonable cost for its occupants. Problems relating to IEQ have a negative impact on comfort, health and productivity of the occupants. Acute effects are immediate reactions that often go away quickly and arise due to chemicals leaking from building materials, mold spores or respiratory diseases due to moisture or inadequate ventilation. Long term exposure to chemicals and indoor air contaminants can cause long term disease such as cancer (United States Environmental Protection Agency, 2018). Other symptoms, commonly called sick building syndrome (SBS) include nose and eye irritations, eczema, headache, fatigue and lack of concentration (Šujanová, Rychtáriková, Sotto Mayor, & Hyder, 2019). Discomfort include aspects of being too hot, too cold or experiencing the air as dry or stuffy or a lack of air movement. Performance loss due to poor indoor quality can arise already from small variations in temperature and humidity and can be associated with ventilation or pollution sources in the building (United States Environmental Protection Agency, 2018).

Indoor environmental aspects are regulated in the building through heating, cooling and ventilation systems and can be designed and controlled in more or less advanced systems. Poor maintenance and incorrect control system of these aspects has been found to result in inadequate indoor climate (Koiv & Kalamees, 2011). Research shows that ideally aspects relating to IEQ needs to be considered already at the design phase of buildings (Al horr, o.a., 2016).

Factors generally included in IEQ are; thermal comfort, visual comfort, acoustic comfort and indoor air quality (Šujanová, Rychtáriková, Sotto Mayor, & Hyder, 2019). Other factors that could be influential for occupant's IEQ satisfaction are visual privacy, space and the ability to control the environment. Especially the absence or inefficiency of adjustments mechanisms drive discomfort and frustration (Šujanová, Rychtáriková, Sotto Mayor, & Hyder, 2019). The resident's opinion should be part of assessing the performance of a building, along with physical measurement, as otherwise the end-user perspective might not be well represented (Hellström, 2018) (Kim, Cho, & Kim, 2013).

The focus of research for IEQ has shifted during the past decennia as displayed in Figure 1. Around 2010 the focus was on health aspects, such as sick building syndrome and ventilation rates. The focus then shifted and around 2014 the focus was more on the energy perspective with topics such as energy efficiency and energy consumption. By 2016 the trend had shifted to control strategies and a focus on the occupant such as behaviour, comfort and productivity (Šujanová, Rychtáriková, Sotto Mayor, & Hyder, 2019). The development is most likely a reflection of ambitious climate targets for 2050 set by the European Commission. The climate goals are feasible from both a technological and economical perspective and it is important to include and manage the social perspective to ensure successful deployment. Lack of including the social perspective in planning of new technologies and measures can jeopardise the implementation and goal achievement. This means that the role of the user in the innovation process has moved from being an important but peripheral role to a key source of innovation.

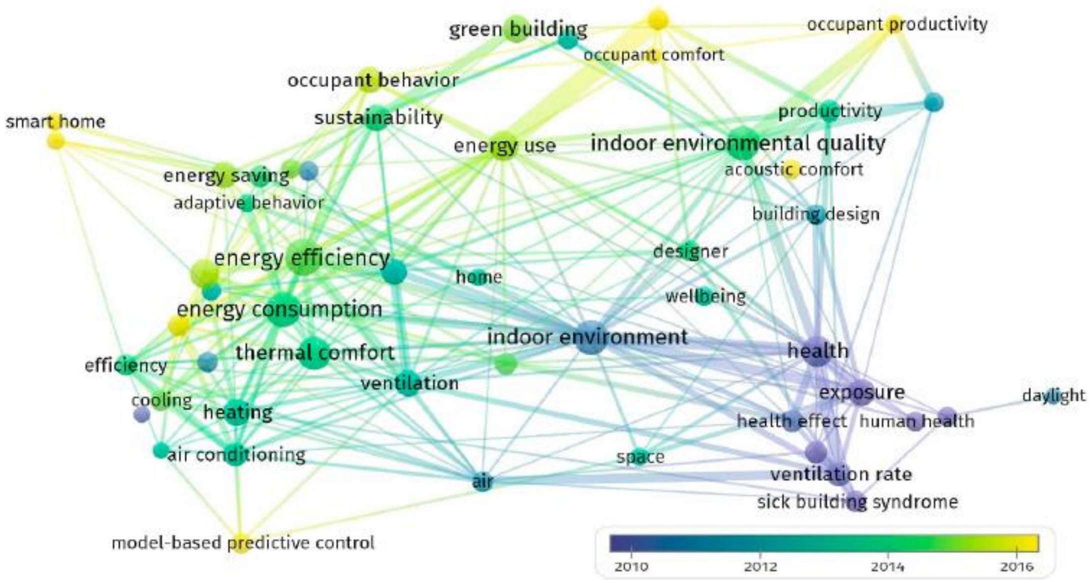

Figure 1: Trends in published search papers on IEQ from 2010-2016 (Šujanová, Rychtáriková, Sotto Mayor, & Hyder, 2019).

2.2.1 Thermal comfort

Thermal comfort is controlled by the H&C system. It is directly linked to the energy consumption and occupants will alter the temperature control system when they experience discomfort (Al horr, o.a., 2016). Thermal comfort has been defined as "the state of mind which expresses satisfaction with the thermal environment" (ISO 7730). Thermal comfort is typically described by the following six factors; air temperature, mean radiant temperature, air humidity, air velocity (environmental factors), activity and insulation through clothing (influence factors) (Guenther, 2019) (Šujanová, Rychtáriková, Sotto Mayor, & Hyder, 2019).

Two basic measures of thermal comfort are predicted mean vote (PMV) and predicted percentage of dissatisfied (PPD), developed by Povl Ole Fanger. PMV is an index related to the heat balance of a group of individuals on a seven-point thermal scale ranging from cold (-3), to neutral (0) and hot (+3). PMV can be used to predict the thermal comfort of a population given an environment and is calculated as a function of the six factors for thermal comfort. PPD represents the percentage of end-users that are likely to experience local discomfort and is calculated as a function based on the PMV value. Since thermal comfort is described through both environmental and personal factors it is difficult to define. Thermal comfort is experienced by an individual and is often described in terms of the occupant being "too hot" or "too cold" (Guenther, 2019).

Productivity of occupants has been found to be mostly affected by temperature, noise level and air quality. Keeping the temperature within a good range can increase performance of occupants, whereas too cold or too warm temperatures reduce productivity (Šujanová, Rychtáriková, Sotto Mayor, & Hyder, 2019). The correlation between physical measurements, such as CO_2-concentration and sound level, and occupants' productivity has been found to be weak. For thermal parameters in the PMV-value the correlation was found to be stronger, suggesting that the thermal factors are the most influential on occupants productivity (Hellström, 2018).

2.3 Demand profiles for heating and hot water

The typical demand profiles of heating and hot water from measurements in previously published literature can be used as a comparison with survey results on customers intraday temporality in the service demand to analyse if respondents' perceived demand is aligned with actual demand.

Demand of domestic hot water (DHW) typically has a very distinct profile in residential buildings with a morning peak between 06:00-09:00, which typically includes 10-20% of the daily demand, and an evening peak at 18:00-21:00, which typically includes 7.5% of the daily demand. During daytime the demand for DHW is low and almost no demand during the night (Fuentes, Arce, & Salom, 2018) (Wajahat Qazi & Flynn, 2012). In the weekend, the peak is slightly shifted to a later time and in winter demand increases compared to the summer (Fuentes, Arce, & Salom, 2018). Space heating typically has a more even demand profile throughout the day but as with DHW the demand has a morning and evening peak (Wajahat Qazi & Flynn, 2012).

Typical demand profiles for heating and hot water

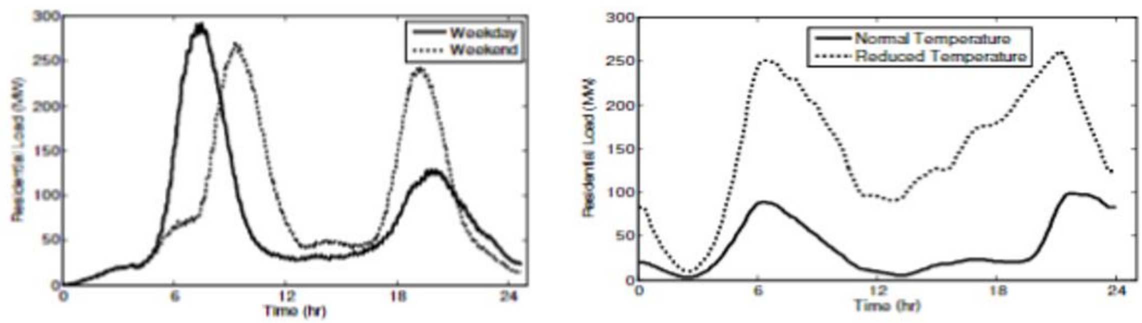

Figure 2: (Left) Demand for DHW- difference between weekday and weekend. (Right) Demand for space heating- difference between summer and winter (Wajahat Qazi & Flynn, 2012)

2.4 Willingness to pay for green energy

The willingness to pay (WTP) can be defined as the highest amount of money a consumer if willing to spend for a product or service (Maradin, Cerovic, & Olgić Draženović, 2016). A product or service that has a lower environmental impact than the conventional alternative can be associated with a green value that consumers might be WTP an additional cost to receive. The WTP for green has been the topics of many research projects. From an energy perspective green electricity seems to be the main topic of research (Maradin, Cerovic, & Olgić Draženović, 2016), (A. Andor, Frondel, & Sommer, 2018), (Bigerna & Polinori, 2014), (Zoric & Hrovatin, 2012), (Kowalska-Pyzalska, 2019), (Sundt & Rehdanz, 2015). Outside the energy context green buildings has received some attention

(Teotónio, Oliveira Cruz, Matos Silva, & Morais, 2020), (Wiencke, 2013), (Zalejska-Jonsson, 2014). The WTP for other green values have included products (Leszczyńska, 2015), such as cars (Costa, Montemurro, & Giuliani, 2019) and products in air travel (Hinnen, L. Hille, & Wittmer, 2015).

Most studies have collected data from respondents on an individual or household level and an interesting contrast is Wiencke (2013) that studied the WTP from a company perspective. Wiencke (2013) identified a 3-5% higher WTP for greener buildings and that the building sector, financial service industry and public sector have the highest WTP. Teotónio et al (2020) looked at WTP for green buildings as green roofs/walls and found a WTP of 2-3% on top of monthly rates, especially if the green roofs were accessible (Teotónio, Oliveira Cruz, Matos Silva, & Morais, 2020). A study in Sweden estimated a 5% WTP for low-energy buildings compared to conventional buildings (Zalejska-Jonsson, 2014). The WTP for green electricity was estimated at around 20% in Italy (mean values) (Bigerna & Polinori, 2014), 13% in Poland (Kowalska-Pyzalska, 2019) and 9% in Slovenia (Zoric & Hrovatin, 2012).

The most frequently occurring factor that drives WTP for green is the respondent's environmental attitude, also expressed as behaviour, concern and awareness. Demographic factors that are often found to drive WTP are a higher education level, a higher income level and younger age groups tend to have a higher WTP for green than older age groups. Gender is a more uncertain variable, one study found that men had a higher WTP, another found that women had a higher WTP and two studies could not identify a significant difference between genders. Knowledge about the technology (product, service) and its benefits was identified as a driver in several studies, but some studies found that it was not important. Social image, or "what other people think", was found be an important driver in two of the studies.

Table 1: Summary of factors that have been found in literature to drive the willingness to pay. '+' indicates that the factor was identified as a driver for WTP and '0' indicates that a significant connection between the factor and the WTP could not be distinguished.

Reference	Category	Environmental	Knowledge	Education level	Income level	Age	Gender	Social image	Altruistic behaviour	Fairness of cost
(Maradin, Cerovic, & Olgić Draženović, 2016)	Green electricity	+	0	+	+	+			+	
(A. Andor, Frondel, & Sommer, 2018)	Green electricity									+
(Bigerna & Polinori, 2014)	Green electricity			+	+	+	M			
(Zoric & Hrovatin, 2012)	Green electricity	+		+	+	+	W			
(Kowalska-Pyzalska, 2019)	Green electricity	+	+	+	+	+		+		
(Wiencke, 2013)	Green buildings	+								
(Teotónio, Oliveira Cruz, Matos Silva, & Morais, 2020)	Green buildings	+	+	+	+		0			
(Zalejska-Jonsson, 2014)	Green buildings	+	+			+				
(Costa, Montemurro, & Giuliani, 2019)	Green products	0	0							
(Leszczyńska, 2015)	Green products	+	+					+	+	
(Hinnen, L. Hille, & Wittmer, 2015)	Green products			0	0	0	0			

The European Energy Certificate System (EECS) defines certificates of a unit of energy defined by the source of energy and production method, the Guarantees of Origin (GO). The certificates can transfer ownership until cancellation and provides proof of the origin of energy. The certificates can be used to enable consumer choice as the customer through buying certificates are guaranteed the origin of the unit of energy (Association of Issuing Bodies, u.d.). Figure 3 displays the volume of recorded cancellations for the participating European countries. Countries were certifications have been cancelled means that customers in that country has paid for the certificate of origin for energy. As can be seen renewable energy consists of most of the cancelled certificates (green), some cancelled certificates are for nuclear energy (pink) and some for fossil fuels (grey). This data can be used as an approximation for the actual WTP for green energy in the respective countries. In surveys typically only the stated or theoretical WTP for green is explored. Some countries with a high absolute volume of cancelled certificates are Germany, Great Britain, Span and Sweden whereas Cyprus, Latvia, Malta, Portugal, Romania and Slovakia have a volume of zero (Figure 3). When considering population size the countries with the largest share of cancelled certificates per inhabitant are Sweden, Island, Austria and Norway (Figure 4). It should be noted that some countries have policies affecting the number of cancelled GOs. For example, all electricity in Austria must have GO, in Germany and England GOs are connected to financial support and sometimes in Sweden the GOs are included for free.

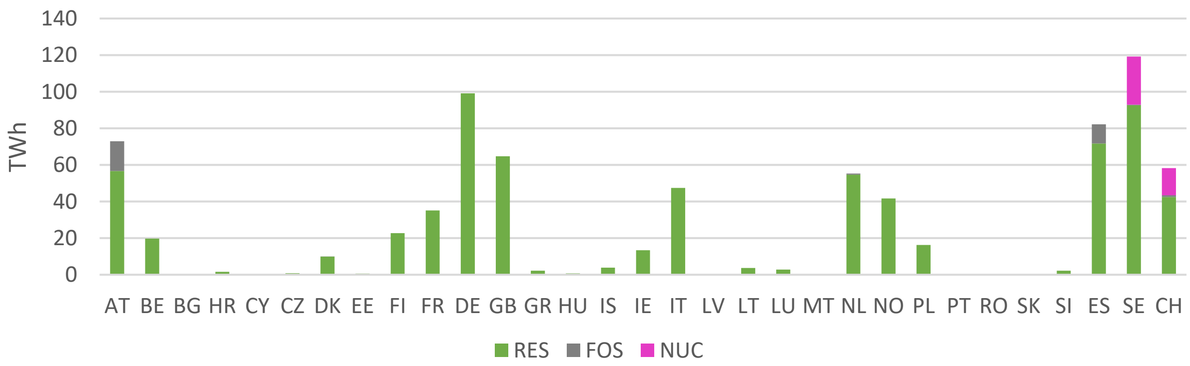

Figure 3: Recorded cancellations of EECS and National GOs in 2018 [TWh] (Association of issuing bodies (AIB), 2019)

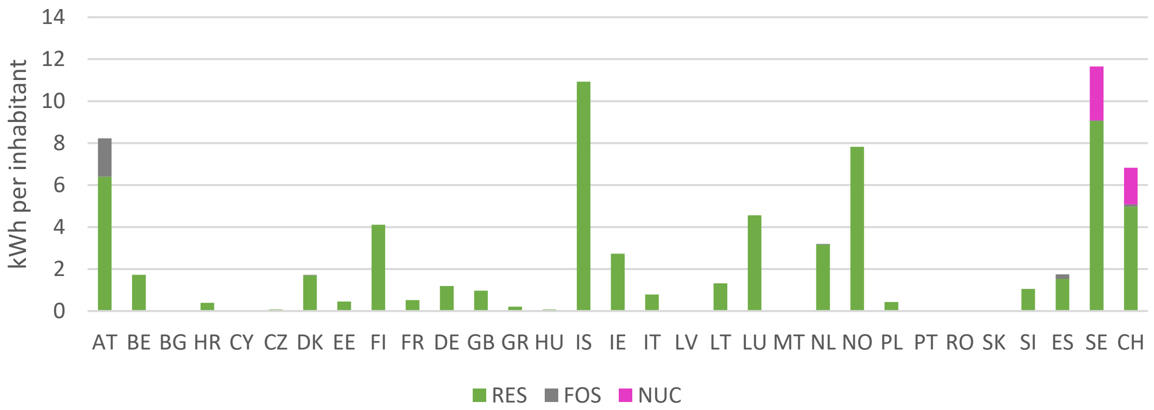

Figure 4: Recorded cancellations of EECS and National GOs in 2018 [kWh/inhabitant] (Association of issuing bodies (AIB), 2019), (Eurostat, 2019).

3 Methodology

3.1 Structure of survey

The survey was structured around four different topics in order to collect the required input for both this deliverable and deliverable 3.1 *REWARDHeat PESTLE analysis:* social acceptance, aspects of comfort and aspects for increased engagement in the H&C solution and respondent profile.

Table 2: An overview of the structure of the survey

Part of the survey	*Aim*	*Themes approached*	*Number of Questions*
Social acceptance	Identify personal perceptions about the technologies	Opinion of DHN, awareness of technology, environmental consideration, perceived risks and benefits, cost expectancy	19
Aspects of comfort	Comfort requirements of customers	Indoor climate, flexibility and temporality of comfort aspects	13
Aspects for increased engagement in the H&C solution	Identify how customers can become more engaged	Interest in servicification, aspects of cost and value of green	10
Respondent profile	Identify and characterize the customer groups	Customer group, building, supplied by DH today	4

The questions in the survey were derived based on existing literature and were tested internally in REWARDHeat, on the other partners involved in WP3 and on the demo site partners, before the survey was finalized. The main feedback provided was the necessity to translate the questionnaire to the local language of each demo site and to add more explanations on the terminology used as customers are often unfamiliar. For example, to explain more about the REWARDHeat project, low temperature district heating networks and waste heat. Other feedback was that the survey was too long, too difficult and that all questions were not relevant for both professional and private customers. Improvements were made according to the feedback but there is still a possibility that respondents thought that the survey was long, difficult or at times irrelevant which could explain the non-response from some customers that were asked to participate. The questionnaire was set-up by a variety of multi-choice boxes, four-point Likert scale and open questions.

The social acceptance section is included to provide input to the social aspect of D3.1 *REWARDHeat PESTLE analysis* and assesses topics related to social acceptance. Aspects of comfort assess the respondent's attitude towards various indoor climate factors, such as temperature, and if the comfort demand has a temporality and flexibility. The customers comfort demand is contrasted to the legal requirements on indoor climate in the respective countries. Aspects for increased end user engagement in the H&C solution are included to understand how engagement for energy can be established. The respondent profile is related to the category of customer that the respondent belongs to, where two categories are distinguished; professional customer and resident/end-user. The former is defined as the customer that signs the contract with the DH company for example a building owner or building operator. The latter is defined as people experiencing the service provided by the DH. Other questions related to the respondent profile concern what type of building the respondent has or lives in and if the building is already connected to a DHN.

3.2 Survey questions

The questions in the survey are listed below and the full survey is available in Annex: Survey.

- Are you a building owner or resident?
- What kind of building do you live in/own?
- How well do you know how a district heating and/or cooling system works?
- Is your home/your building connected to a district heating and/or cooling system today?
  - If yes, what services do you receive from the district heating and/or cooling system?
  - If no, how is your heating and/or cooling and hot water supplied today?
- What is your general opinion of district heating and/or cooling systems?
- Are district heating and/or cooling systems common in your country?
- How much of the fuel mix in your country's district heating and/or cooling system is fossil fuels?
- District heating and/or district cooling is a convenient option for space heating and/or cooling and hot water.
- District heating and district cooling is a resource efficient option for space heating and/or cooling and hot water.
- District heating and district cooling is a cost-efficient option.
- Do you consider your local district heating and/or cooling supplier to be transparent (fair/honest)?
- Have you heard about low temperature district heating and/or cooling systems*?
- Have you heard about the low temperature district heating project (REWARDHeat project) in your local community?
  - If yes, where from?
- What benefits do you believe comes from having a low temperature district heating and/or cooling system?
- What risks do you perceive from having a low temperature district heating and/or cooling network?
- Compared to a conventional district heating system, how do you think the energy bill of district heating/cooling will be affected by having a low temperature system?
- Do you know of any district heating and/or cooling systems with excess heat* recovery and/or renewable energy sources (e.g. solar energy, geothermal energy?
- What benefits do you believe come from including excess heat and/or renewable energy sources in the district heating and/or cooling system?
- What risks do you perceive from including excess heat and/or renewable energy source in the district heating and/or cooling system?
- How do you think the energy bill of district heating and/or cooling will be affected if excess heat and/or renewable energy is included in the district heating system?
- How important is the cost of heating and/or cooling to you?
- Would you like to receive space heating and/or cooling as a comfort service agreement or as a commodity?
- How desirable would it be for you to pay a fixed cost to receive a specified indoor climate?
- Do you want to be able to impact your heating and/or cooling cost)?

- Do you want to manage the maintenance of technical equipment for heating and/or cooling yourself or not?
- Do you have the option to receive heating and/or cooling as a comfort service agreement today?
- What benefits do you foresee with a comfort service agreement?
- What risks do you foresee with a comfort service agreement?
- How concerned are you about the impacts of climate change?
- Are you considering climate change impact when you use energy for heating and/or cooling?
- Do you believe that the forecasted effects of climate change are uncertain?
- Do you believe that including excess heat and renewable energy sources in district heating and/or cooling systems is beneficial for the environment?
- Would you pay more for a greener (less GHG) heating and/or cooling system?
- What would be the driving motivation for you to reduce your energy use?
- What factor related to indoor climate is the most important to you?
- What do you consider to be a comfortable indoor temperature (°C)?
- How much deviation from your preferred indoor temperature would you accept?
- Are there any indoor rooms that you consider to be LESS important with regards to indoor climate?
- How important is having an evenly distributed temperature in all living spaces to you?
- How important is security of supply of heating and/or cooling to you (the constant availability of heating/cooling and hot water)?
- How important is the floor temperature to you?
- How important is the indoor quality of air to you?
- How important is it for you to avoid drafts?
- How important is it for you to avoid noise from heating and/or cooling equipment?
- Is SPACE HEATING more important to you during some parts of the day?
- Is SPACE COOLING more important to you during some parts of the day?
- Is HOT WATER more important to you during some parts of the day?
- In relation to heating, cooling and hot water systems, are there any other factors or considerations that are especially important to you?

3.3 Distribution of survey and response rate

The survey was set up in "Google forms" and translated to the local language of each demonstration site by partners in the respective countries. Prior to answering the survey information was provided to respondents on the processing of personal data in relation to the survey and informed consent. Respondents could only access the survey by consenting to the information provided and the informed consent allowed respondents to withdraw the participation at any point during the stated response period. The survey was distributed by the respective partners connected to each demonstration site, to customers with a close relationship to the REWARDHeat demo sites creating an open climate for knowledge generation, an "open lab".

The goal was to collect 80 responses for the survey, 10 responses per demo site, and the demo site partners were instructed to select 5 respondents that are professional customers and 5 end users. This goal could not be fully met at the time of the redaction of this deliverable. The number of responses collected per customer group and demo site can be seen in Table 3. The main reason for not achieving 80 responses is that one demo site was undergoing replacement at the time of constructing this deliverable, resulting in 10 respondents less being available for the survey. The professional customers have the largest deviation from targeted responses. This is both due to less professional customers being available in connection to the demo sites and an unwillingness to respond to the survey. This results in professional customers being less represented in the data. For those demos were the target was not achieved an explanation is provided under the respective sections below. Responses were collected during spring and summer 2020 and in total 63 responses were collected, 25 from professional customers and 38 from end-users.

Measures taken to reduce the non-response rate included:

1) Prior distribution to partners in REWARDHeat for feedback (as explained in 3.1),

2) Informed consent and GDPR procedure included and accepted before respondent started answering the survey,

3) Survey was distributed by the local partner,

4) Multiple reminders were sent to the selected respondents.

Table 3: Overview of responses collected

Country	Demo site	Professional customer	End users	Collection method
Denmark	Albertslund	3	5	Email
Croatia	Topusko	5	5	Door-to-door
Germany	Wärme Hamburg	4	4	Email
Germany	-	0	0	-
France	La Seyne-sur-Mer	1	5	Email
Italy	Milan	7	5	Email
Sweden	Mölndal & Helsingborg	2	5	Email
Netherlands	Mijnwater	3	9	Email
Total		25	38	

3.3.1 Denmark- Albertslund

8 responses were collected, 5 end-users and 3 professional customers. Despite multiple reminders it was not possible to reach the goal of 5 professional customers as the requested customers were unwilling to respond due to unknown reasons. The respondents were all connected to the DHN today. In Denmark responses were collected by distributing the survey via email to customers connected to the REWARDHeat demonstration site.

3.3.2 Croatia- Topusko

In Croatia responses for the survey were collected by going door-to-door with customers connected to the REWARDHeat demonstration site. 10 responses were collected, 5 end-users and 5 professional customers. The respondents were all connected to the DHN today.

3.3.3 Germany- Wärme Hamburg

8 responses were collected, four end-users and four professional customers. Five of the respondents are connected to DHN today, one did not know and two were supplied with natural gas. Responses for the survey in Germany were collected by distributing the survey via email. Because the demo site in Hamburg is still under construction there are no end-users connected to the demo site and instead an approximation for customers was made by considering that some of the building will be social housing and the rest more expensive apartments. Four end-users were deemed enough to represent the variety of potential customers. The professional customers were difficult to engage due to unknown reasons.

3.3.4 Germany – To be decided

At the time of constructing this deliverable there was on-going replacement activity for the second German demo site. Hence causing an unforeseen loss of 10 respondents toward the goal of 80 responses.

3.3.5 France- La Seyne-sur-Mer

From the French demo site, 6 responses were collected via email distribution of the survey. 5 responses from end-users and 1 professional customer. Only four professional customers are available in the demo, all were asked to participate but three opted out due to unknown reasons. Since only one professional customer has responded to the survey the results for professional customers are omitted from the country analysis as it might expose the professional customer. Hence all results, tables and figures in the French result section only includes the responses provided by end-users. 3 of the end-users were connected to a DHC network today and received space heating and cooling as a service. The other end-users had a heat pump as well as an electric boiler for hot water, one of them (living in a house) had a biomass boiler additionally.

3.3.6 Italy- Milan

7 professional customers responded to the survey and five end-users. In Italy responses were collected by distributing the survey via email to selected respondents. The professional customers are foreseen to be connected to the REWARDHeat solution but for the end-user category no respondents were available as the apartment buildings do not have any residents. Therefore, an approximation of respondents was made under the assumption that the residential buildings that will be connected to the REWARDHeat demonstration sites are social housing. Respondents for the end-user category was selected as residents of social housing in Italian cities were DHNs are present. Five of the professional customers were connected to a DHN as well as three of the end-users. Those who were not connected to a DHN had gas as supply source.

3.3.7 Sweden- Mölndal & Helsingborg

2 professional customers and 5 end-users responded to the survey. In the Swedish demo only 2 professional customers were available. In Sweden responses were collected by distributing the survey via email to selected respondents. The professional customers are foreseen to be connected to the REWARDHeat solution, as well as one of the private customers. For the remaining end-users it was not possible to reach customers foreseen to be connected to the demo site and hence an approximation was made that the future end-users would be mainly families and students and four additional persons were asked to respond to the survey. The professional

customers, and one private customer, were connected to DH today. One had a ground-source heat pump and the remaining did not know.

3.3.8 Netherlands- Mijnwater

9 end-users, all in apartment buildings, and 3 professional customers, mix of apartment building, separate house and commercial buildings, replied to the survey. Despite multiple reminders it was not possible to reach the goal of 5 professional customers as the requested customers were unwilling to respond due to unknown reasons. Responses for the Netherlands were collected via distributing the survey online to customers connected to, or foreseen to be connected to, the demo site. All but one professional customer was connected to a DHN and received space heating, space cooling and hot water. The only customer not connected used gas for heating and electricity for cooling.

3.4 Method for analysing new evidence

The first step in processing the data was to translate all responses to English through an automatic translation service. Excel was used to aggregate and visualise data, both on country-level and aggregated for all respondents. Analysis of collected data in EU-projects are often presented as frequencies, percentage of people that share an opinion (e.g. CITyFiED and REMOURBAN). On country-level the data are sometimes displayed for end-users and professional customers respectively. Where data on country-level are displayed for all respondents the resulting values were adjusted so that the professional and private customer perspective have equal weight in the scoring.

The willingness to pay for green was further analysed in an analysis of variance (ANOVA) in R (The R Foundation, u.d.). R is a programming language and free software environment for statistical computing and graphics widely used among statisticians for performing data analysis. ANOVA looks for statistically significant differences between groups in the dataset by comparing the mean value. It was applied in this deliverable to compare the WTP between surveyed countries, among different customer groups, among different levels of technology awareness and among different levels of environmental awareness. These groups were selected to be used in the comparison based on the literature review of factors that drive WTP in section 2.4. Performing the ANOVA test by comparing different groups on a single variable is called a one-way ANOVA test. The null hypothesis in ANOVA is that all group means are equal and if the null hypothesis cannot be rejected then there is no statistically significant difference between the groups with regards to the tested statement. The null hypothesis can be rejected if the p-value, the probability of obtaining the results if the null hypothesis is correct, is below 0.05. For more information about the ANOVA test (Sigma Plus Statistiek, 2020) and its applications in R (RDocumentation, u.d.).

Prior to the ANOVA test some of the data needed to be processed. The WTP for green was adjusted to numerical categories ranging from -1 (Customers who want to pay less) to 4 (Customers willing to pay more than 10% more). As previous literature identified technology awareness and environmental awareness as factors that drive WTP for green, two indexes were developed for each respondent: technology awareness index and environmental awareness index. The technology awareness index was developed by averaging the respondents scores to the following four questions. “How well do you know how a DH/C system works?”, “Are DH/C systems common in your country?”, “Have you heard about LTDH/C systems?”, “Do you know of any DH/C with WH and/or RES?”. The environmental index was developed by averaging the respondents scores to the following four questions, 1) “How concerned are you about the impacts of climate change?”, 2) “Are you considering climate change impact when you use energy for H/C?”, 3) “Do you believe that the forecasted effects of climate change are uncertain?”, 4) “Do you believe that including WH and RES in DH/C beneficial for the environment?”. Using a different combination of questions, or different questions, when developing the indexes could yield a different outcome. The indexes were then categories into four groups prior to analysis; Very low, low, moderate and high.

4 Results

4.1 Comfort demand

4.1.1 Factors impacting comfort

When comparing a fixed set of indoor climate aspect, 51% of respondents consider having a comfortable indoor temperature to be the most important aspect. In addition, 25% consider having an evenly distributed temperature in all living spaces to be the most important aspect. This shows that temperature is a very important aspect to customers as illustrated in Figure 5.

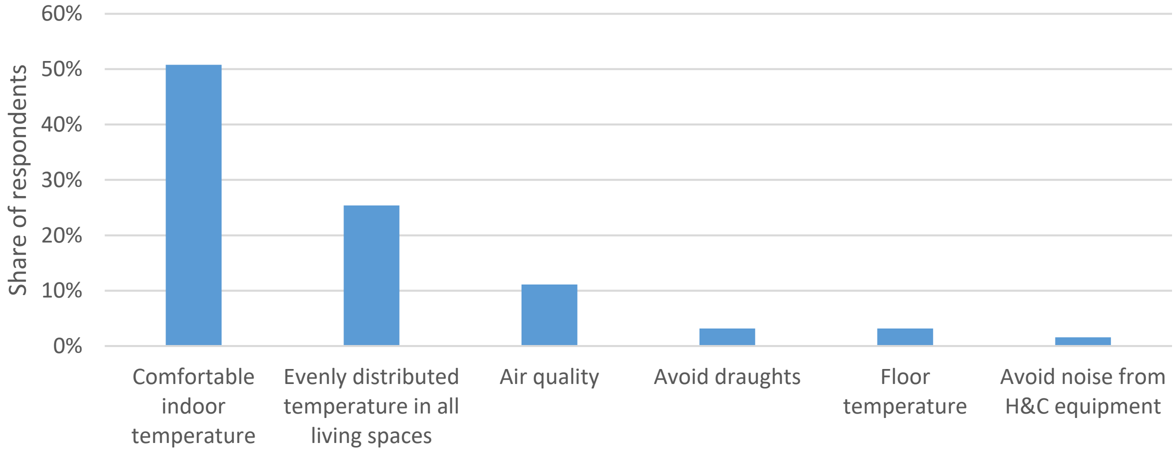

Figure 5: Most important indoor climate aspects when comparing the factors against each other.

When rating the factors individually, displayed in Figure 6, air quality, avoiding draught and avoiding noise from H&C equipment are considered to be very important. Floor temperature and having an evenly distributed temperature are still rated as important, but to a lesser degree.

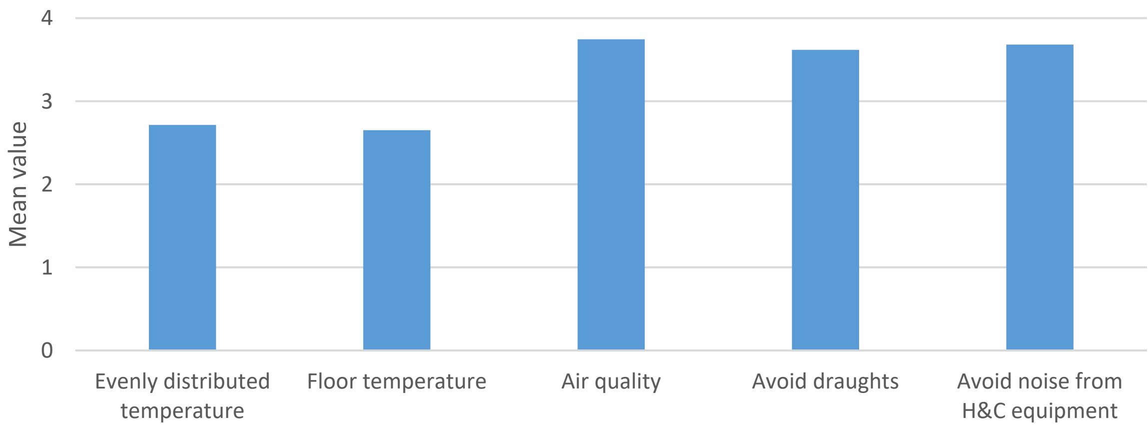

Figure 6: Importance of various indoor climate aspects when rated individually. The scale on the y-axis goes from (1) - not important to (4) - very important.

4.1.2 Temporality and flexibility

The flexibility in indoor climate depending on room was examined by asking the respondents which rooms they considered as less important to maintain a comfortable indoor climate. The garage and basement are the least important rooms with 71% and 65% of respondents respectively stating that the room is less important. 41% of the respondents think that the bedroom is less important and 10% think that the kitchen is less important. Leaving the dining room, bathroom and living room as the most important rooms where a good indoor climate must be ensured. 19% of respondents show no flexibility and think that all rooms are equally important.

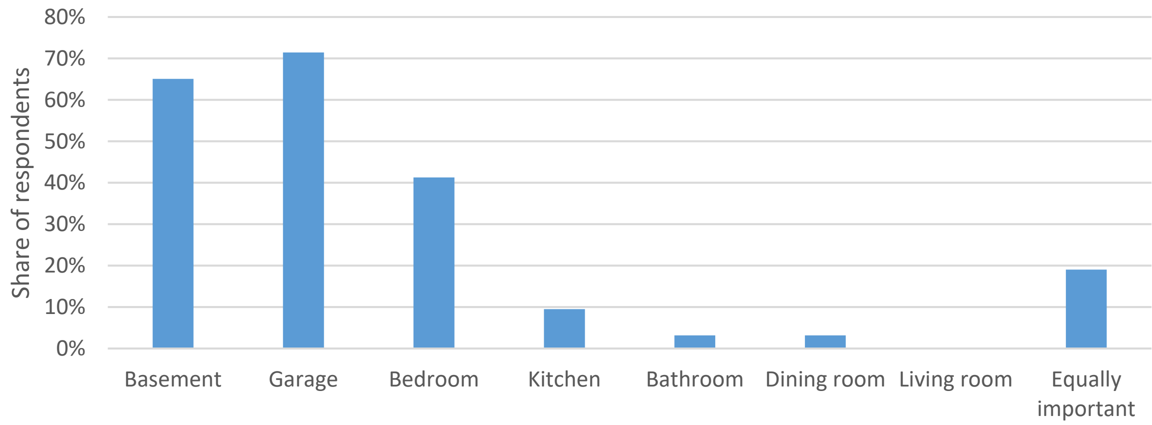

Figure 7: Share of respondents that consider a specific room to be less important with regards to comfortable indoor climate. The results display the flexibility in indoor climate depending on room. Respondents could choose multiple rooms.

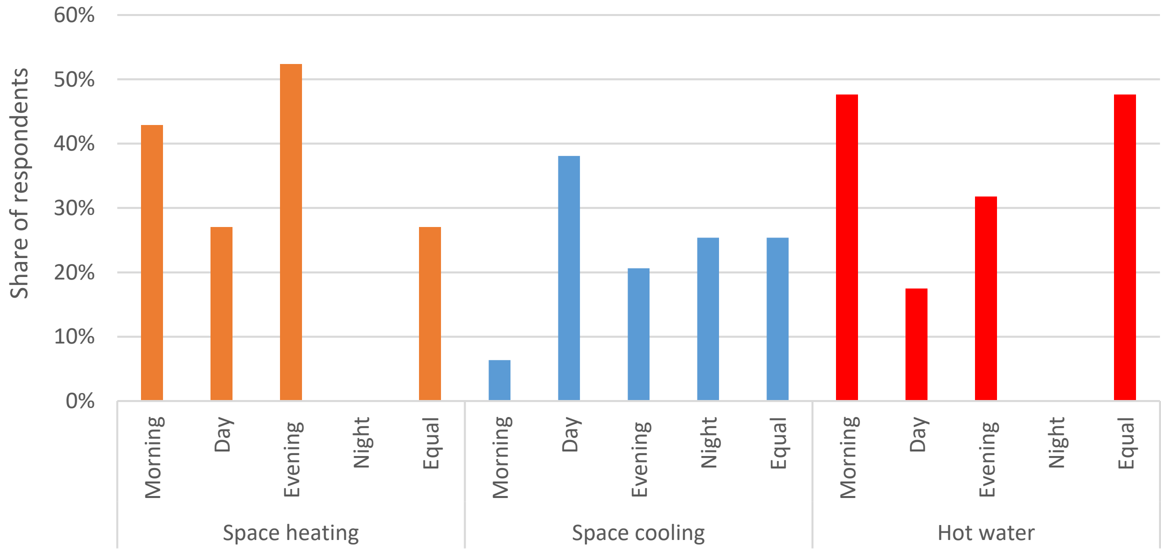

Figure 8: Temporality in service demand (intraday). Respondents could choose multiple times during the day, or that the service is equally important throughout the day.

DHW is the service that most respondents think is equally important throughout the day (48%) and hence the service where respondents show the least flexibility. DHW is especially important in the morning and less so during night-time. Space heating is most important during the evening and the morning, again less important during the night. Space cooling is most important during the day and compared to SH and DHW, space cooling is also very important during the night (Figure 8).

Comparing the customer perception of when a service is more important to the demand profiles for that service (section 2.3) can indicate if customers stated temporality matches their demand. DHW demand in residential buildings have a high peak in the morning, less demand during the day, a lower peak in the evening and basically no demand during night. For a large share of respondents, their stated temporality matches the demand profile but those that think the service is equally important throughout the day, even though there is hardly any demand during the night, indicates an unwillingness to be flexible with the service. For space heating customers the customers stated importance of space heating matches the demand profile with a morning and evening peak.

4.2 Aspects for increased end user engagement in energy

4.2.1 User engagement

89% of respondents thinks that the cost of H&C is very important or important (Figure 9) and 94% would like to be able to impact the cost (for example through incitement-based pricing/motivational tariffs).

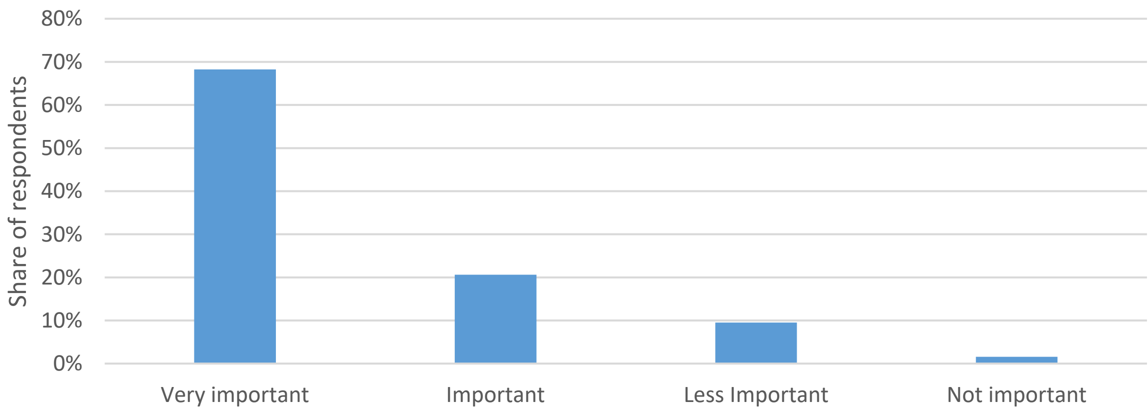

Figure 9: Respondents thinks that the cost of H&C is very important or important.

75% of respondents want someone else to manage the maintenance of their H&C equipment and 25% prefer to manage it themselves. 81% of respondents want to pay per unit energy delivered for their H&C supply (commodity) and 19% would like to receive H&C as a service.

Respondents were asked to state their perceived benefits and risks of having a comfort service agreement (high level of servicification). Customers answered to this question in an open text response and could state as many or few benefits/risks as they wanted. The main identified benefits were a convenient contract (21% of respondents), for example all-inclusive/carefree, and increased comfort (16%). Many respondents answered that they did not know (29%), that they saw no benefits (17%) or opted out of answering (8%). The main identified risk was that it would be more expensive (32%). A few respondents stated a risk of energy being wasted (and reduced incitement for energy efficiency measures) (6%), difficult to manage the system (5%) and contractual risks (such as less control and long-term contracts) (5%). Again, many respondents answered that they did not know (27%), that they saw no risks (10%) or opted out of answering (11%).

4.2.2 Risks, benefits and cost expectancy towards REWARDHeat solutions

Respondents were asked to state their perceived benefits and risks of having LTDH supply and integrating WH and/or RE. Customers answered to this question in an open text response and could state as many or few benefits/risks as they wanted. The main benefit identified by customer in having a LTDHN is a more energy efficient system with lower losses (48% of respondents), followed by environmental benefits (16%). Other stated benefits with fewer responses were the possibility to use more WH/RE sources (11%), less pollution (10%), financial savings (6%), increased comfort (5%) and less GHG/CO_2 emissions (5%). 8% of respondents did not know and 3% saw no benefits. When asked about perceived risks of having a LTDHN most respondents did not know (25%). The main stated risk was related to security of supply (19%), for examples that the house would not be warm enough. Other risks with less responses were higher cost (6%), immature technology (6%), less energy efficient (5%) and decreased comfort (5%). 14% of respondents did not see any risks.

Similarly, a question was asked about the customers perceived risks and benefits towards integrating WH and/or RES in the DH supply. The main benefits were identified as energy savings (37%), environmental (24%), financial savings (14%), less GHG/CO_2 emissions (13%) and less pollution (10%). 10% of respondents did not know any benefits. 33% of respondents did not see any risks of integrating WH and/or RES in the DH supply and 22% of respondents did not know. Security of supply, mainly related to the supply from the heat source, was the most frequently mentioned risk (21%), followed by a more expensive cost of energy (6%).

14% of respondents think that having a LTDHN will result in a higher energy bill than a conventional DHN and 16% of respondents think that integrating WH and/or RE will be more expensive. 30% think the price will remain the same as with conventional DH and 56% think the price will decrease.

4.2.3 Willingness to pay for green heat

56% of respondents show a WTP more for a greener H&C supply. 38% are willing to pay a few percentages more (1-5% more) and 18% would pay more than 6% more. 44% of respondents are unwilling to pay additionally for a greener H&C supply and want the price to be the same as today or even lower.

A one-way analysis of variance (ANOVA) was performed to compare the means in WTP for green in the surveyed countries, among different customer groups, among different technology awareness index and among different environmental index as described in section 3.4.

Comparing the WTP for green among the different countries using ANOVA in R yielded no significant difference between the WTP between respondents in the various countries (Figure 11). The p-value was at 0.077 and with a significance level of 5% the null hypothesis (the countries have similar WTP for green) cannot be discarded.

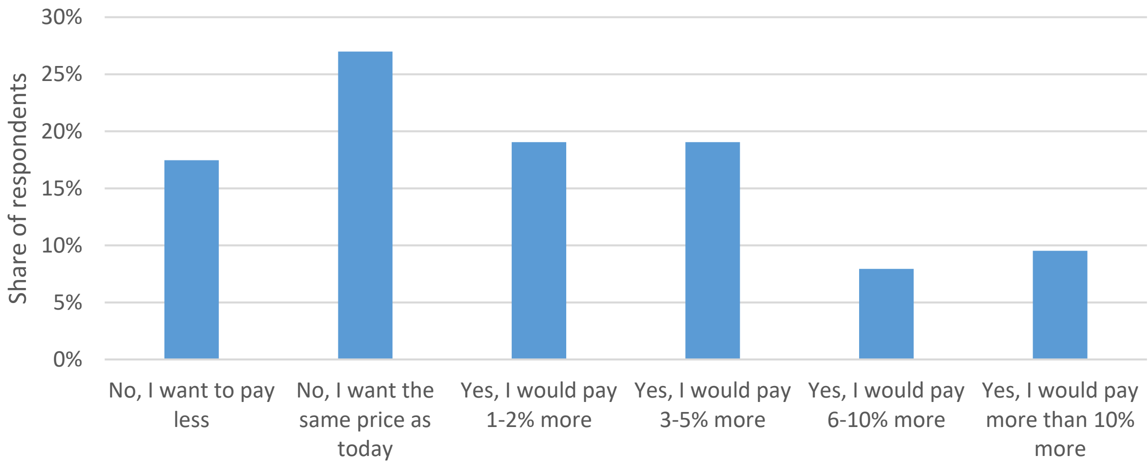

Figure 10: Respondents WTP for a greener H&C supply

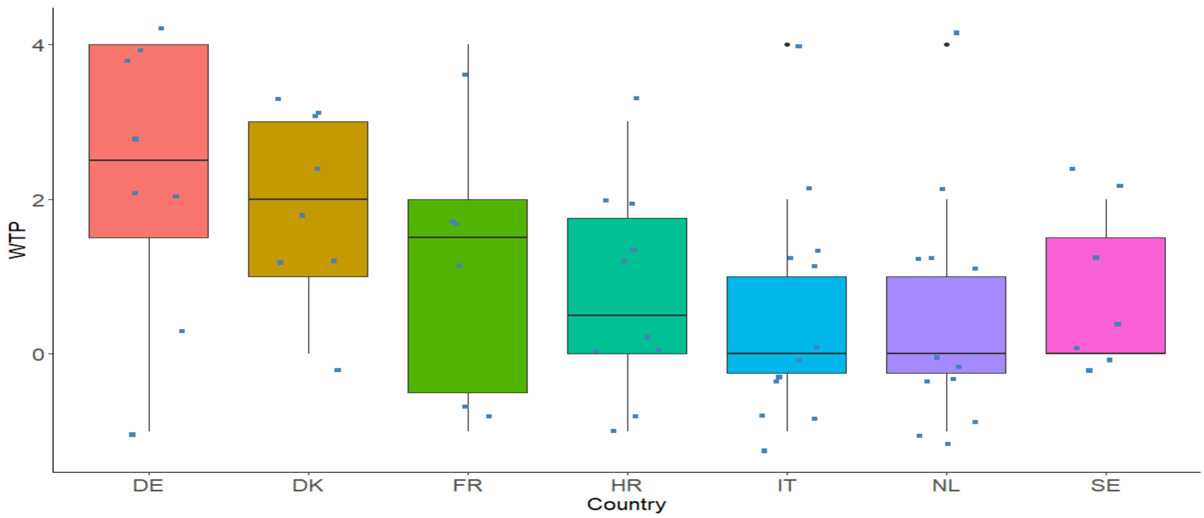

Figure 11: WTP for a greener H&C supply in the surveyed countries. The y-axis is the increased WTP, ranging from -1 (want to pay less) to 4 (would pay more than 10% more). The midline through the boxplot indicates the median, the hinges corresponds to the first and third quartiles (the 25th and 75th percentile) and the whiskers extend from the hinge to the highest and lowest value respectively, that is within 1.5 times the inter-quartile range (distance between whiskers).

Knowledge of technology was found in the literature to increase the WTP and therefore an ANOVA test was performed to see if the findings in the literature could be confirmed using the survey data. Since no respondent had a "very low" technology awareness this category was omitted from the analysis. The p-value was calculated at 0.40 meaning that no significant difference could be identified between different respondent's technology awareness index (

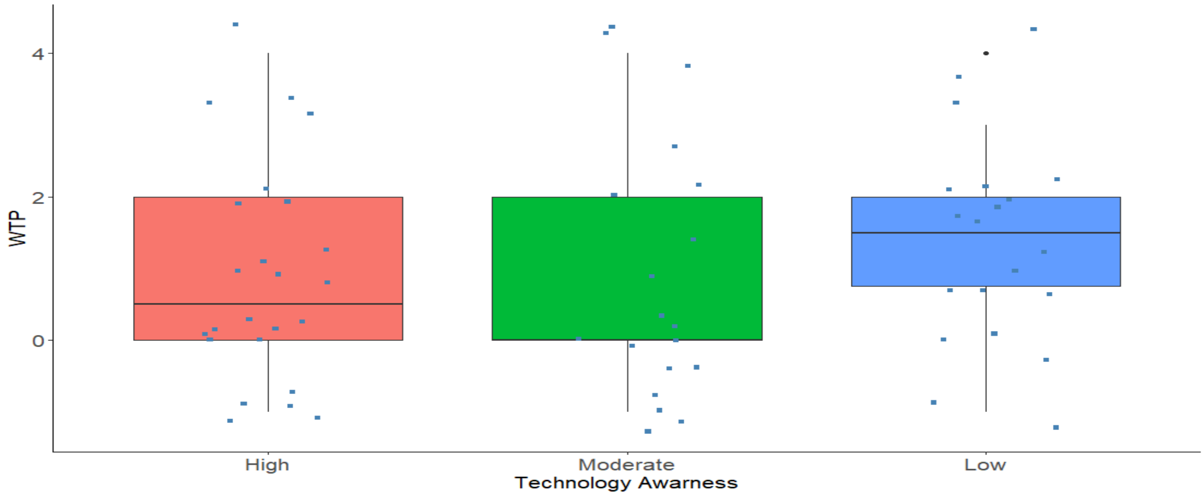

Figure 12).

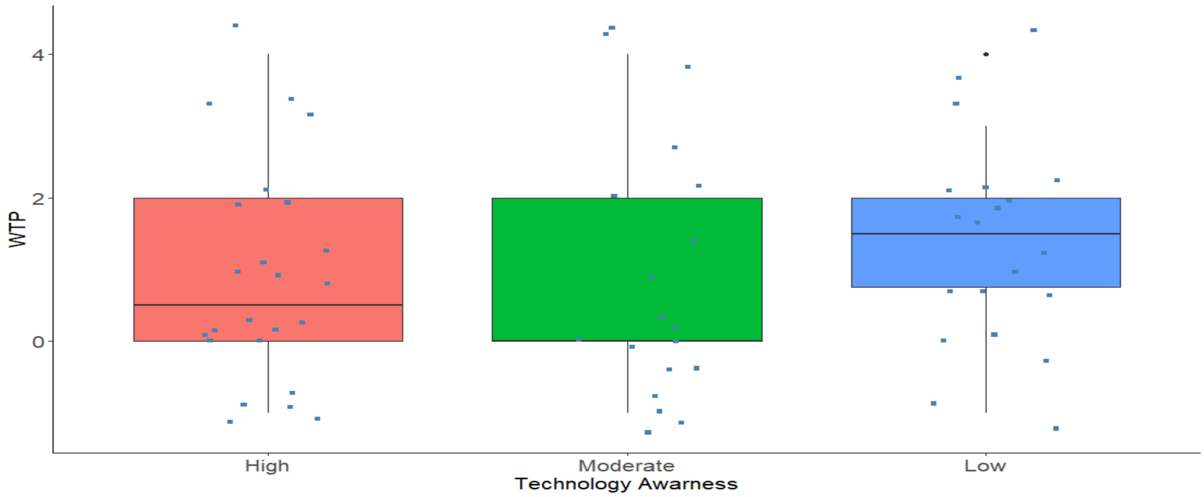

Figure 12: WTP for a greener H&C supply between different groups of respondents divided by their technology awareness index.

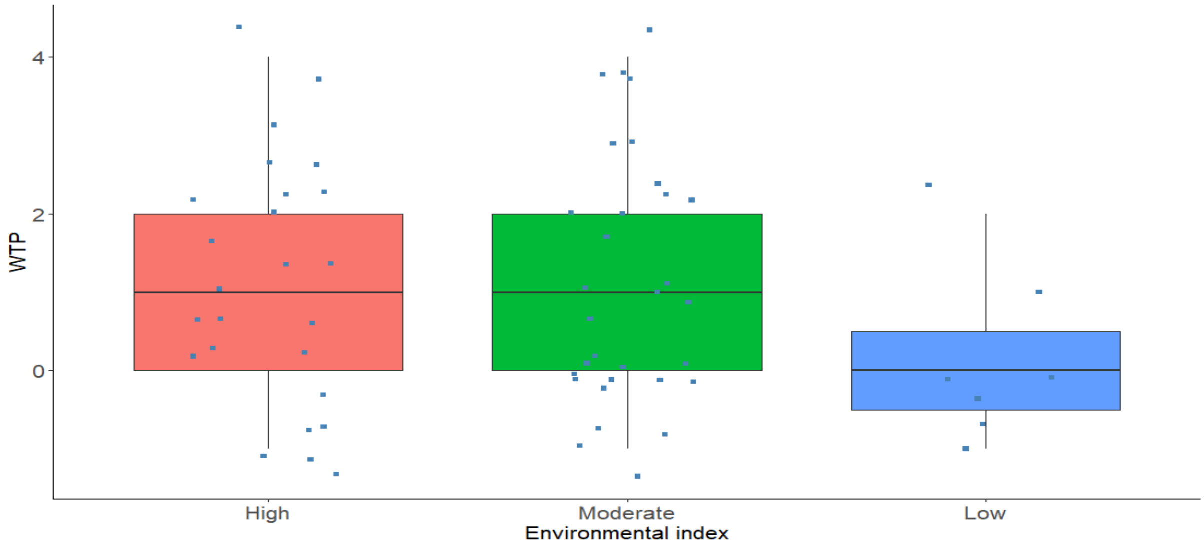

Figure 13: Figure 14: WTP for a greener H&C supply between different groups of respondents divided by their environmental index.

Environmental concern, awareness and engagement was also found in the literature to increase WTP for green. Since no respondents had a "very low" environmental awareness this category was omitted from the analysis. Again, no significant difference was found between customers (p-value of 0.29) (Figure 13).

No significant difference was found between the different respondent groups, professional and end-users, WTP to pay for green. The p-value was calculated at 0.92 indicating that the groups are very similar (Figure 14).

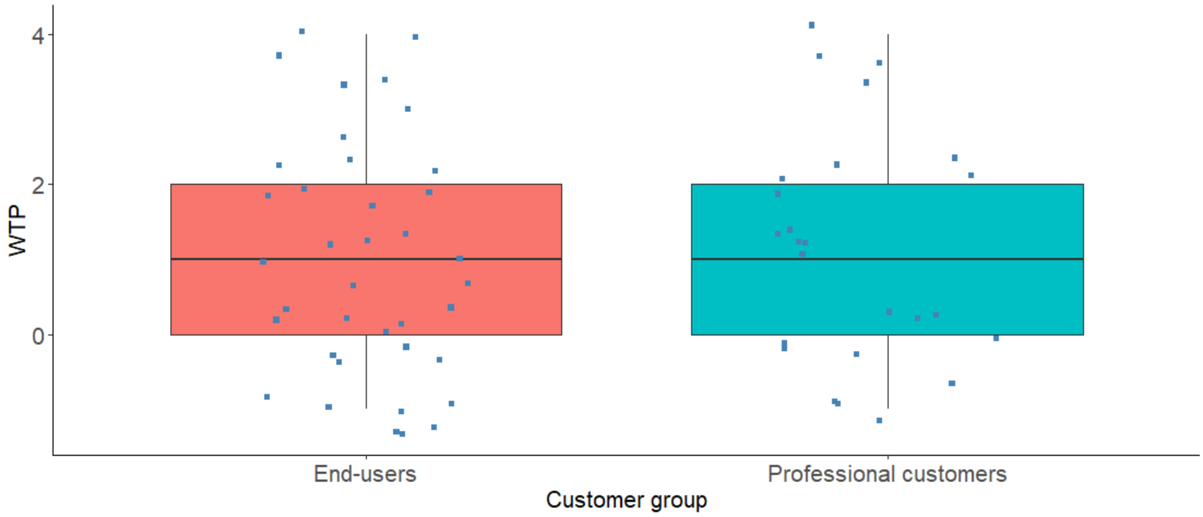

Figure 14: WTP for a greener H&C supply among respondent groups.

4.3 National requirements on indoor climate

4.3.1 Denmark

In Denmark the Building Regulation Act sets out the standards and minimum requirements for indoor climate in buildings. The general idea is that buildings must be constructed to provide a "healthy, safe and comfortable indoor climate". The regulation provides about thermal conditions, air quality, acoustic indoor climate and light conditions. In Denmark requirements have developed during a long time and are well-established. Thermal indoor climate is focused on ensuring a satisfactory indoor temperature, both in winter and summer (The Danish Ministry of Economic and Business Affairs, 2010). The thermal indoor climate in Denmark is further regulated by DS 474 Danish Code for Indoor Thermal Climate which sets out that the temperature must not exceed 26°C more than 100 hours, or 27°C more than 25 hours. No lower temperature limit in winter is in place (Kunkel, Kontonasiou, Arcipowska, Mariottini, & Atanasiu, 2015).

Air quality relates to ventilation and indoor pollutions caused by moisture or building materials and is a topic clearly addressed in Danish regulation. Building materials with low emissions of pollutants should always be used as there are regulation on pollutants from building material. Ventilation rates have regulated minimum requirements (Kunkel, Kontonasiou, Arcipowska, Mariottini, & Atanasiu, 2015). Fresh air supply in domestic buildings must be at least 0.3 $l/s/m^2$, in the kitchen and bathroom it must be possible to increase the exchange of air. The ventilation must be designed to ensure draughts does not arise and the air velocity in occupied spaces must be below 0.15 m/s, if in summer the temperature exceeds 24 °C higher velocities are accepted (The Danish Ministry of Economic and Business Affairs, 2010). Maximum values for air velocity to avoid drafts are only recommended values in Denmark (Kunkel, Kontonasiou, Arcipowska, Mariottini, & Atanasiu, 2015). Air must not be circulated from a more air-polluted room (e.g. kitchen, bathroom) to a less air-polluted room (e.g. living room, bedroom) (The Danish Ministry of Economic and Business Affairs, 2010). Air quality is recognised as an important aspect in Danish legislation (Kunkel, Kontonasiou, Arcipowska, Mariottini, & Atanasiu, 2015).

Requirements on acoustic indoor climate concerns the structure of the building to reduce the noise level and insulate between rooms and against external noise. Light conditions relate to the construction of window size in proportion to the properties of the room (The Danish Ministry of Economic and Business Affairs, 2010).

In sum, requirements focusing on ensuring a satisfying indoor temperature are well aligned with customers as indoor temperature was rated as the main priority when comparing indoor climate factors. The allowed maximum temperature at 26 (27)°C is well above the accepted temperature of 19.5-23°C by customers. No lower temperature limit in winter is applied but there is an overall requirement to ensure satisfactory temperature conditions. All customers considered air quality to be very important and most also considered air flows (draught) and noise to be very important and as can be seen in the requirements these aspects are again covered by building requirements.

4.3.2 Croatia

In Croatia legal requirements guard the thermal systems and the indoor climate. A general requirement is that indoor temperature must not be less than 18°C. The heating season starts at least by 15th of September and lasts until 15th of May and during this time DH systems must operate at least between 05:00-22:00 and ensure an indoor temperature of 24°C for residential buildings in continental Croatia and 22°C in coastal regions of Croatia. Outside operating hours (night time) the indoor temperatures must still be secured above 15°C (Hrvatska energetska regulatorna agencija, 2014), (Sveučilište u Zagrebu Fakultet strojarstva i brodogradnje, 2017). Domestic hot water is required to be at least 43°C after the heat exchanger or at the outlet of the thermal storage (Hrvatska energetska regulatorna agencija, 2014). Recommended values for indoor environmental quality (including air quality, thermal comfort, lightning and acoustics) are available in HRN EN 15251:2008. Acoustic regulation requirements are available as well as limits on air flows (Rasmussen & Machimbarrena, 2014).

In sum, the requirements on indoor temperature are not well aligned with what customers would prefer. Customers in Croatia want the temperature to be between 21.5-24°C. A requirement to maintain the temperature at 24°C is therefore not aligned with customer preference. The lower limit at 15°C is well below what customers would prefer and accept.

4.3.3 Germany

Requirements for buildings and indoor climate are regulated in several standards. The German standard DIN 4108 sets thermal and humidity standards while DIN 4109 determines the requirements between residential units. In addition, the international EN ISO 6946 standard, for uniform assessment of the thermal properties of building elements of the building envelope, is also applied. Furtherly, the VDI 6022 standard sets requirements for technical systems (above all air conditioning systems), and DIN 1946-2 as well as DIN EN ISO 7730 define requirements for thermal comfort of users.

New buildings in Germany must be built to ensure a healthy and warm indoor environment with high requirements on air tightness as an energy savings measure. Ventilation is included in the building regulation as a recommendation (non-binding) for minimum ventilation rates. Bathroom and kitchen should by ventilated at 45m^3/h (nominal exhaust flow). No requirements are identified regarding air velocities to avoid drafts. No country-specific legislation includes indicators for toxic particles as a part of the indoor air quality. Evaporation of pollutants are included in the national implementation of the EU construction product regulation. Germany has requirement on minimal temperature in buildings in winter at 20°C and bathrooms should be able to reach 22°C. Germany further has limitations against too warm indoor temperatures ranging from 25-27 °C depending on region. The size of windows must be adapted to a percentage of the floor area to allow natural lighting (Kunkel, Kontonasiou, Arcipowska, Mariottini, & Atanasiu, 2015). Noise levels in sleeping rooms is recommended to be below 35 dB (Brelih, 2013).

The requirements on minimum indoor temperature of 20°C is within the accepted temperature range (19-22.5°C) for customers. The limitation of maximum indoor temperature of 25-27°C is higher than the 23°C customers would prefer and accept. Air quality and noise is very important to customers. In the requirements, there are no indicators for toxic particles and the ventilation rates are only provided as recommendations.

4.3.4 France

Thermal requirements for new buildings and at replacements of existing building heating systems are defined in the French building thermal regulation (RE 2020 recently replace RT2012 and focusing on reducing the overall carbon footprint of new buildings) and further descriptions in relation to DHC projects (Réseaux de chaleur et territoires, 2014). The requirements concern e.g. indoor temperature control and hot tap water systems (requirements for legionella prevention).

Air quality in French buildings must ensure an air exchange rate and a level of emissions that guarantees no danger for occupants. France has minimum requirements on ventilation in buildings depending on number of rooms between 35 (1 room)-135 (7 rooms) m^3/h. Special requirement for the kitchen of ensuring a continuous flow between 20-45m^3/h and in the toilet a minimum of 15m^3/h. Air quality is further guarded by limits in CO_2 levels and emissions from pollutants must be kept below a harmful level to the occupant. No requirements are in place to restrict the maximum allowed indoor air velocity. The area of windows must be 17% of the floor area according to legislation to provide natural lighting. Indoor air temperature requirements are 18°C as a minimum in winter and 28°C maximum in summer (Kunkel, Kontonasiou, Arcipowska, Mariottini, & Atanasiu, 2015). Acoustic regulation requirements are available (Rasmussen & Machimbarrena, 2014).

Customers' acceptance for indoor temperature range from 17.5-23.5 °C and a minimum required temperature of 18 °C is within this range. However, to allow for 28 °C in summer is well outside the accepted range of customers. Air quality is important to customers and requirements on ventilation and pollutants are well guarded. Avoiding draught is another very important aspects to customers but there are no restrictions on air velocity.

4.3.5 Italy

Legislative requirements on indoor climate conditions are described in The Ministerial Decree 26/06/2015 (DM) (Italian Ministry of Economic Development, 2015) and are in line with the technical standard UNI EN 10339 (UNI - Ente Italiano di Normazione, 1995). Building regulations are however applied on regional level and the requirements can be inhomogenous across the country (Kunkel, Kontonasiou, Arcipowska, Mariottini, & Atanasiu, 2015).

Minimum ventilation rates in Italy are only provided as recommendations and generally natural ventilation in encouraged. For the residential sector an air exchange rate of 0.6 vol/h is usual. In bathrooms the recommendation is 4 vol/h. Maximum values for air velocity is provided as recommendations, in summer 0.2m/s and in winter 0.15m/s. There is no legislation defining limits of aspects related to indoor air quality in residential buildings, some requirements on pollutants from building products exist. The window area in relation to floor area must be 12.5%. With regards to indoor air temperature, Italy has a different set-up than the other countries, the required temperatures are defined as a means to reduce energy consumption rather instead of using temperature as an indicator of thermal comfort. Cooling systems in summer are limited to cool down to 26°C (-2°C tolerance) and heating systems in winter are limited to heat up to 20 °C (+2°C tolerance) (Kunkel, Kontonasiou, Arcipowska, Mariottini, & Atanasiu, 2015). In Italy the recommendation for highest equivalent noise level in sleeping rooms is 35 dB (Brelih, 2013).

Customers accepted indoor temperature range from 19.5-23°C. In Italy heating and cooling limits are used as a measure to reduce energy consumption rather than ensuring thermal comfort. The requirements state that the temperature can only be raised to 20°C (winter) or lowered to 26°C (summer) indicates that customers will often not be content with the indoor temperature unless outside temperatures are within the range. The temperature requirements are decided to guard energy consumption, not as a measure for thermal comfort. Air velocity and ventilation rates are only provided as recommendations.

4.3.6 Sweden

Requirements on heat systems, thermal performance and indoor quality are set by the Swedish Building regulations (Boverkets byggregler, BBR). BBR prescribes that buildings and their installations must be constructed to ensure satisfying air quality, lighting, humidity, temperature and hygiene conditions. Limit values on factors, inspection obligations and other undertakings are in place to guard the outcome.

Ventilation is included as a requirement in the building regulation and the minimum value is set to 0.35 l/s/m^2 or no lower than 0.5 vol/h. Indoor pollutants should be below limits that are harmful to the occupants. Requirements on maximum air velocity to avoid draughts are limited to 0.15m/s in winter and 0.25m/s in summer. In building regulations a guideline is provided that the window area should be dimensioned at 10% of the floor area (Kunkel, Kontonasiou, Arcipowska, Mariottini, & Atanasiu, 2015).

Minimum indoor air temperature in winter vary depending on who is occupying the space, generally not below 18°C but for older people the temperature should not be less than 20 °C. Sweden also has a requirement that temperature differences between different rooms in a dwelling should not exceed 5°C. To avoid overheating of buildings in summer the building regulation in Sweden asks for passive solutions to be considered in order to avoid the need for cooling systems. If a cooling system is installed it must be designed violating the requirements on air velocity or unevenly distributed temperature. Sweden also has requirement on floor temperature. Maximum temperature should not exceed 2°C. Minimum floor temperature is 16°C in most living spaces, in bathrooms not less than 18°C and in spaces occupied by children no less than 20°C (Kunkel, Kontonasiou, Arcipowska, Mariottini, & Atanasiu, 2015).

Customers accept a temperature range between 19.5-23°C. The lower limit in winter at 18 degrees is hence below what customers considered to be good thermal comfort. No upper temperature limit is applied in Sweden, but the building code states that buildings should be designed to ensure satisfactory indoor temperature. Air quality and noise is the most important aspect to customers, and this is well guarded in legislation.

4.3.7 Netherlands

Indoor temperature levels are only allowed to exceed 25°C during 100 hours per year and to exceed 28°C during 10-20 hours per year. The Dutch Building Code 2012 regulates aspects related to the indoor climate. Ventilation rates in the residential dwelling should be 0.9l/s/m^2 seen to total living area, kitchen 21l/s and bathroom 14l/s. Air velocity, both in summer and winter, should be below 0.2m/s. In the Netherlands no lower temperature limit has been identified (REHVA, 2012). The limit for noise levels in sleeping rooms in the Netherlands is 30 dB (Brelih, 2013).

A 2017 study carried out by the Dutch National Institute for Public Health and the Environment (RIVM) found that there is less national regulation in the Netherlands to improve the quality of the indoor environment, compared to other European countries (National Institute for Public Health and the Environment, 2017).

Customers prefer the indoor temperature to be in the range of 19.5- 23°C. The regulated upper limit of 25°C (28°C) is higher than what customers perceive to be a good thermal comfort. No lower limit has been identified in the requirements. Air flows (draught) are very important to customers and this is limited in the Building Code. Air quality and noise is also very important, and no limits have been identified.

4.3.8 Comparison between national requirements on indoor climate and respondents' perspectives

Indoor air temperature is the most used indicator of thermal comfort in national regulations. This is aligned with the customers' perspective as 76% of respondents in the survey consider temperature to be the most important aspect. Recommended indoor temperature values in general standards are 20°C in winter and 26°C in summer (Brelih, 2013). France and Sweden have a regulated lower limit below 20°C. No lower temperature limit was identified for Denmark and Netherlands and no upper limit was identified for Croatia and Sweden. Italy is the country where thermal comfort legislation on temperature is lagging the most. Italy is the only country providing temperature limits only as a measure to reduce energy consumption instead of guarding the occupant thermal comfort.

On average, respondents in all countries but Croatia accept a lower limit of 19.5°C and regulations with a lower limit of 20°C is well-suited with the customer perspective. The accepted upper limit of customers is around 23°C (+/- 1°C) for a good thermal comfort. Upper temperature limits on country-level are higher than what customers perceive as acceptable, with France having the highest upper limit at 28°C. As the need and demand for cooling will increase in the future (as it has in recent decennia) it is important that legislation adapts to enforce stricter requirements on building constructions to minimise the need to use energy for cooling (using passive solutions such as shading) but also that the occupants well-being and comfort is guarded by stricter upper temperature limits. Solutions being able to supply both heating and cooling are well-suited for the future.

Table 4 provides an overview of section 4.3 by comparing the national requirements to the respondents' perspective on indoor climate. The table is meant to provide an overview on what aspects are covered in legislation, either as a requirement or as a recommendation, only to allow for a comparative analysis in this deliverable where the focus is on temperature as it is the most important comfort factor to customers. Even if an aspect is covered in the legislation does not mean that the limits are good, or even enough, in ensuring a good indoor environment. A study from 2015 identified gaps in legislation for indoor climate which is reducing the efficiency, health and comfort of occupants in all countries included in the study, including Denmark, France, Germany, Italy and Sweden (Kunkel, Kontonasiou, Arcipowska, Mariottini, & Atanasiu, 2015). There is less national regulation in the Netherlands to improve the quality of the indoor environment, compared to other European countries (National Institute for Public Health and the Environment, 2017). Aspects provided on regulation are informative only, as legislation is periodical, data provided could be obsolete. For some aspects, especially in Croatia, it has been difficult to assess whether regulation is a requirement or only recommendations.

Table 4: Summary of comparison between national requirements on indoor climate and respondents' perspectives. An (x) indicates that the comfort factor is very important to respondents in that country. Covered by legislation (green), covered only as recommendations (yellow), not covered in legislation (red).

		Temperature range		Very important comfort factors			
		Upper limit [°C]	Lower limit [°C]	Indoor temp	Air quality	Air flows	Noise
Denmark	Respondents	23	19.5	x	x	x	x
	Regulation	26 (27)	-				
Croatia	Respondents	24	21.5		x	x	x
	Regulation	-	24 (15)				
Germany	Respondents	22.5	19	x	x		x
	Regulation	25–27	20				
France	Respondents	23.5	17.5	x		x	x
	Regulation	28	18				
Italy	Respondents	23	19.5	x	x	x	x
	Regulation	20(winter)	26(summer)				
Sweden	Respondents	23	19.5		x		x
	Regulation	-	18				
Netherlands	Respondents	23	19.5	x	x	x	x
	Regulation	25 (28)	-				

5 Conclusions

Returning to the research questions:

1. What comfort factors are most important for customers and are national requirements on indoor climate aligned?

Temperature is the most important aspect of indoor climate according to respondents. To 51% of respondents the most important indoor climate factors is indoor temperature and to another 25% an evenly distributed temperature is the most important. Thermal factors affecting the indoor climate are often described by occupants in literature in terms of "too hot" or "too cold" and the importance and focus on temperature are emphasised by the results of the survey. Air quality, avoiding draughts and avoiding noise are other very important factors to respondents.

Previous literature has identified gaps in legislation for indoor climate which is reducing the efficiency, health and comfort of occupants in all countries included in this deliverable. An interesting finding from the analysis of national requirements on indoor climate performed in this deliverable is that the upper temperature limit is much higher than what customers experience to be an acceptable temperature. With increasing global warming and heat waves, thermal comfort of customers' needs to be better guarded against high temperatures. Both passive and active solutions for cooling should be implemented in legislation to increase thermal comfort.

Low temperature district heating requires a closer dialogue with customers and a possibility arises to provide a higher service level and to tailor a comfort solution that is better adjusted in temperature to the customers comfort demand. The additional value in providing cooling can be increasingly important in the future. Low temperature systems utilizing waste heat and renewables can improve local air quality and district heating in general does not cause draught or noise inside the living spaces of occupants and is hence well-suited towards all very important comfort factors of customers.

2. Does the customers comfort demand reflect temporality?

Most customers (84%) display a temporality in when at least one of the services (space heating, space cooling, DHW) is less important during the day. The service for which respondents are the least flexible is DHW, 48% of respondents think it is equally important throughout the day. For space heating, 27% are not flexible, and the equivalent number for space cooling is 25%. With more people working from home during the COVID-crisis, and the trend towards more work flexibility policies, the services could be more important to maintain also during daytime in residential buildings. The garage (71% of respondents answered that it is less important) and basement (65%) are the least important room to ensure a comfortable indoor climate, followed by the bedroom (41%). The most important rooms where comfortable indoor climate must be ensured are the bathroom (3% of respondents answered that it is less important), dining room (3%) and living room (0%). 19% of respondents thinks that all room are equally important and do not display a flexibility in comfort demand.

Increased control of the heating solution has potential to improve the experienced thermal comfort of customers. Low temperature district heating is well-suited for floor heating installations which can enable individual temperature settings in different rooms. This is an advantage of hydronic systems compared to single source heating (such as some heat pump solutions).

3. How can customers be more engaged in the H&C solution?

The cost of heating and cooling is important or very important to 89% of respondents and 94% want to be able to impact the cost. 81% of respondents perceive energy as a commodity and are prone to demand such pricing schemes. 75% of respondents prefer that someone else managed the maintenance of the equipment. The main risk perceived by 32% of respondents towards increasing the level of servicification is a more expensive bill but there are benefits like increased comfort (17%) and a carefree contract (21%). 17% of respondents did not perceive any benefits and 27% did not know.

There is a clear need to increase awareness about both benefits and risks of increased servicification in relation to heating systems to create a pull from the market. The market for increased servicification in heating systems has reached different levels of maturity in the different surveyed countries. In Sweden and Denmark, were district heating is well-established, increased servicification is more developed (not only heat being sold as commodity). One example from Sweden is the interest in optimizing the customers individual heat pump against the district heating system to achieve optimized performance and cost-efficiency in both systems (Ottosson, o.a., 2020).

4. Is there a willingness among customers to pay for a greener heat supply?

Other studies looking at the WTP for greener buildings identified a WTP of a few percentages per month whereas the WTP for green electricity was found to be higher. In this study 56% of the respondents display a willingness to pay for a greener heat supply. 18% are willing to pay more than 6% more and 38% would be willing to pay a 1-5% higher price. In reviewed articles socio-economic factors found to drive WTP for green were environmental concern, technology knowledge level, higher education level, higher income level and age (younger). In this study an ANOVA test was performed to test if the WTP for green was significantly different between countries, customer groups, technology awareness or environmental concern. The ANOVA test could not distinguish a difference in WTP for green between any of the tested variables. When differences between groups are smaller, a larger population could be necessary to distinguish statistical differences.

In a climate-neutral Europe in 2050 there will be no rooms for fossil fuels in the H&C sector and a greener and more resource efficient supply system is the only option to achieving the targets. To increase the pace of investments in greener solutions the incentive and willingness to pay for the green value among customers' needs to increase.

5.1 General conclusion

In conclusion, an understanding of the customers comfort preferences for heating and cooling has been derived. The most important indoor climate factor is indoor temperature, some rooms are more important than others and certain times of the day are more important. The new generation of district energy solutions (LTDHC) necessitates increased control of the system, from the heat source to the customer unit. The systems are also apt for floor heating, allowing control per room. For LTDHC these traits are competitive advantages compared to other heating alternatives as they directly can match the most important comfort factors. In terms of national legislation on indoor climate, all countries must see improvement to avoid reducing the efficiency, health and comfort of occupants. Especially the customers' thermal comfort needs to be better guarded against high temperatures. For an efficient transition to 2050 targets a homogenization of building practices is needed where the key point is the incorporation of flexibility where customers need to engage and become the much-desired energy citizens. An increased level of awareness of benefits and risks is necessary for customers to make this transition. For a more rapid energy transition incentives for customers to actively choose green energy are needed.

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7 Annex: Country analysis

7.1 Denmark

7.1.1 Contractual desirables

63% of respondents think that the cost of H&C is very important. All respondents want to be able to impact the cost (for examples by incitement-based pricing). All but one respondent would be WTP more for a greener H&C system. End-users have a somewhat higher WTP, up to 6-10% more, than professional customers (Figure 15).

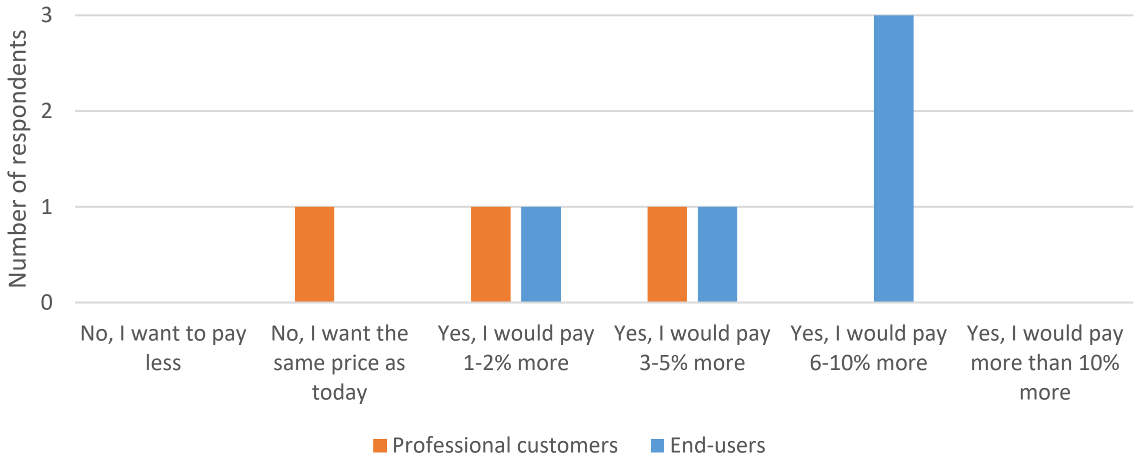


Figure 15: Willingness to pay for a greener H&C supply among customer groups (Danish demo site)

Respondents perceived benefits and risk towards a comfort service agreement (high level of servicification) can be seen in Table 5. Identified benefits are that it is easier to have increased service and that it would improve the indoor climate. Identified risks are that it lowers the incitement to perform energy efficiency measure, increases consumption and is more expensive.

Table 5: Risks and benefits perceived by customers toward a high level of servicification (Danish demo site).

	Benefits	**Risks**
Professional customers	Easier cost distribution Better indoor climate	Lower incitement for energy efficiency measures Bound by contract None
End- users	No equipment risks Easier Better indoor climate Don't know	More expensive Increased consumption None Don't know

In Denmark respondents are in favor of receiving the space heating and/or cooling as a commodity and only two end-customer preferred to receive it as a service. Half of the respondents want to manage the maintenance of the equipment themselves and the other half prefer that someone else takes care of maintenance (Figure 16).

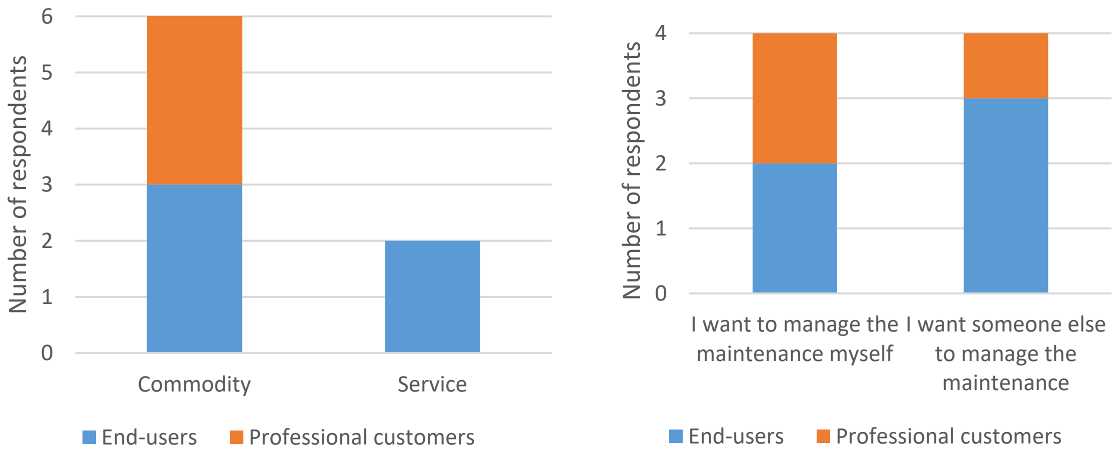


Figure 16: (Left) Customers propension to receiving space heating and/or cooling as a commodity or service. (Right) Customers wanting to manage the maintenance of H&C equipment themselves or as a service.

7.1.2 Aspects of comfort

Seven respondents in Denmark think that having a comfortable indoor temperature is the most important aspect with regards to indoor climate. One professional customer thinks that having an evenly distributed temperature is the most important aspects. Looking at how customers rated the factors individually (Figure 17) shows that air quality, avoiding drafts and avoiding noise are very important.

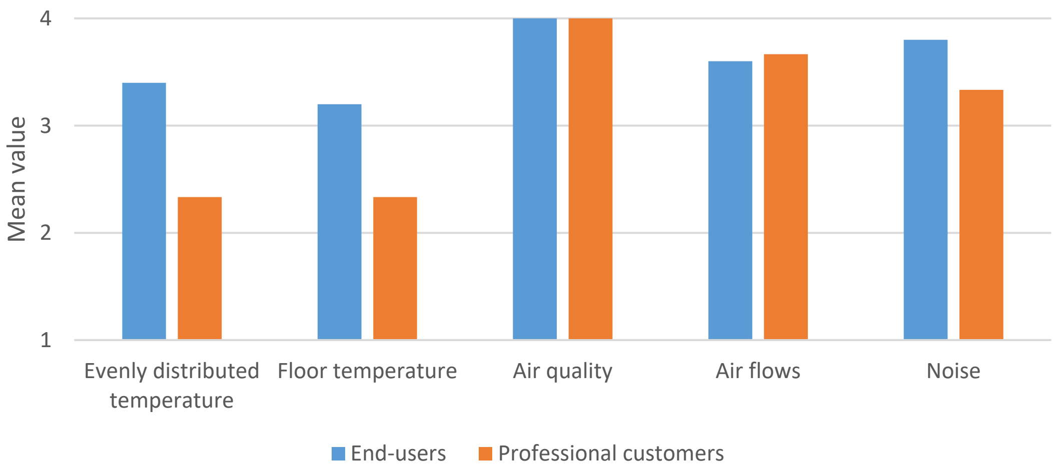


Figure 17: Importance of indoor climate factors (Danish demo site). The respondents could choose on a 4-degree Likert-scale were 1= not important and 4= very important.

Acceptable indoor temperatures and deviations from the preferred temperature is very similar between professional customers and end-users at around 21°C +/- 1.5°C deviation (Figure 18).

Figure 18: Mean preferred indoor temperature and accepted deviation from preferred temperature (Danish demo site)

Two end-users think that all indoor rooms are equally important, all other respondents have some flexibility with regards to indoor climate. Five respondents think that the garage is less important, four thinks that the basement is less important and three consider the bedroom as less important.

One respondent considers space heating and space cooling respectively to be equally important throughout the day and two consider DHW to be equally important. Indicating a temporality in the demand for DHC services. For respondents in Denmark space heating is important throughout the day, whereas space cooling grows more important towards the night. Hot water is mainly important in the morning and again in the evening (Figure 19).

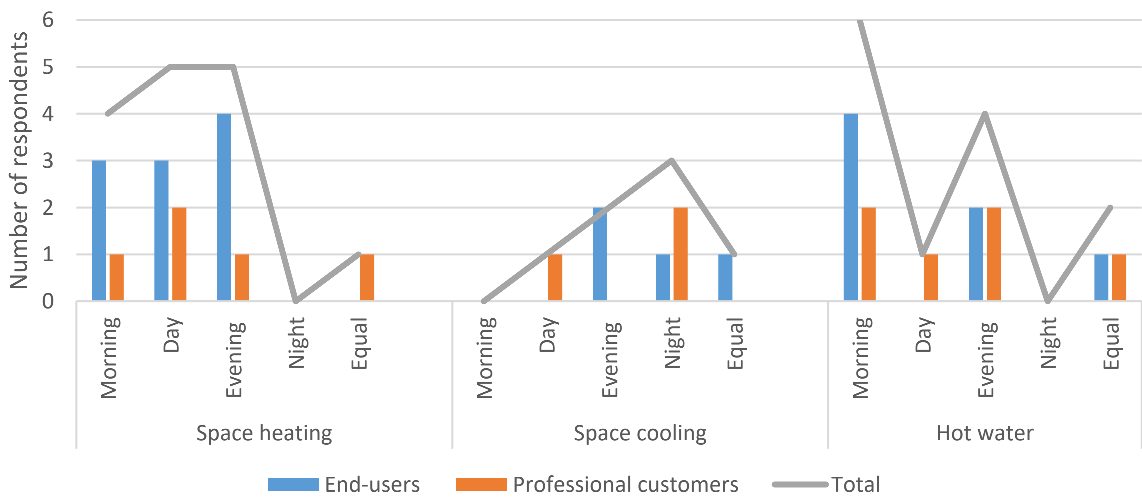


Figure 19: Temporality in comfort demand by customers (Danish demo site)

7.2 Croatia

7.2.1 Contractual desirables

90% of respondent in Croatia think that the cost of H&C is very important. All respondents want to be able to impact the cost of H&C. A slight difference can be seen in the WTP for a greener H&C system between customer groups in Croatia where professional customers state that they would be WTP for the value of green to a larger extent than end-user (Figure 20).

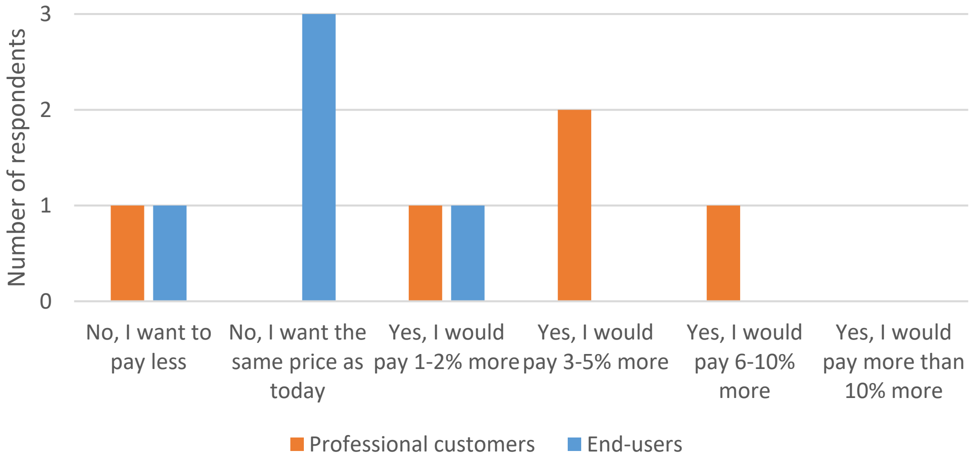


Figure 20: Willingness to pay for a greener H&C supply among customer groups (Croatian demo site)

Most professional customers are unsure about the benefits and risks of receiving a high level of servicification via a comfort service agreement. End-users perceive the benefits to be increased indoor climate, fixed price and convenience. Most end-users are unsure of the risks.

Table 6: Perceived risks and benefits of receiving a high level of servicification by respondents in Croatia

	Benefits	**Risks**
Professional customers	Fixed indoor temperature Unsure	Unpredictability of consumption Unsure
End- users	Convenient contract Fixed price for the same thermal comfort Secure supply Fixed indoor temperature	Inability to influence the amount of the bill Unsure

In Croatia customers are strongly in favor of receiving the space heating and/or cooling as a commodity and only one end-customer preferred to receive it as a service (Figure 21). One reason could be due to many respondents being unsure of the benefits and risks of increased service and require more information. Most respondents prefer someone else to manage the maintenance of the H&C equipment.

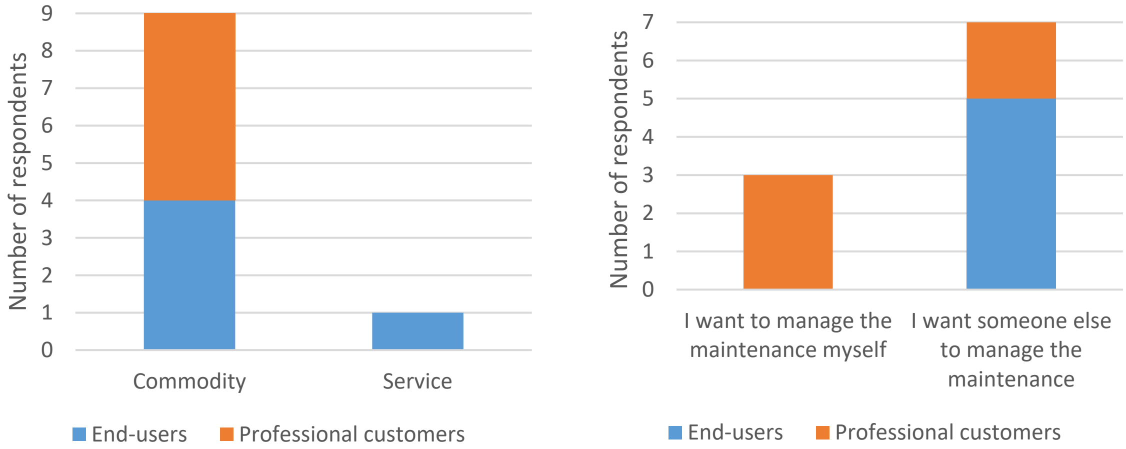


Figure 21: (Left) Customers propension to receiving space heating and/or cooling as a commodity or service. (Right) Customers wanting to manage the maintenance of H&C equipment themselves or as a service.

7.2.2 Aspects of comfort

80% of respondents think that having an evenly distributed temperature in all living spaces is the most important factor in relation to indoor climate. One end-user thinks floor temperature is the most important and one professional customer thinks that having a comfortable indoor climate is the most important. Looking at the factors one by one it is identified that all factors are important to very important to customers.

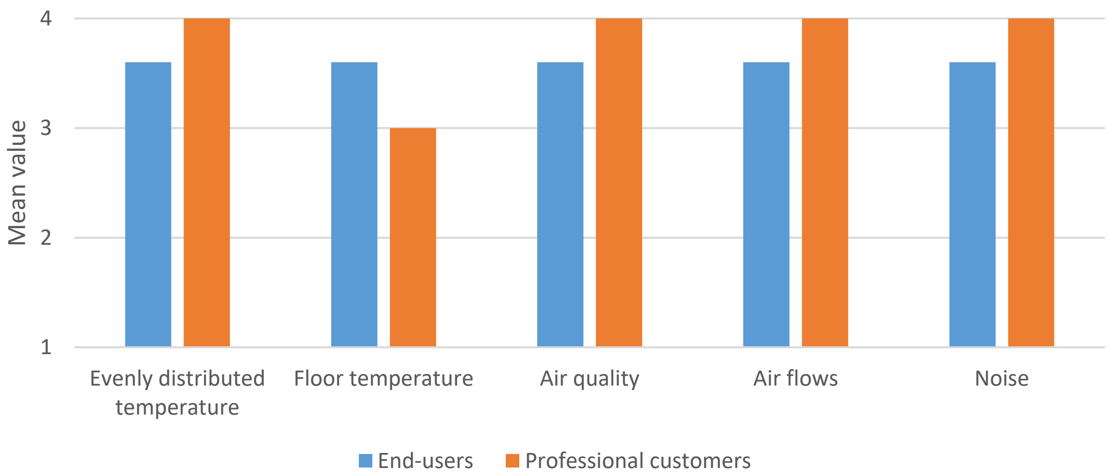


Figure 22: Importance of indoor climate factors (Croatian demo site). The respondents could choose on a 4-degree Likert-scale were 1= not important and 4= very important.

Professional customers have a preferred mean temperature of 22.6°C and only accepts deviation of +/- 1°C. End-users prefer a higher mean temperature of 23.2°C and accept a deviation of +/- 1.6°C.

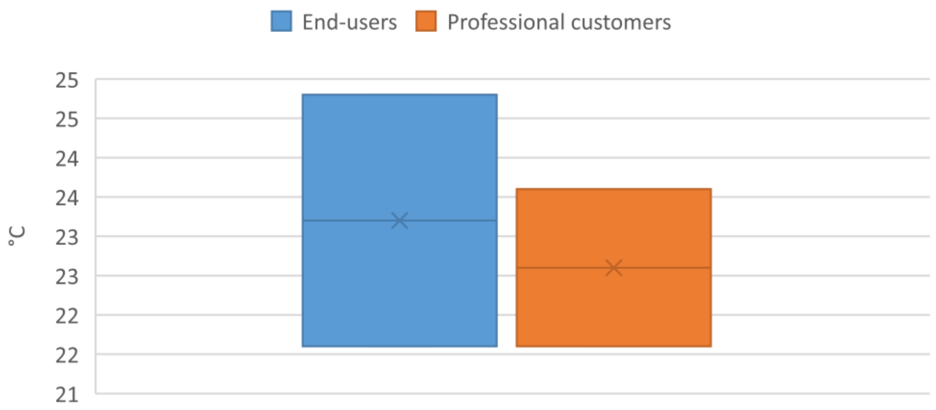


Figure 23: Mean preferred indoor temperature and accepted deviation from preferred temperature (Croatian demo site)

With regards to indoor climate professional customers have a very low flexibility and consider all spaces to be equally important. End-users are more flexible, and all respondents answered that the basement and garage are less important. In addition, one end-user also thinks that the bedroom is less important.

Temporality in the services that can be delivered is displayed in Figure 24. Space heating must be available in the morning and space cooling during the day. Hot water is always seen as equally important by end-users but most important in the morning and day by professional customers. Night-time is generally less important to receive the services.

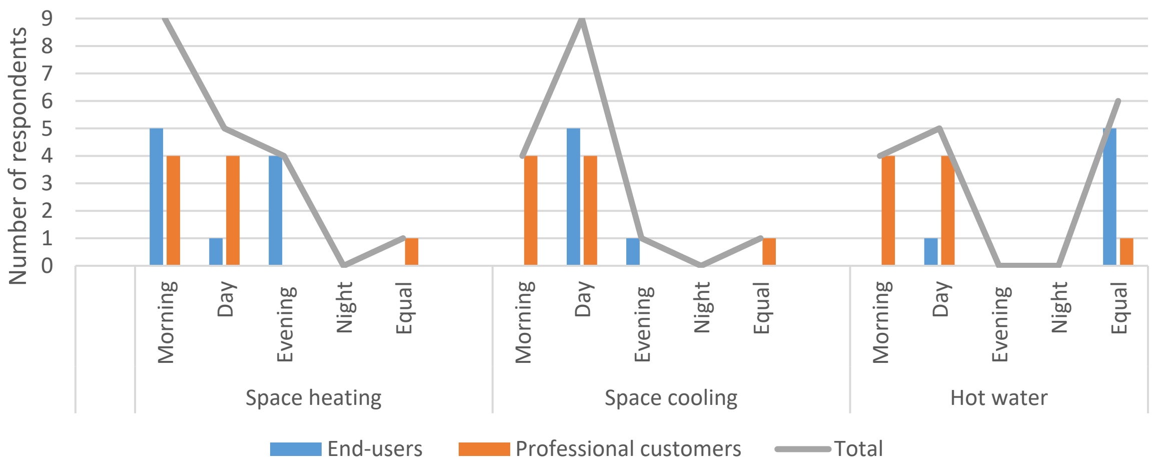


Figure 24: Temporality in comfort demand by customers (Croatian demo site)

7.3 Germany

7.3.1 Contractual desirables

63% of respondents think that the cost of H&C is very important. All but one respondent wants to be able to impact the cost (for example by incitement-based pricing). Customers show a wide range in their WTP more for a greener H&C system. Some end-users want to pay less than today, and some are willing to pay more than 10% more. Professional customers would be willing to pay up to more than 10% more than the price today for a greener system (Figure 25).

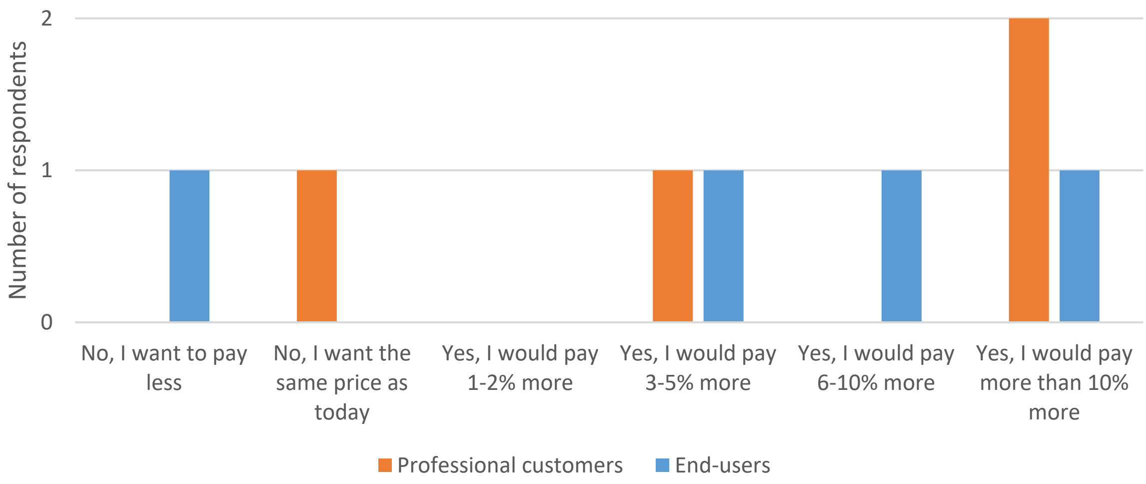


Figure 25: Willingness to pay for a greener H&C supply among customer groups (German demo site)

Benefits identified by respondents in Germany to a comfort service agreement are related to increased comfort and an easier H&C supply. Some respondents do not see any additional benefits. Identified risks are mainly related to higher costs but also that the system could become more complex (Table 7).

Table 7: Risks and benefits of a high level of servicification as perceived by respondents in Germany

	Benefits	**Risks**
Professional customers	Increased comfort Less responsibility No benefits	Higher cost Complicated interfaces
End- users	Simpler contracts Fair energy bills No benefits	Lack of transparency Higher cost No risks

Three respondents would like to receive H&C as a service, but the majority still prefers to have it as a commodity (Figure 26). Given that some respondents did not perceive any benefits towards increased service the benefits probably need to be better communicated. All respondents want to receive the maintenance of H&C equipment as a service.

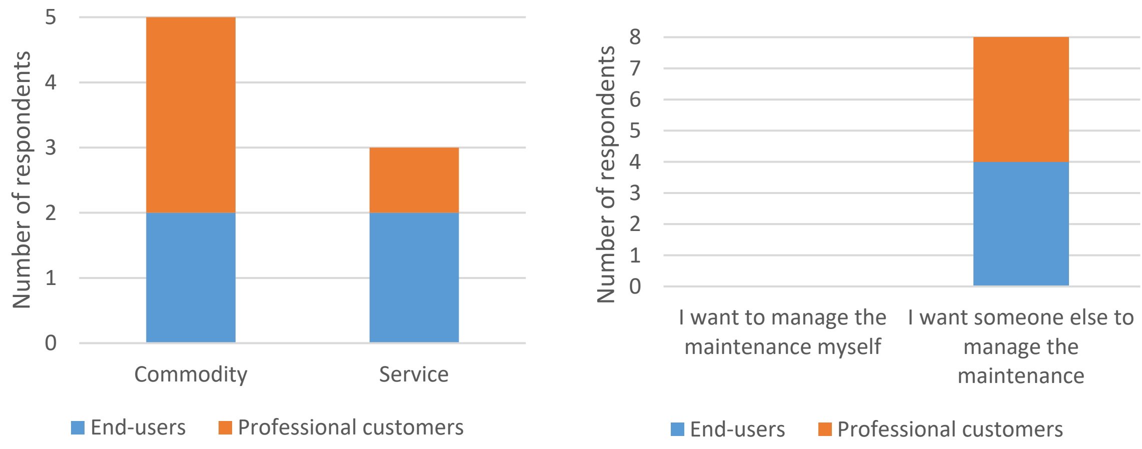


Figure 26: (Left) Customers propension to receiving space heating and/or cooling as a commodity or service. (Right) Customers wanting to manage the maintenance of H&C equipment themselves or as a service.

7.3.2 Aspects of comfort

Half of the respondents consider having a comfortable indoor temperature to be the most important aspect with regards to indoor climate. 2 respondents thought that all aspects are equally important, one selected floor temperature and one selected air quality to be the most important. When rating the aspects individually, air quality, air flows and noise are considered important to very important. Floor temperature and an evenly distributed temperature is less important (Figure 27).

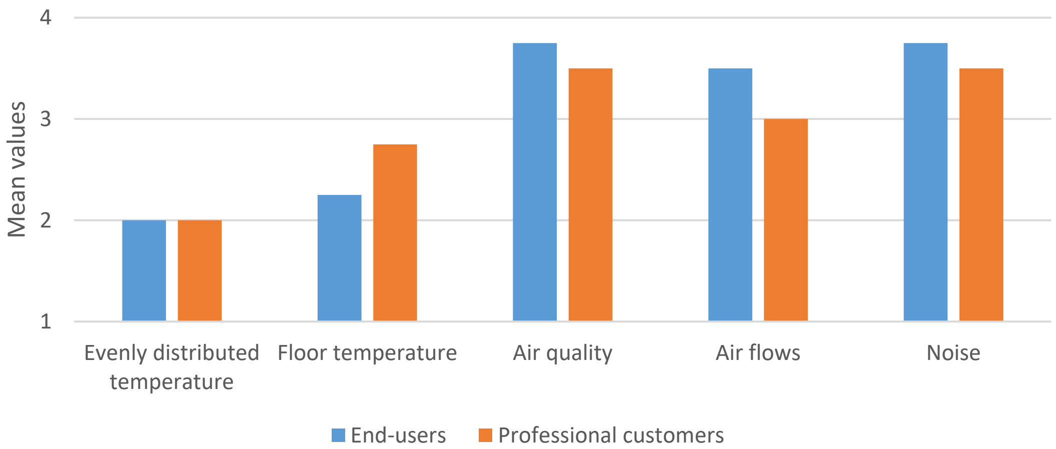


Figure 27: Importance of indoor climate factors (German demo site). The respondents could choose on a 4-degree Likert-scale where 1= not important and 4= very important.

The preferred indoor temperature is similar between professional customers and end-users around 21°C and the accepted deviation is 1.75°C for both groups. Professional customers prefer a slightly lower indoor temperature (Figure 28).

Figure 28: Mean preferred indoor temperature and accepted deviation from preferred temperature (German demo site)

One professional customer considers all indoor rooms to be equally important with regards to indoor climate, all other respondents show a flexibility. Six out of eight respondents think that the bedroom is less important, five consider the garage and basement to be less important and three thinks that the kitchen is less important.

Space heating is for half of respondents equally important throughout the day but overall, most important in the evening. Space cooling is less important in the morning. Hot water is equally important throughout the day for half of respondents, most important in the morning and evening (Figure 29).

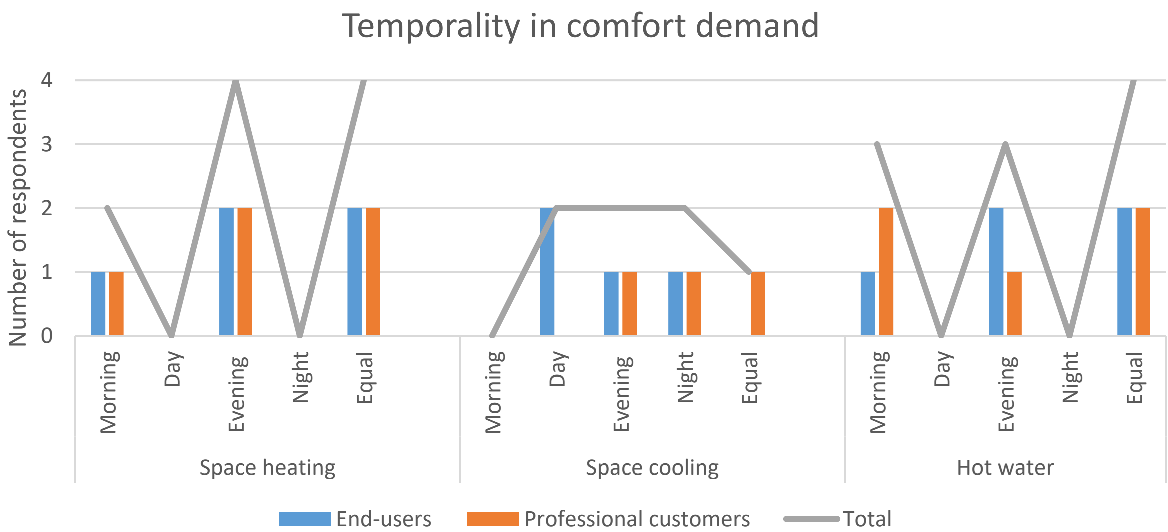


Figure 29: Temporality in comfort demand by customers (German demo site)

7.4 France

7.4.1 Contractual desirables

80% of respondents think that the cost of H&C is important or very important. 60% of respondents want to be able to impact the cost (for examples by incitement-based pricing). All but one end-user would be WTP more for a greener H&C system with the peak at a WTP 3-5% more (Figure 30).

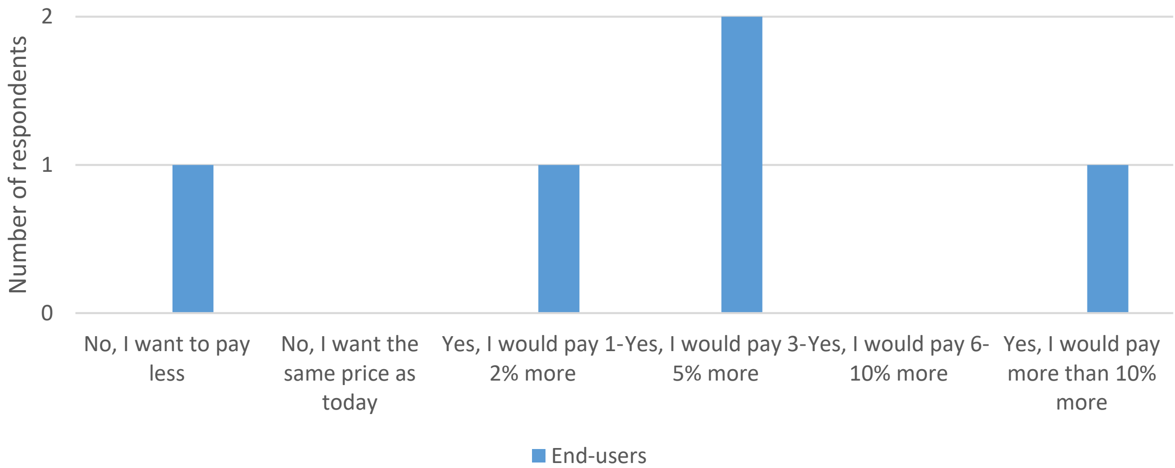


Figure 30: Willingness to pay for a greener H&C supply among end-users (French demo site)

End-users in France see the main benefit of a comfort service agreement to be carefreeness and receiving the same comfort level. One end-user did not see any benefits. The main risk was the perception of the service being more expensive than the alternatives (Table 8).

Table 8: Risks and benefits perceived by respondents in France toward a high level of servicification.

	Benefits	**Risks**
End- users	Carefree/all-inclusive Same comfort level No benefits	More expensive Energy being wasted

Most end-users in France prefer to receive space heating and/or cooling as a commodity rather than as a service (Figure 31). That most customers think that increased service leads to a higher resulting cost could be a reason to prefer receiving space heating and/or cooling as a commodity. 80% of end-users prefer someone else to manage the maintenance of the H&C equipment.

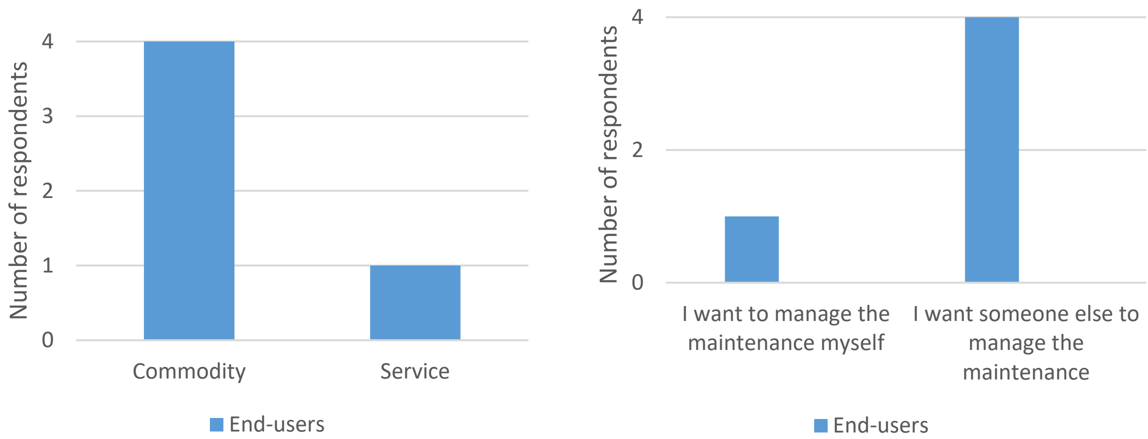


Figure 31: (Left) Customers propension to receiving space heating and/or cooling as a commodity or service. (Right) Customers wanting to manage the maintenance of H&C equipment themselves or as a service.

7.4.2 Aspects of comfort

End-users in France think that having a comfortable indoor temperature (40%) and avoiding air flows (40%) are the most important factors with regards to indoor climate, one end-user though that having an evenly distributed temperature was the most important. When rating indoor climate factors individually noise, avoiding air flows and air quality were identified as important to very important whereas floor temperature and temperature distribution are not so important (Figure 32).

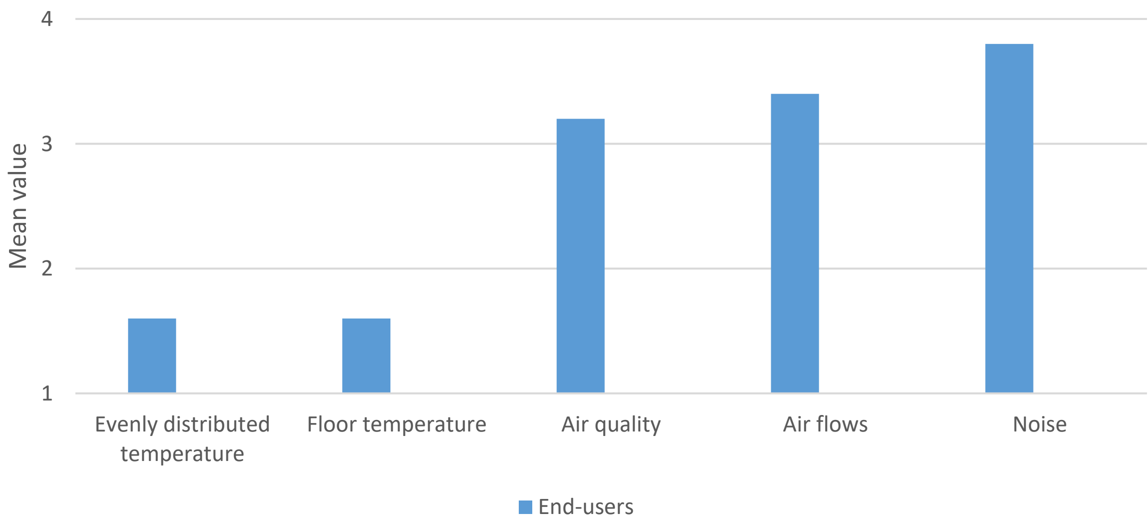


Figure 32: Importance of indoor climate factors in (French demo site). The respondents could choose on a 4-degree Likert-scale were 1= not important and 4= very important.

Average preferred indoor temperatures by end-users in France is 20.5 °C with quite a large accepted deviation of +/- 3 °C (all respondents accepted this much deviation) (Figure 33).

Figure 33: Mean preferred indoor temperature and accepted deviation from preferred temperature (French demo site)

All end-users consider the basement and garage to be less important rooms with regards to indoor climate. Two also thought that the kitchen was not as important. The bathroom, dining room and bedroom was considered to be less important by one respondent respectively.

The services provided by a DHCN have a clear temporality in demand by end-users in France. No respondent considered any of the services to be equally important throughout the day. Space heating is more important in the morning and evening, space cooling is most important during the night and hot water is more important in the morning, and again in the evening (Figure 34).

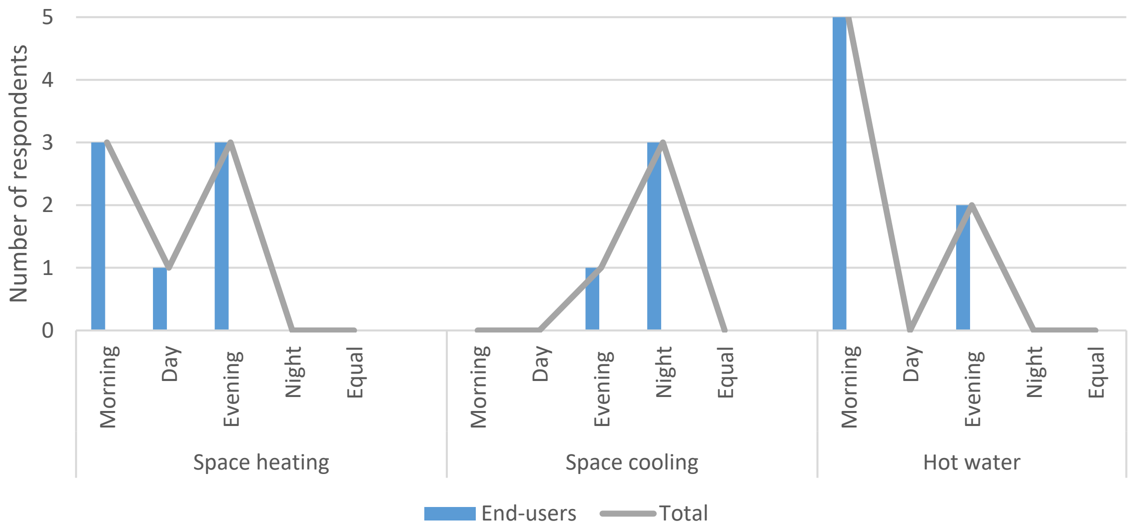


Figure 34: Temporality in comfort demand by customers (French demo site)

7.5 Italy

7.5.1 Contractual desirables

All but one respondent think that the cost of H&C is important or very important. All respondents want to be able to impact the cost (for examples by incitement-based pricing). End-users tend to want about the same price as today for a greener H&C system, possible 1-2% more. Professional customers are spread across the range from wanting to pay less up to a WTP more than 10% more (Figure 35).

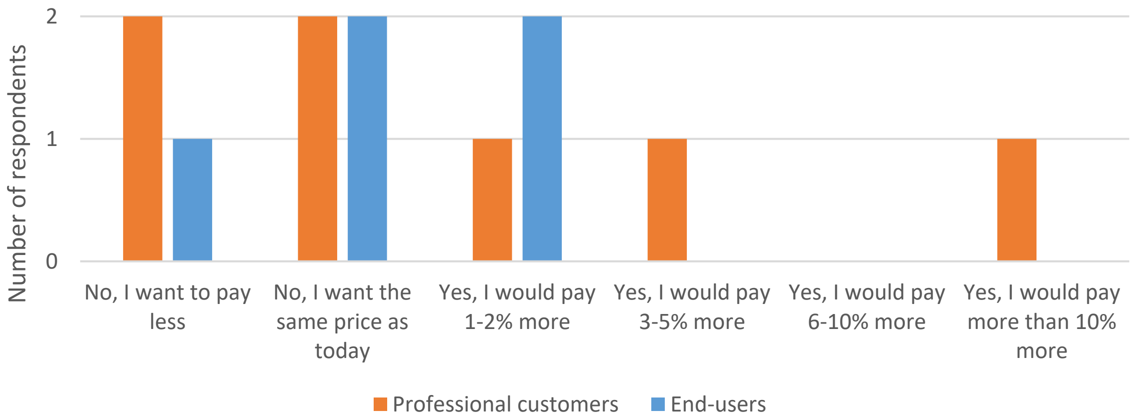


Figure 35: Willingness to pay for a greener H&C supply among customer groups (Italian demo site)

5 professional customers don't have enough information about comfort service agreements to identify any risks or benefits. 2 thinks that it would improve the indoor climate and make it easier as they don't have to care for maintenance or management of the system. Identified risks relate to potentially increased cost and generally a higher risk, also for management issues. Two end-users did not perceive any benefits and one did not know. Two respondents think it would improve the indoor climate and that it would be easier as the customer only needs to pay the bill. All but one end-user thinks that there is a risk of higher cost.

Table 9: Perceived risks and benefits towards receiving a high level of servicification by respondents in Italy

	Benefits	**Risks**
Professional customers	Don't know Better indoor climate Easier (no maintenance or management)	Don't know Increased cost Increased risk and management issues
End- users	Better indoor climate Easier (only pay the bill) Don't know No benefits	Higher cost Don't know

All end-users in Italy would like to receive their space heating and/or cooling as a commodity whereas the professional customers opinion are divided in favour of receiving it as a service or as a commodity (Figure 36). Since end-users perceive increased service to results in a higher bill and professional customers generally are not aware of benefits towards increased service, customers need more information. 7 respondents want someone else to manage maintenance of the H&C equipment.

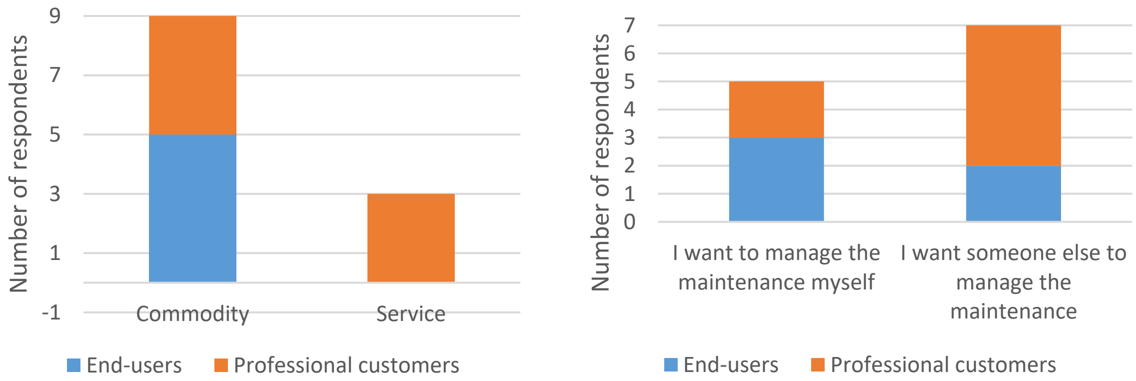


Figure 36: (Left) Customers propension to receiving space heating and/or cooling as a commodity or service. (Right) Customers wanting to manage the maintenance of H&C equipment themselves or as a service.

7.5.2 Aspects of comfort

67% of respondents think that having a comfortable indoor temperature is the most important factor in relation to indoor climate. Two professional customers think that having an evenly distributed temperature is the most important factor and one end-user thinks that noise is the most important factor. Rating the factors one by one as displayed in Figure 37, floor temperature is the least important, especially among end-users. Air quality, air flow and noise were rated between important and very important for both end-users and professional customers.

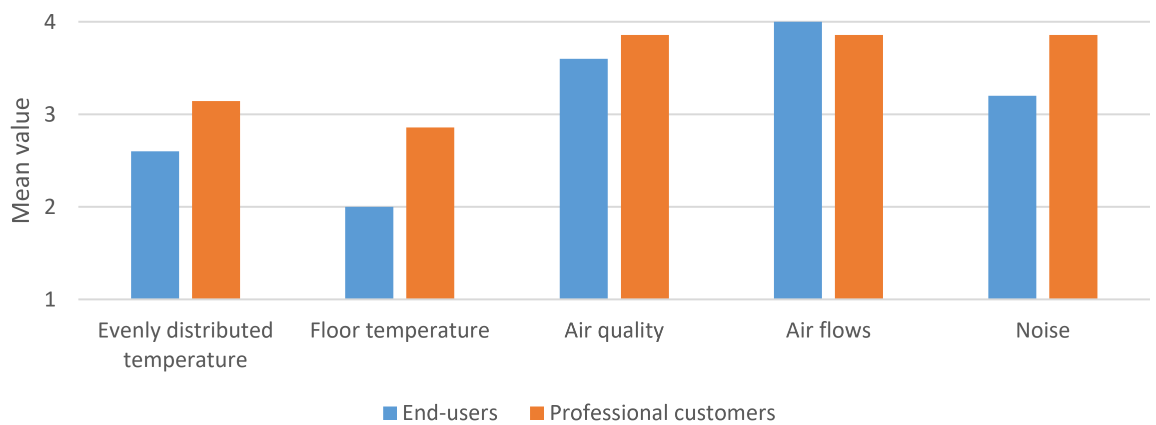


Figure 37: Importance of indoor climate factors (Italian demo site). The respondents could choose on a 4-degree Likert-scale were 1= not important and 4= very important.

Professional customers have a somewhat lower preferred indoor temperature than end-users (21.7 and 21°C respectively). The accepted deviation for professional customers is 1.6°C on average and for end-users 2°C, visualized in Figure 38.

Figure 38: Mean preferred indoor temperature and accepted deviation from preferred temperature (Italian demo site)

One professional customer did not express any flexibility with regards to indoor rooms that were less important from an indoor climate perspective. The other respondents agreed that the garage was less important and 67% thought that the basement was less important. 50% of respondent also thought that the bedroom was less important. Only one respondent said that the kitchen was less important.

Results, displayed in Figure 39, with regards to temporality of comfort demand among respondents in Italy is that space heating is very important during the evening and hot water should always be available. Space cooling is more important for end-users during the day and evening whereas for professional customers it is either equally important or more important during the evening and night.

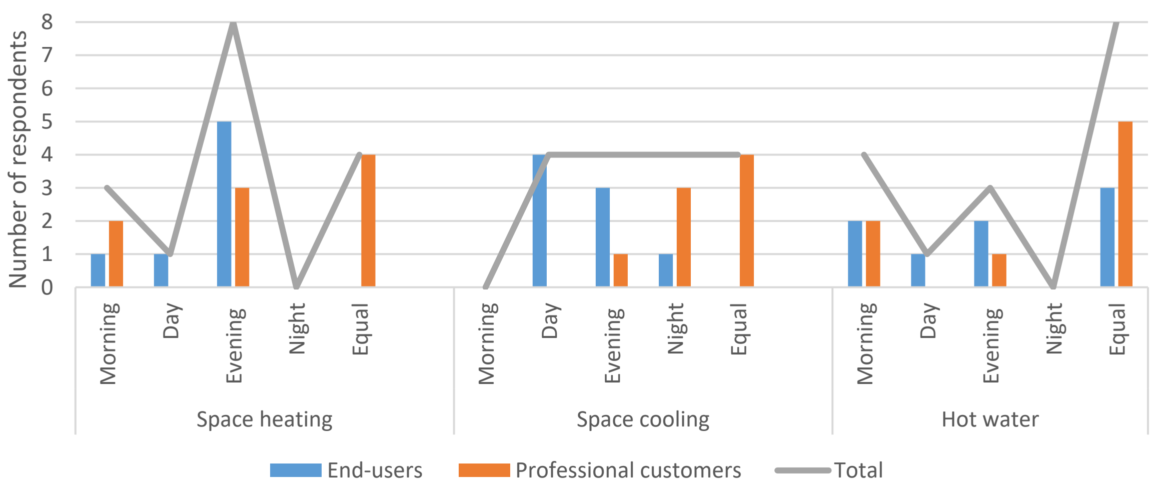


Figure 39: Temporality in comfort demand by customers (Italian demo site)

7.6 Sweden

7.6.1 Contractual desirables

Five respondents think that the cost of H&C is very important. All respondents want to be able to impact their cost (for examples by incitement-based pricing). Five respondents want to pay the same price as today even if the supply of heat was greener. Three respondents would be willing to pay a few percentages more (Figure 40).

Three respondents did not know, and one did not foresee any benefits of receiving a high level of servicification through a comfort service agreement. More information about benefits is required to convince customers. Three respondents did not foresee any risk, two did not know and two saw a risk being that increased service would become more expensive (Table 10).

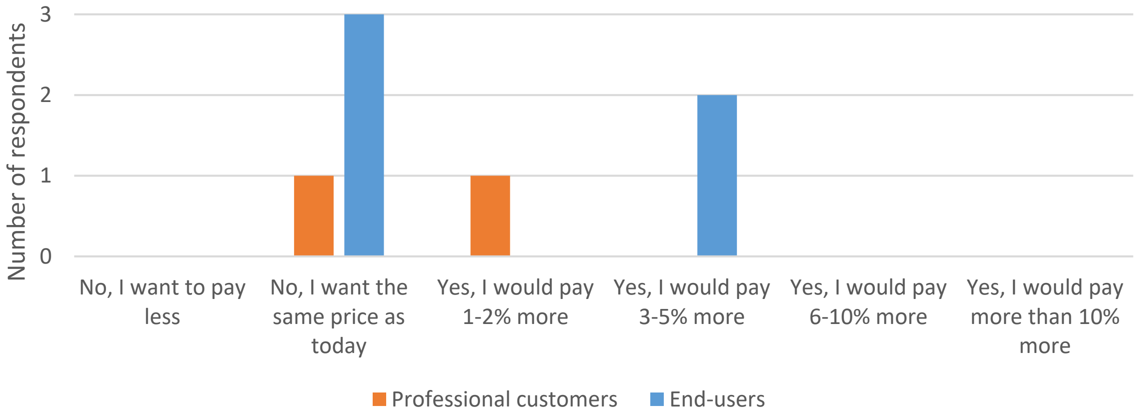


Figure 40: Willingness to pay for a greener H&C supply among customer groups (Swedish demo site)

Professional customers did not see any benefits with a comfort service agreement. 3 end-users did not know about any benefits, one end-user saw fixed price as a benefit and one thought that the system would be better optimized. The professional customers either saw no risk or did not know. 2 end-users did not perceive any risks, one did not know and two saw a risk in that it would be more expensive.

Table 10: Risks and benefits toward receiving a high level of servicification by respondents in Sweden

	Benefits	**Risks**
Professional customers	None	None Don't know
End- users	Don't know Fixed price System better optimized	More expensive None Don't know

One end-user would prefer to receive their space heating and/or cooling as a service, all others preferred to pay for it as a commodity. All end-users want someone else to manage the maintenance of the H&C equipment and both professional customers prefer to manage the equipment by themselves (Figure 41).

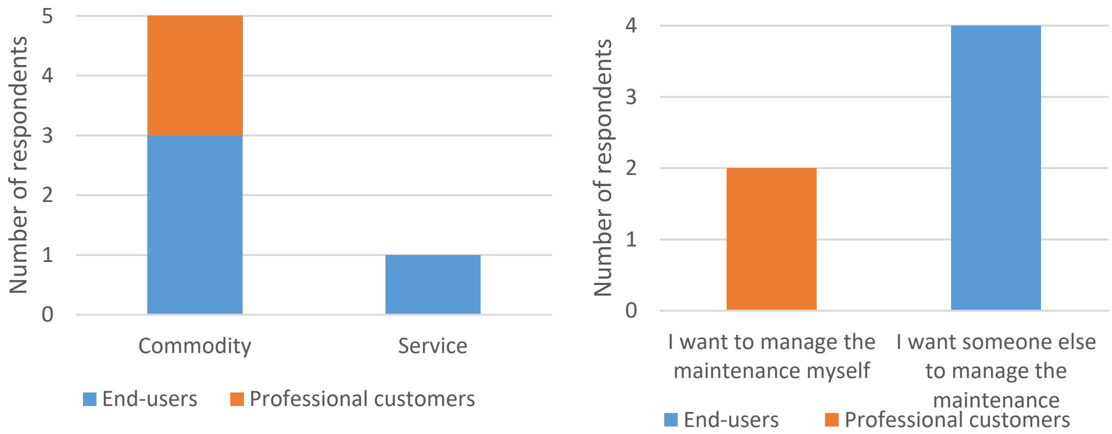


Figure 41: (Left) Customers propension to receiving space heating and/or cooling as a commodity or service. (Right) Customers wanting to manage the maintenance of H&C equipment themselves or as a service.

7.6.2 Aspects of comfort

Having a good air quality is the most important factor in relation to indoor climate for respondents in Sweden. Looking at how customers rated the factors individually in Figure 42it is noticeable that air quality is again very important. Avoiding drafts and noise is also important to very important to both customer groups. Floor temperature is less important to both customer groups.

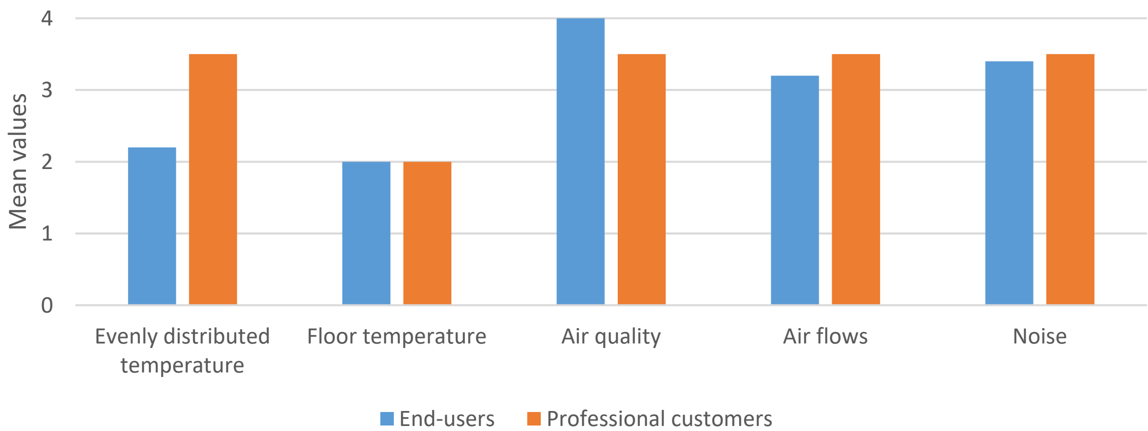


Figure 42: Importance of indoor climate factors (Swedish demo site). The respondents could choose on a 4-degree Likert-scale were 1= not important and 4= very important.

On average both customers groups think that an indoor temperature of around 21 °C is optimal. Professional customers have a somewhat larger tolerance of temperature deviation than end-users, but again similar (Figure 43).

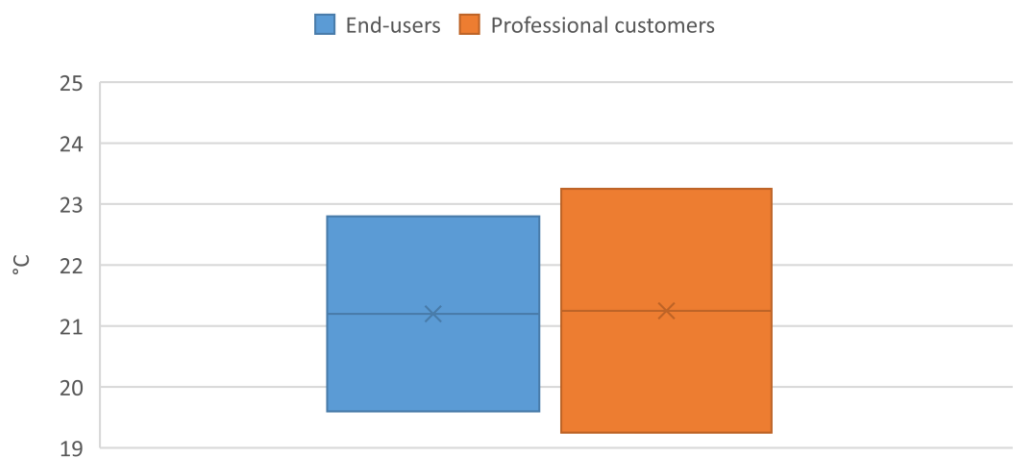


Figure 43: Mean preferred indoor temperature and accepted deviation from preferred temperature (Swedish demo site)

Two respondents show no flexibility in comfort demand between rooms. 5 respondents agree that the garage and basement are less important with regards to indoor climate.

Respondents in Sweden indicate that the services that can be provided by a DHN is equally important throughout the day for most customers (Figure 44). Space heating is more important in the morning and evening, space cooling is more important during the day and hot water is more important in the evening.

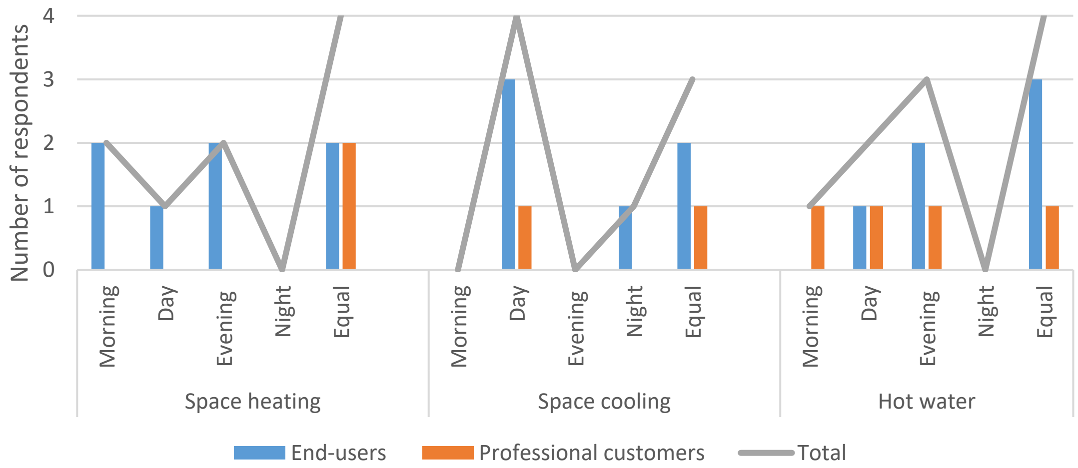


Figure 44: Temporality in comfort demand by customers (Swedish demo site)

7.7 Netherlands

7.7.1 Contractual desirables

83% of respondents think that the cost of H&C is very important. All but one respondent wants to be able to impact the cost (for examples by incitement-based pricing). 5 out of 9 end-users want to pay less or the same price as today even with a greener H&C system, 3 end-users are WTP a few percentages more and one is WTP more than 10% more. Professional customers want the same price or very little higher (Figure 45).

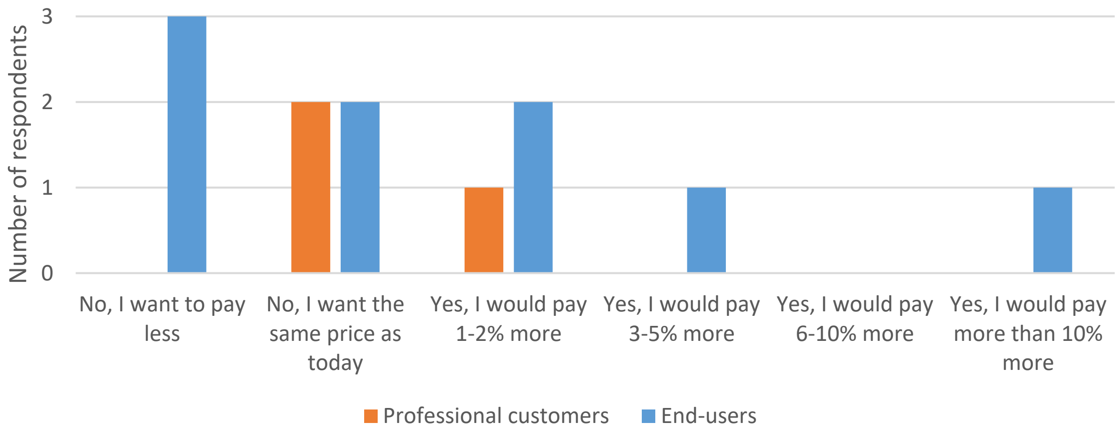


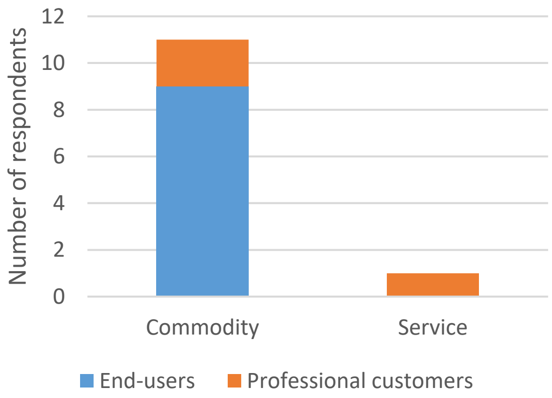
Figure 45: Willingness to pay for a greener H&C supply among customer groups (Dutch demo site)

Professional customers identify the benefit of a comfort service agreement as shared risk and increased comfort. One professional customer saw no benefits. Identified risks are that it will be more expensive and reduce the incentive to save energy. All end-users either saw no benefits of a high level of servicification or did not know. Most did not know what possible risks could be but some perceived that it would be more expensive (Table 11).

Table 11: Risks and benefits toward receiving a high level of servicification by respondents in Netherlands

	Benefits	**Risks**
Professional customers	Shared risk Increased comfort No benefits	More expensive Reduced incentive to save energy
End- users	No benefits Don't know	More expensive Don't know

All end-users in Netherlands would like to receive their space heating and/or cooling as a commodity whereas the professional customers opinion are divided in favour of receiving it as a service or as a commodity (Figure 46). Given that customers generally perceive that the resulting cost will be higher with increased service and do not know or do not perceive any benefits it is reasonable that customers would like to receive H&C as a commodity.



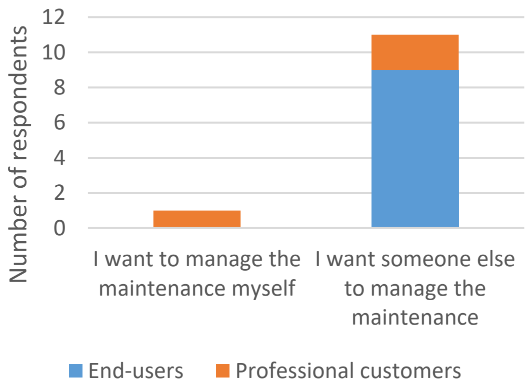


Figure 46: (Left) Customers propension to receiving space heating and/or cooling as a commodity or service. (Right) Customers wanting to manage the maintenance of H&C equipment themselves or as a service.

7.7.2 Aspects of comfort

Most customers think that having a comfortable indoor temperature is the most important factor in relation to indoor climate. Two end-users prioritized air quality and one end-user thinks floor temperature is the most important.

Looking at how customers rated the factors individually in Figure 47 it is noticeable that having an evenly distributed temperature is the least important, followed by floor temperature. Especially for professional customers, end-users rated floor temperature as important to very important. Air quality, air flow and noise were rated between important and very important for both end-users and professional customers.

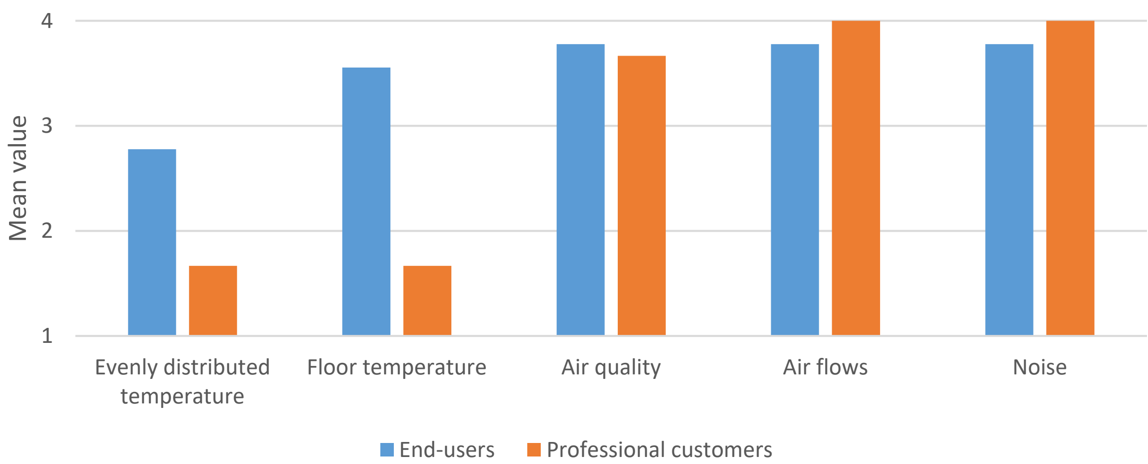


Figure 47: Importance of indoor climate factors (Dutch demo site). The respondents could choose on a 4-degree Likert-scale were 1= not important and 4= very important.

Professional customers have a marginally lower preferred indoor temperature than end-users (21 and 21.3 °C respectively). The accepted deviation for professional customers is 1.7 °C on average and for end-users 1.8 °C, visualized in Figure 48.

Figure 48: Mean preferred indoor temperature and accepted deviation from preferred temperature (Dutch demo site)

Only one end-user answered that all rooms were equally important. Respondents thinks that the garage, basement and bedroom are less important with regards to indoor climate.

By investigating customers attitude on being flexible with space heating, space cooling and hot water it is found that different services are more important to customers during specific times of the day (Figure 49). Space heating is most important during the evening and less important during night. Space cooling is important throughout the day but especially during daytime. Hot water is less important at night, but most customers find it to be equally important throughout the day.

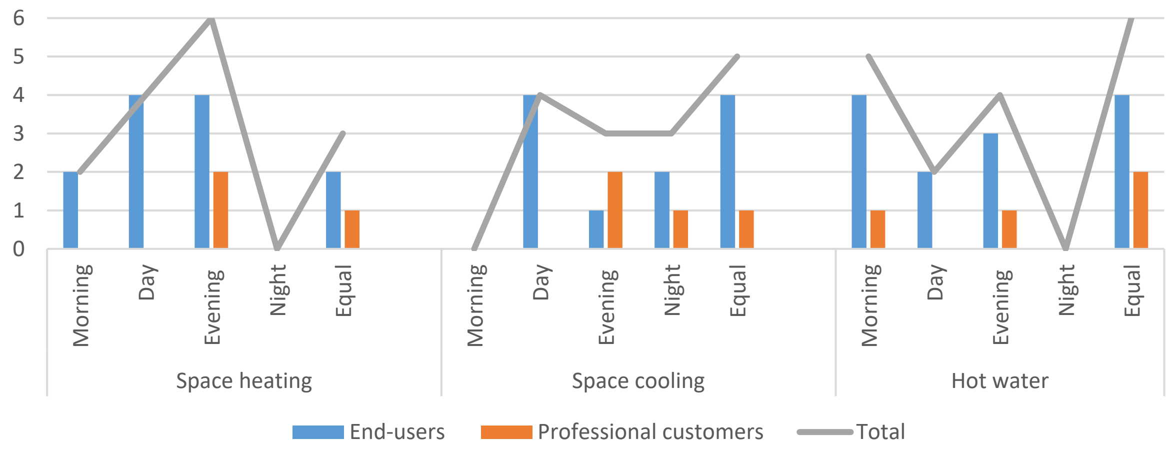


Figure 49: Temporality in comfort demand by customers (Dutch demo site)

8 Annex: Survey

Social acceptance and comfort factors of REWARDHeat technologies

IVL Swedish Environmental Research Institute (IVL) is carrying out the "REWARDHeat" research project co-financed by the European Union within the H2020 Program of the European Union under the financing agreement n. 857811.

The scientific purpose of this research is the development of a strategy for the implementation of more efficiency district heating and cooling networks. The purpose of conducting this survey is to understand the customers perspective of the REWARDHeat solutions. Interviews are conducted with building owners and residents that are connected to or foreseen to be connected to the REWARDHeat demonstration site. Interviews are performed during Spring 2020. Estimated completion time is 20 minutes.

IVL in Sweden is the responsible partner for this interview and will be assisted by local partners in 7 European countries collecting the respondents for the interview in the respective country.

Thank you for participating! Learn more about the EU funded REWARDHeat project here: https://cordis.europa.eu/project/id/857811

Processing of personal data

Purpose and time of processing

IVL will allow a respondent to access, modify and erase the submitted information during the response period. After participation, but during the response period, IVL might also communicate necessary personal data with the relevant local partner in order to avoid irrelevant response reminders from the local partner to the respondent.

When the form is completed by all respondents in all 7 countries, i.e. when the response period has ended and the form is closed for modifications, the information provided in the form by the respondent will be used in the EU funded REWARDHeat project to reach the project objectives and deliverables in an anonymous form. The respondent's email address will be deleted from IVL's systems.

Processed personal data

Email address, country of residence and other personal information included in the submitted information (e.g. type of accommodation).

Basis of processing

IVL will process personal data during the response period with the respondent's clearly given, and informed consent. The respondent has the right to withdraw the consent at any time contacting IVL on the e-mail address below.

Recipients of personal data
IVL does not transfer the personal data submitted to IVL to any third party other than the local partner in the respondent's country.

Other
For more information about how IVL process personal data, please contact Joakim Torén (joakim.toren@ivl.se) and Nathalie Fransson (nathalie.fransson@ivl.se). *Required

1. Email address *

2. CONSENT *

Mark only one oval.

- [ ] By selecting this checkbox, you consent to IVL Swedish Environmental Research Institute's use of your personal data (e-mail address, country of residence and other data submitted using the form) to allow you to access, modify and erase your submitted data during the response period, and to ensure that you will not receive irrelevant response reminders. You may withdraw your consent at any time.

REWARDHeat

Customer profile

3. Are you a building owner or resident? *

Mark only one oval.

- [ ] Building owner (professional customer)
- [ ] Resident (potential end user of district heating and/or cooling)
- [ ] Other:

4. What kind of building do you live in/own? *

Mark only one oval.

- ◯ Separate house
- ◯ Apartment building
- ◯ Tertiary building
- ◯ Other: ____________

5. How well do you know how a district heating and/or cooling system works? *

Mark only one oval.

	1	2	3	4	
I don't know what it is	◯	◯	◯	◯	Very well

6. Is your home/your building connected to a district heating and/or cooling system today? *

Mark only one oval.

- ◯ Yes
- ◯ No
- ◯ I don't know

7. If yes, what services do you receive from the district heating and/or cooling system?

Tick all that apply.

- ☐ Space heating
- ☐ Space cooling
- ☐ Hot water
- ☐ I don't know

Other: ☐ ____________

8. If no, how is your heating and/or cooling and hot water supplied today?

Your opinion of District Heating and/or Cooling Systems

9. What is your general opinion of district heating and/or cooling systems? *

Mark only one oval.

	1	2	3	4	
Very negative	◯	◯	◯	◯	Very positive

10. Are district heating and/or cooling systems common in your country? *

Mark only one oval.

- ◯ Available in most cities
- ◯ Available here and there
- ◯ Uncommon
- ◯ Non-existing

11. How much of the fuel mix in your country´s district heating and/or cooling system is fossil fuels? (Guess if you don't know) * *Mark only one oval.*

0 1 2 3 4 5 6 7 8 9 10

0 %												100 %

12. District heating and/or district cooling is a convenient option for space heating and/or cooling and hot water. *

Mark only one oval.

	1	2	3	4	
I don't agree					I agree completely

13. District heating and district cooling is a resource efficient option for space heating and/or cooling and hot water. * *Mark only one oval.*

	1	2	3	4	
I don't agree					I agree completely

14. District heating and district cooling is a cost-efficient option. *

Mark only one oval.

	1	2	3	4	
I don't agree					I agree completely

15. Do you consider your local district heating and/or cooling supplier to be transparent (fair/honest)? * *Mark only one oval.*

Yes

No

There is no local district heating and/or cooling supplier

Other:

Technology awareness

16. Have you heard about low temperature district heating and/or cooling systems*? *Low temperature systems have a supply temperature of less than 60 °C. Compared to conventional systems the heat losses are reduced and low temperature renewable and excess heat sources can be easier integrated into the system. *

Mark only one oval.

Yes

No

17. Have you heard about the low temperature district heating project (REWARDHeat project) in your local community? * *Mark only one oval.*

Yes

No

18. If yes, where from?

19. What benefits do you believe comes from having a low temperature district heating and/or cooling system? *

20. What risks do you perceive from having a low temperature district heating and/or cooling network? *

21. Compared to a conventional district heating system, how do you think the energy bill of district heating/cooling will be affected by having a low temperature system? * *Mark only one oval.*

- More expensive
- Less expensive
- Same cost

22. Do you know of any district heating and/or cooling systems with excess heat* recovery and/or renewable energy sources (e.g. solar energy, geothermal energy? *Heat that would otherwise be wasted, from example air conditioners, cooling systems, refrigerators. * *Mark only one oval.*

Yes- with excess heat recovery

Yes- with renewable energy sources

Yes- with both excess heat recovery and renewable energy sources

No

23. What benefits do you believe come from including excess heat and/or renewable energy sources in the district heating and/or cooling system? *

24. What risks do you perceive from including excess heat and/or renewable energy source in the district heating and/or cooling system? *

25. How do you think the energy bill of district heating and/or cooling will be affected if excess heat and/or renewable energy is included in the district heating system? *

Mark only one oval.

- More expensive
- Less expensive
- Same cost

Contractual desirables

26. How important is the cost of heating and/or cooling to you? *

Mark only one oval.

	1	2	3	4	
Not important					Very important

27. Would you like to receive space heating and/or cooling as a comfort service agreement (e.g. receive fixed temperature interval for a fixed price) or as a commodity (pay per consumed energy volume)? * *Mark only one oval.*

- Service
- Commodity

28. How desirable would it be for you to pay a fixed cost to receive a specified indoor climate (e.g. fixed temperature interval)? * *Mark only one oval.*

	1	2	3	4	
Not desirable					Very desirable

29. Do you want to be able to impact your heating and/or cooling cost (incitement-based pricing)? * *Mark only one oval.*

Yes

No

30. Do you want to manage the maintenance of technical equipment for heating and/or cooling yourself or not? * *Mark only one oval.*

Iwant to manage the maintenance myself

I want someone else to manage the maintenance

31. Do you have the option to receive heating and/or cooling as a comfort service agreement today? (Receiving the energy as a service instead of paying per consumed energy volume) * *Mark only one oval.*

Yes

No

Idon't know

32. What benefits do you foresee with a comfort service agreement? *

33. What risks do you foresee with a comfort service agreement? *

The green value

34. How concerned are you about the impacts of climate change? *

Mark only one oval.

	1	2	3	4	
Not concerned					Very concerned

35. Are you considering climate change impact when you use energy for heating and/or cooling? *

Mark only one oval.

Yes

No

36. Do you believe that the forecasted effects of climate change are uncertain? *

Mark only one oval.

Yes

No

37. Do you believe that including excess heat and renewable energy sources in district heating and/or cooling systems is beneficial for the environment? * *Mark only one oval.*

- Yes
- No

38. Would you pay more for a greener (less greenhouse gas emissions) heating and/or cooling system? * *Mark only one oval.*

- No, I want to pay less
- No, I want the same price as today
- Yes, I would pay 1-2% more
- Yes, I would pay 3-5% more
- Yes, I would pay 6-10% more
- Yes, I would pay more than 10% more

39. What would be the driving motivation for you to reduce your energy use? *

Mark only one oval.

- Economic reasons
- Environmental reasons
- Other:

Aspects of comfort

40. What factor related to indoor climate is the most important to you? *

Mark only one oval.

- Comfortable indoor temperature
- Evenly distributed temperature in all living spaces
- Floor temperature
- Avoiding air flows
- Quality of air
- Noise
- Other:

41. What do you consider to be a comfortable indoor temperature (°C)? *

42. How much deviation from your preferred indoor temperature would you accept? *

Mark only one oval.

- 0 °C
- +/- 1 °C
- +/- 2 °C
- +/- 3 °C
- +/- 5 °C

43. Are there any indoor rooms that you consider to be LESS important with regards to indoor climate? *

Tick all that apply.

- [ ] Bedroom
- [ ] Kitchen
- [ ] Bathroom
- [ ] Living room
- [ ] Dining room
- [ ] Basement
- [ ] Garage
- [ ] Equally important

Other: [ ] ____________________

44. How important is having an evenly distributed temperature in all living spaces to you? *

Mark only one oval.

	1	2	3	4	
Not important	◯	◯	◯	◯	Very important

45. How important is security of supply of heating and/or cooling to you (the constant availability of heating/cooling and hot water)? * *Mark only one oval.*

	1	2	3	4	
Not important	◯	◯	◯	◯	Very important

46. How important is the floor temperature to you? *

Mark only one oval.

	1	2	3	4	
Not important	◯	◯	◯	◯	Very important

47. How important is the indoor quality of air to you? *

Mark only one oval.

	1	2	3	4	
Not important	⬭	⬭	⬭	⬭	Very important

48. How important is it for you to avoid drafts? *

Mark only one oval.

	1	2	3	4	
Not important	⬭	⬭	⬭	⬭	Very important

49. How important is it for you to avoid noise from heating and/or cooling equipment? *

Mark only one oval.

	1	2	3	4	
Not important	⬭	⬭	⬭	⬭	Very important

50. Is SPACE HEATING more important to you during some parts of the day *

Tick all that apply.

- [ ] Morning
- [ ] Day
- [ ] Evening
- [ ] Night
- [ ] Equally important

Other: [ ] ____________________

51. Is SPACE COOLING more important to you during some parts of the day *

Tick all that apply.

- ☐ Morning
- ☐ Day
- ☐ Evening
- ☐ Night
- ☐ Equally important

Other: ☐ ______________________

52. Is HOT WATER more important to you during some parts of the day *

Tick all that apply.

- ☐ Morning
- ☐ Day
- ☐ Evening
- ☐ Night
- ☐ Equally important

Other: ☐ ______________________

53. In relation to heating, cooling and hot water systems, are there any other factors or considerations that are especially important to you?

____

____

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