DISTRHEAT

Digital intelligent and scalable control for renewables in heating networks

Deliverable 7.1

Report on the results from the questionnaire for evaluation of how customers respond to heat storage in their buildings with varying temperature

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Executive summary

This document describes the development, distribution and evaluation of a questionnaire that was addressed to end users of apartment buildings in Västerås. A description of the considerations for developing the questionnaire, as well as practical information on the distribution is provided. The results of the questionnaire are presented and analyzed. Conclusions on the levels of satisfaction and possible shortcomings with respect to the present operation of heating systems are drawn. Different perceptions of thermal comfort and ideal levels for indoor temperature are assessed. Evaluation of acceptance levels for a future control system that promotes indoor temperature flexibility is attempted. Finally, directions and requirements for the development of a smart control system are derived.

1. Introduction

Social acceptance and adaptation are key elements for penetrating smart control technologies into the future district heating system. To do this, it is required that the shortcomings of present systems are identified, and the potential perception of thermal flexibility is evaluated. Flexibility shall be assigned around a specific baseline; therefore, a definition of comfortable indoor temperature levels shall be explored. Besides environmental and economic benefits (Saletti et al., 2020, Saletti et al., 2021), smart control comes with associated responsibilities for the end users. Evaluation of the present awareness levels, and possible needs for further incentivization are essential.

2. Development and distribution of questionnaires

2.1. Development

The main considerations for developing the end-user questionnaire are listed as follows:

- Balanced demographic representation.
- Balanced educational and income levels.
- Target apartment buildings where higher impact is expected.
- Assessment of present satisfaction levels and indoor temperature variations.
- Identification of comfort standards and subjective perception of comfort.
- Evaluation of potential flexibility margins and operational requirements.

It is noted that demographic questions were only included for evaluating the distribution of responses. Answers to the questionnaire were anonymous and no individual details were by any means collected.

An introductory piece of text is provided at the beginning of the questionnaire to explain the scope and motivate respondents about the need for indoor temperature flexibility and smart control.

The questionnaire comprises 13 questions in total, out of which 5 are demographic- or status-related, and 7 are multiple choice questions, to allow for easy and consistent completion by the respondents. One question is of free-text type to allow respondents to express perspectives that are not covered through the set questions. It was deemed important to provide a questionnaire that can capture dense information, while at the same time achieving high response rates.

The questionnaire is developed collaboratively between Mälardalen University and Mälarenergi, with support from Mimer AB.

The specific questions will be presented in section 3, along with the corresponding answers.

2.2. Distribution

In past works by Mälardalen University and Mälarenergi, it was found that paper-based questionnaires receive very low response rates, whilst imposing high administrative and environmental overheads. Therefore, the questionnaire was distributed in digital form to maximize response rate.

Mimer AB, which is one of the largest housing providers in the region, handled the distribution to their tenants. The questionnaire was released on their website to filter out any non-relevant responses from a mass digital release. Tenants were electronically notified twice.

3. Results

A total of 305 individual responses were received which is deemed to be satisfactory for the purpose of this study. It is noted that 98% of the responses represent tenants living in apartment buildings which is the target group for this control technology.

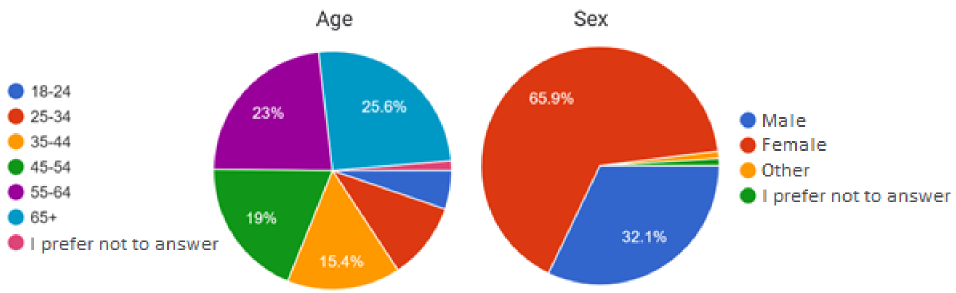

Figure 1: Demographic details about respondents.

Demographic information on respondents is presented in **Fig. 1**. It is shown that a relatively balanced representation of different age groups has been achieved. In terms of sex, approximately two thirds of the total sample are females.

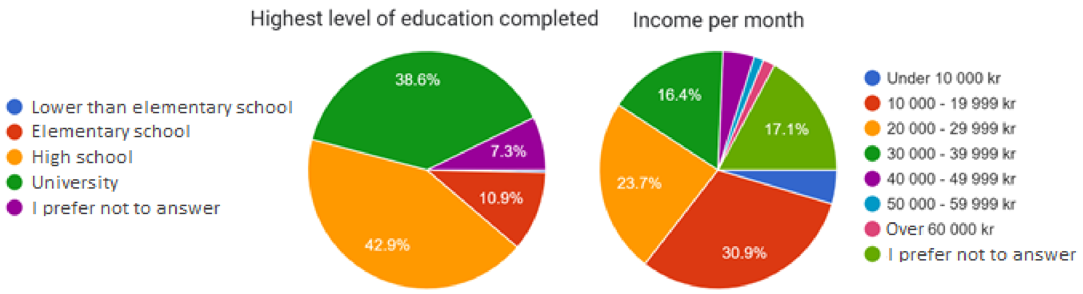

Figure 2: Educational and financial status of respondents.

More than 38% of the respondents have completed a university degree and a total of more than 80% have been through high school, as per **Fig. 2**. The level of education does not relate to the perception of comfort or environmental awareness. A similar disclaimer can be drawn with respect to monthly income levels, where a relatively balanced representation has been achieved.

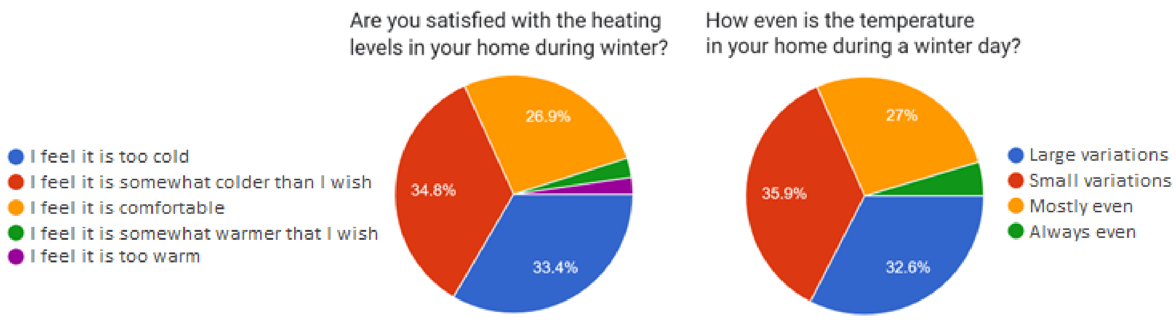

Figure 3: Satisfaction rates about present heating levels and indoor temperature variations.

It is observed that approximately 68% of the respondents feel that heating levels are lower that what they would like in their apartments, as shown in **Fig. 3**. Only 26% of the respondents find that heating levels are comfortable, whilst a minuscule percentage considers present heating levels as warmer than it should be. This is an indication of not satisfactory comfort levels for the end users. However, this does not necessarily mean that the housing company has deliberately decided to provide low heat levels. Housing companies in Sweden are required by law to provide at least 21 degrees to all tenants and usual setpoints imposed by operators are in the range of 21 to 22 degrees. The present architecture of heat control schemes does not directly account for indoor temperature variations, neither as a feedback stream nor as a predictive stream. Therefore it is concluded that a smart controller that accounts for indoor temperature, as well as operating parameters of the heating system and weather forecasts would be required to address this issue.

Figure 4: Perception of comfort indoor temperature by the respondents.

Comfortable indoor temperature levels can be perceived differently by individuals. As shown in **Fig. 4**, more than 57% of the respondents would prefer a temperature between 21- and 22-degrees during daytime. This gives directions for the operation of present and future control systems for space heating.

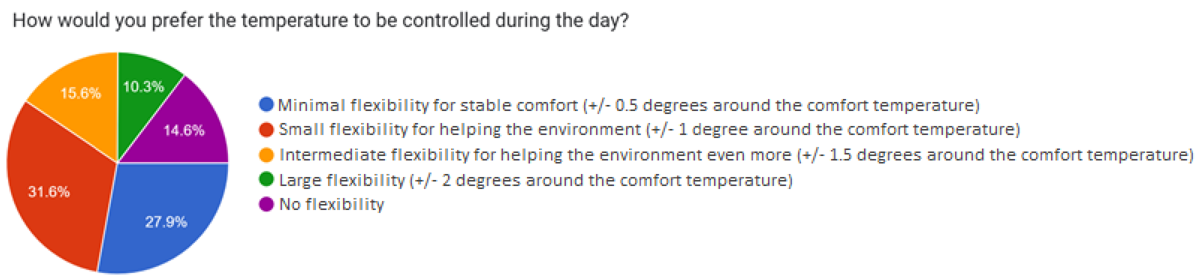

Figure 5: Impression on indoor temperature flexibility during daytime.

Indoor temperature flexibility during the day allows for a more resilient heating system and potential energy and economic savings for the tenants, housing companies and the heating network. The potential benefits of flexibility on the environment have been particularly emphasized in the introduction of this questionnaire. It is observed that around 59% of the respondents would prefer minimal or small flexibility margins, i.e., between 0.5 and 1 degrees around the above-defined comfort levels, as shown in **Fig. 5**. About 25% of the respondents would opt for intermediate to high flexibility for helping the environment while 14% of the end users would not accept any flexibility. The relatively conservative flexibility preferences are attributed to the low levels of satisfaction with regards to present heating conditions.

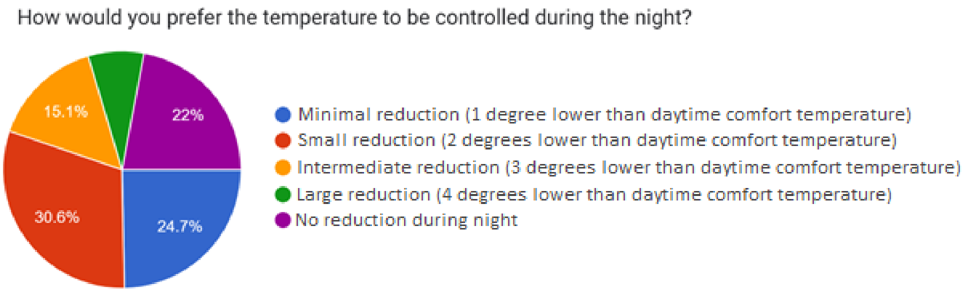

Figure 6: Impression on indoor temperature flexibility during nighttime.

Wider reduction margins would be allowed by tenants during nighttime. As shown in **Fig. 6**, more than 55% would prefer a reduction of 1-2 degrees relative to the comfort temperature indicated for daytime. No reduction was suggested by 22% of the respondents, while the rest would allow higher reductions. Therefore, incorporation of night setbacks in a smart control system would be perceived positively by the majority end users.

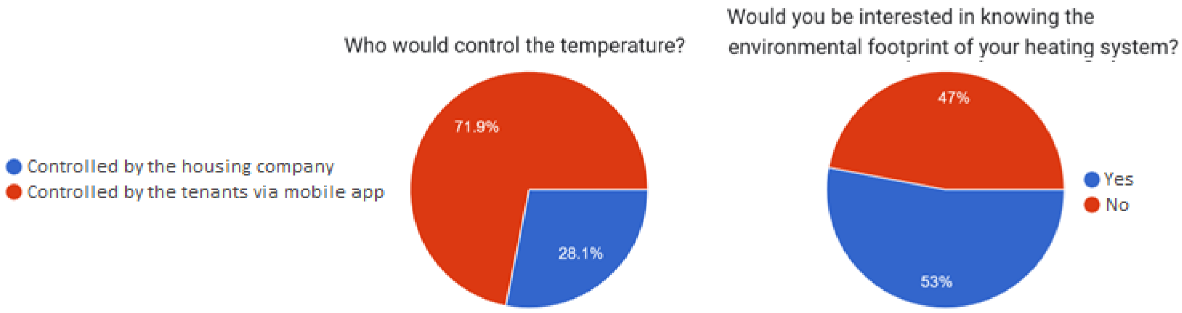

Figure 7: Individual responsibility and environmental awareness.

Almost 72% of the respondents would prefer to take control of the indoor temperature setpoint in their buildings, which depicts the low levels of trust to the heating managers, at least under the present arrangement. However, this appears contradictory to the environmental awareness when it comes to the footprint of such a solution: only 53% of the respondents would be interested to know the impact of their heating system on the environment, as per **Fig. 7**. Social engagement is indispensable towards a smart district heating system, therefore further information and motivation is required for realizing this transition.

Further to the questions above, 66 free-text inputs were received. Selected inputs are provided in **Table 1** below.

Table 1: Selected free-text inputs from the respondents of the questionnaire.

I have coolers in the bedrooms (turned down the elements) but do not want coolers in the rest of the apartment.
If you have to pay for your own heating, you must also be able to control it.
Radiator thermostats are missing, but it would be desirable so you can have, for example, 1-2 degrees cooler in the bedroom.
It is around 18 degrees here according to my own measurement in the middle of the rooms, I experience it very cold during the day. At night I pull down the element in the bedroom. Always wear woolen clothes and socks and blankets on the sofa. Therefore, it is difficult to predict what flexibility would be like.
Old elements in the apartment that cause the temperature to vary between the rooms.
We have a minimum of 22° in winter. In summer we "must" use AC. The temperature is between 25° and 28° despite blackout curtains and blinds.
An insight into the function of the heating system and dialogue with the property owner, about measures for stable heat/comfort, is desirable.
The ventilation system has big variations during the winter, it feels like it's blowing cold out of the ventilation.
Why should we control the temperature with a mobile app? Not everyone has a mobile phone that can be used for that. I simply want a thermostat that can be set to the temperature I'm comfortable with, but also be able to regulate the ventilation, because strong drafts affect how cold it feels inside, which a thermometer can't show.
Dry indoor environment.
Property manager Mimer could start by replacing the old manual radiator valves, adjusting the flows and installing maximum-limited thermostats, if the heating costs are to be reduced. There are, like, large overshoots of the room temperature if the sun is shining. But as far as the "energy crisis" is concerned, property heated by district heating is not the biggest problem. A CHP production must cool off the excess heat, and this is done via the district heating system to which this property is connected.
Much is about limiting the maximum output from the district heating network. Partly because it costs a lot to produce district heating for the peak load hours in the morning when everyone gets up and shower and, in the evening, when everyone comes home from work, and partly because the subscription fees are controlled by the maximum power taken and by the district heating water flow through the subscriber's heat exchanger. It is suggested that the temperature of the water to the radiators be lowered by a couple of degrees between 06.00-09.00 and 17.00-21.00, as hot water consumption is greatest then. It lowers the plant's maximum output power. Pumping water around in a district heating network costs a lot and for that reason a flow fee is charged. I wish my landlord Mimer understood the point of reducing the flow of the radiator water in the heating system by half and raising the control curve so that warmer water goes out to the radiators. The same output on the radiators, but significantly larger Dt and thus significantly reduced flow fees to pay and reduced disturbing noise from the heating system.

It is observed that besides heating, cooling is often required, especially in the summer months. The need for modern equipment and smart control solutions is depicted by the end users. Some relative conservativism is attributed to the low levels of satisfaction with respect to the present heating systems. Some apartments are warmer than needed, therefore the need for reducing indoor temperatures is also present. The impact of ventilation systems on indoor temperature levels appears to be significant. Besides outdoor weather conditions, ventilation is rendered as an extra term to be accounted for in the design of smart control schemes.

4. Conclusions

A digital questionnaire was developed and distributed to apartment end users in Västerås. The majority of respondents are not satisfied with the operation of the present heating systems. Although positive to an improved solution, they appear reluctant to accept high flexibility margins due to low levels of satisfaction and trust the current operations. Indoor temperatures between 21 and 22 degrees are suggested to be preferred as baseline comfort levels during daytime. An associated flexibility of up to +/-1 degree would be allowed by the majority during daytime. A night setback of up to 2 degrees would be preferred during nighttime. Although tenants seem positive in participating in the definition of daily temperature setpoints, low levels of environmental awareness are observed. It is concluded that end users would be positive to adopt a smart control system with conservative levels of flexibility, however further information and motivation would be required to incentivize and increase environmental awareness.

List of references

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