Thermo-staat

NWO EINDRAPPORTAGE

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1 Introduction

30 heat waves have been measured in the Netherlands since 1911, 14 of which have occurred in the past 20 years (KNMI). Also in the future it is predicted that summers will be with longer and more extreme heatwaves. More high temperatures will lead to more physical and mental health concerns, such as sleep deprivation, reduced labour productivity, and reduced efficacy of some medications (RIVM, 2023). Although these effects are universal, elderly or physically vulnerable people, e.g. with pre-existing medical conditions, are the most affected. Cultural and economic factors also come into play when it comes to improving heat resilience. People with lower incomes generally have less opportunities to reduce indoor heat, because they lack the financial resources or because they live in rented houses and need to rely on housing corporations/private landlords to act (Zuurbier et al, 2024).

Two recently published reports about heat in dwellings (Kluck et al, 2023) and (de Vries, 2024) in The Netherlands show that main risk factors for overheating are the window area through which sun enters the dwellings and the possibilities for night time ventilation. Among Dutch dwellings apartments with unshaded window exteriors and large window panes are most vulnerable.. The reports also show that high level of insulation and airtightness, lead to high entrapment of heat during a day and many hours with temperatures above 25 degrees, which is generally regarded as overheating. Also, it highlights the crucial role of the tenant of the apartment in maintaining comfortable temperatures. The two most efficient ways to keep one's apartment cool is the use of outdoor blinds and intensive ventilation when the outside temperature is lower than the inside temperature (usually at night).

Citizens themselves can play a vital role when it comes to heat adaptation. ,Increased awareness about heat and general interest in measures against heat could help to adapt effectively to urban heat. The difficulty lies in developping a method to get the public actively involved. Brager and Dear (1997) show that the thermal adaptation in the built environment is influenced by how actively the participants interact with their surrounding through multiple feedback loops. Ziegler et al. (2019) show that involvement of the citizens in the process of research and implementation of solutions in a low-income neighbourhood increased trust in the results of academic research and also enhanced the research by uncovering local knowledge. Also disseminating the knowledge and the acceptance of suggested solutions was improved by involving the community from the beginning of the research. Similar results were found by Guardaro et al. (2020).

The importance and benefits of participatory research has been shown in the Netherlands for other aspects than heat as well. For example, in the case of transition away from natural gas to more sustainable options, Teladia & van der Windt (2024) show that a low participatory environment can hinder engagement and implementation of measures. They conclude that sharing information and implementing feedback of the local communities were crucial for the successful engagement of the broader public. On top of that, they show that presence of the energy companies during the process was a key success factor, as it brought a transparency to the process and facilitated citizen power in decision-making. Similarly, Abrahamse et al (2007) show the importance of giving households insight into their energy consumption by installing a measurement tool and throughout the measurement period give (personal) feedback to make people more aware of their energy behaviour.

1.1 Research objectives

In the Thermo-staat project we investigate the potential of citizen science as a way to increase the adaptation capacities of general public. This research was initiated from four standpoints: 1) heat in apartments is a serious issue and is going to become even more important in the future, 2) occupants play a crucial role in maintaining a comfortable temperature in their own apartments or houses during summer, 3) participatory research can contribute to better acceptance of (heat related) measures suggested by government or academia/experts and stronger ownership of the issue itself, and 4) participatory research can lead to a better understanding of local consequences of climate change. Based on these aspects, the main research question in the Thermo-staat project was formulated as follows:

How can we use community creation and citizen science to make people more aware of and more adapted to "heat in apartments as a consequence of climate change"?

This question was then divided into two sub-questions:

1. What are effective choices in order to build a successful community using citizen science and citizen-oriented journalism around the problem of indoor heat?
2. To what extent does the chosen approach contribute to more insight into scientific knowledge/facts (climate literacy) of the participants and of the general public?

This project aims to contribute to the emerging research field of citizen science / urban climate adaptation by drawing on the wisdom of the crowd by creating a platform to which citizen scientists can contribute with sensor data (temperature, humidity), report on the impact of heat stress on their personal lives, discuss efforts to mitigate the effects and take collective action.

In this project, citizens are involved as experts of their own living environment. With this form of citizen science, we aim to gain more insights into how citizens experience their environment during hot days, to achieve a greater ability to act and to improve climate literacy among them. The citizens join forces with scientists from TU Delft ('TU') and Amsterdam University of Applied Sciences ('AUAS'), investigative journalists at VPRO Argos ('VPRO'), and experts from Waag Futurelab ('Waag'). Together they investigate which characteristics of the dwelling and its surroundings influence the occurrence and perception of heat stress, and what adaptation strategies can be employed. This project explores an innovative form of science communication by forming a community around the subject of heat in apartments. *Thermo-staat* opens up the scientific and journalistic process by deploying citizen scientists to monitor an urgent climate issue, putting them in direct contact with involved scientists via a community platform and at the same time contributing as a co-producer to the journalistic communication of their research.

1.2 Project history

The Thermo-staat project as conducted by VPRO, Waag, AUAS and TU Delft is built on previous scientific work as well as journalistic and citizen science projects around community building and heat stress. In the summer of 2021, Ties Gijzel, a freelance journalist at VPRO Argos, conducted independent research into heat stress. Due to the enormous response from the VPRO audience he decided to further explore the topic. He founded a collaboration with Waag who could build sensing technology to measure temperature in houses and a data platform where the collected data could be visualised and made available to download. In the meantime, they also conducted research into online platforms in order to get in touch with the community and do co-creative journalism based on citizen science. For this, the platform Kenniscloud (see also 2.3.1.) was tested in a predecessor of the Thermo-staat project at the beginning of 2022. Later that year, the actual Thermo-staat project was started, but the time it took to develop the technology meant that we would only be able to measuring at a large scale (100 households) in the summer of 2023. Before that, we ran a test group in the autumn of 2022 to improve the technology and methodology used.

2 Methodology of the project

In order to answer the research questions about 1)effective choices in order to build a successful community while making use of citizen science and citizen-oriented journalism around the problem of indoor heat and 2) how the chosen approach contributes to more insight into scientific knowledge/facts (climate literacy) of the participants and of the general public, the project follows a multi-pronged approach. In this project robust datasets are created, potential story leads are developed and communities actively engaged on a the topic of indoor heat, that will most likely have a growing impact on people's well-being in the near future. In this way the project aims to create an understanding of climate change and an agency for citizens to act.

The main research approach was to support participants in measuring the temperatures in their homes during a heat wave and to provide them with the possibility to view the measured data and to relate their situation to the situation of people in their neighbourhood. In line with Waag's citizen sensing approach (see Making Sense toolkit, 2018), residents were included in all stages of the research process. Furthermore, an important element to increase involvement with the subject was to interview the participants in order to collaboratively create journalistic productions and therewith reach and represent a broader group to inform about living in hot spots. With the creation of online platforms, these journal articles could be produced, information about urban heat and effective measures could be shared and the collected data has been visualized on the website. The combination of the project website and the data visualisation fosters transparency, accessibility, and engagement in the project's research and findings. By providing users with easy-to-navigate tools and comprehensive information, we aim to promote public understanding of heat stress in the built environment and encourage informed decision-making. Several workshops were held with participants to explain the research setup and the measurement of data. By interviewing the participants before and after the measurements, the effect of participating in the research on their awareness of scientific knowledge and facts (climate literacy) about urban heat and climate change was investigated. The results of the surveys were compared with a reference group that represents 'the general public'. Via this way we could research how effective active involvement in measuring is to better understand the local effect of more extreme temperatures because of climate change. In the following paragraphs the choices and methods are described.

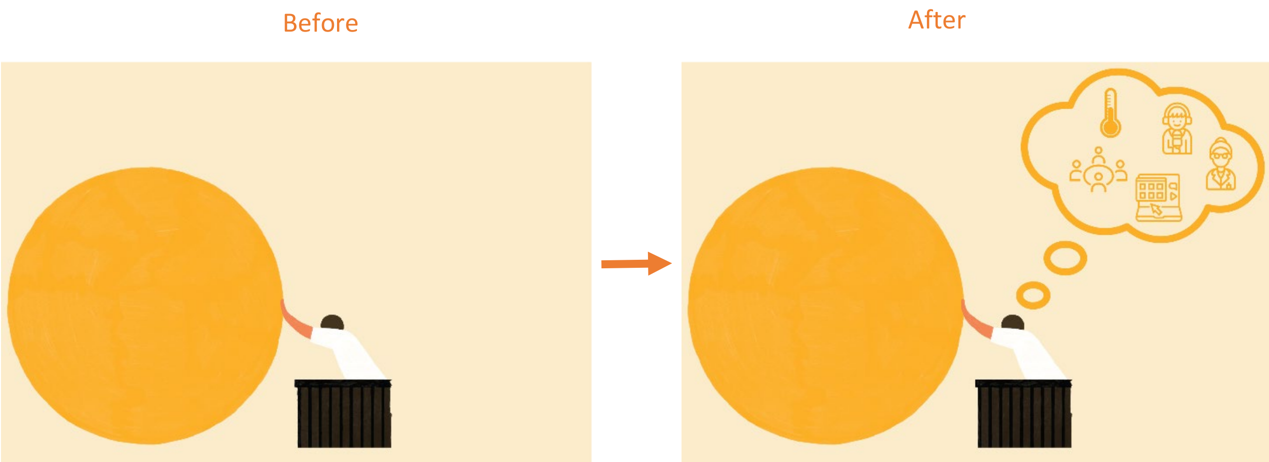


Figure 1. Schematic overview of set-up of this research project: we have not improved the situation of the residents but aim to provide more knowledge and insight and therewith more involvement and awareness which might lead to a greater ability to act.

In the following paragraphs, different (methodological) elements are described:

1. locations
2. communities
3. online platforms
4. measurements
5. surveys

2.1 Choice of locations

In this project we aimed to find diverse citizen scientists that are either location-based (e.g. in the same apartment building or neighbourhood/district) and/or are living in similar houses (in terms of ownership, insulation, building type, orientation etc.). These criteria were set to be able to compare both quantitative and qualitative data between dwellings; too many variables would yield statistically irrelevant results. Second, we aimed to reach a balanced group of 60-70% social housing/rented units and 30-40% owner-occupied properties. To reach this group of people, we approached housing corporations and tenants' associations to assist in finding a suitable location and have access to a large group of tenants. Eventually, we managed to secure three locations with similar characteristics. Two building complexes in IJmuiden and one in Amsterdam. The buildings in IJmuiden were found via a call through the Woonbond, the biggest tenants' organization in the Netherlands that offers advice, support and information to tenants and home seekers. The Huurdersraad Velsen (a tenants' council active in IJmuiden) responded to this call with the suggestion to measure in two newly built locations from the Woningbedrijf Velsen, a housing association from IJmuiden. The complex in Amsterdam was found through Huurders Ymere Amsterdam (HYA), the tenants' organisation of Ymere, a housing association that offers social and private rental housing in the Amsterdam Metropolitan Area.

2.1.1 Description of the buildings

The first location in IJmuiden consists of four residential blocks which were built in 2018. Three blocks with a total of 78 rental homes, falling under the project name UNIC. The fourth block contains thirty owner-occupied apartments and three commercial spaces. They all have the same characteristics in terms of (façade) layout, window percentage, insulation values, and energy systems. Figure 2 shows that the window percentage of the apartments in relation to the façade is high (between 60-70%). Some windows are placed under an overhang that prevents direct sunlight from entering. The apartments on the top floor have skylights. Also here, no outdoor blinds have been installed and the sun shines in all day long.

The second location is the Nieuwe Orion, see figure 3. The apartments on this site were built in 2021 and consist of three residential blocks; the first has 21 owner-occupied apartments over 6 floors, the middle building has 28 social rental apartments over 8 floors, and the last building contains 45 social rental apartments over 10 floors. The layout of the apartments is similar with one big living room and open kitchen, 2 or 3 bedrooms and a balcony. Also these apartments have big windows, with a window percentage between 60-70%. The windows are unshaded, with some exceptions below balconies of the floor above.

Figure 2. UNIC complex in IJmuiden

Figure 3. The Nieuwe Orion complex in IJmuiden

In Amsterdam, measurements have taken place in the Westerkaap complex. This complex was built in 2008 and is situated along the IJ river. It consists of 2 complexes of eight connected towers of different heights. 30 percent of the houses is social housing, 15 percent private rent and 55 percent owner-occupied. The variation in home ownership has also led to different types of layouts of apartments. The social housing apartments do not have outdoor blinds on the outside and only have internal balconies, more like a glass-walled part of the apartment, or a balustrade in front of their big windows (see also figure 4). The owner-occupied apartments do have outdoor blinds attached on the outside. This was done through a joint purchasing campaign organized by the owner's association (VVE).

Figure 4. Westerkaap Complex in Amsterdam. On the right you see the social housing (without sunblinds) versus owner occupied housing (with sunblinds)

As previously shown in the research of NKWK (2023), apartments with the aforementioned characteristics, i.e. large glazing ratio, limited to no outdoor blinds and well-insulated and airtight, are amongst the most vulnerable when it comes to accumulation of heat during summer. Buildings with these features should reduce heat gain from the outdoor environment through the opaque building envelope components, but also retain the trapped heat indoors longer, which creates the risk of overheating during extreme and longer heatwaves. If the indoor space is not well ventilated or there are no possibilities of cross-ventilation (because of one facade apartments) or lack of mechanical air conditioning, this risk increases. This vulnerability is exacerbated by the fact that many of those apartments are social housing units whose tenants do not have the possibility to implement structural measures against heat (e.g. placing outdoor outdoor blinds) or cannot afford to install mechanical ventilation.

2.2 Communities

During the whole Thermo-staat project we involved three different communities: a test group consisting of friends and family living across the Netherlands in different types of houses, the measurement group residing in the selected measurement locations in Amsterdam and IJmuiden who installed a sensorkit in their homes, and a broader community of Heethoofden (Hotheads), involved through the VPRO and the online platform Kenniscloud. Due to the scientific value of measuring in houses with similar characteristics, we made an explicit choice not to reach out to the Heethoofden community on Kenniscloud or our test group, who had both been involved prior to the summer of 2023, because of various housing types. In the following paragraphs elaboration of reaching and communication of three different communities will be found, in order of time.

2.2.1 Heethoofden community

In the summer of 2021, VPRO Argos launched Thermo-staat with a series of online stories about people suffering from heat stress. They covered a.o. the story of Levi, a 27 year old tenant who occasionally in summer needed to flee to his bathroom and sit in the shower with his dog in order to escape the heat in his house. He spoke about feeling powerless, angry and even depressed, not being able to sleep at night or to focus during the day. Levi was one out of >100 people who contacted VPRO about heat in their houses, thereby showcasing a significant problem.
Throughout the summer of 2021 a community was established which resulted in a network of 140 Heethoofden joining the project. These people were brought together in the winter of 2021/2022 to test different online platforms for co-creative journalism and climate story-telling, in a lead-up project to Thermo-staat. Through this testing phase with Heethoofden the platform Kenniscloud was chosen, resulting in a Heethoofden community existing on this platform.
Due to the time needed to build and test the technology we were not able to start measuring at a large scale in the summer of 2022. This meant that the Heethoofden community was not activated again until 2023. Moreover, due to the measuring strategy focusing on specific apartment buildings, it was not possible to crowdsource the Heethoofden for the citizen sensing aspect of the project. We have distributed 20 sensorkits amongst the Heethoofden in order to support the continuation of the storytelling aspect.

Case Nijmegen

Through direct contact, two of the sensorkits set aside for journalistic storytelling were handed out to Daisy Petrona and her neighbour from a social housing apartment building in Nijmegen. Daisy had previously started a court case against her housing corporation about the heat in her house, attempting to prove that the temperatures rose over 26,5 degrees for more than 300 hours per year. But the pictures and data she regularly collected from her thermostat were deemed insufficient evidence by the court. Supported by her lawyer, she decided to appeal the decision and reached out to the VPRO as she had heard about the Thermo-staat project. She was able to measure from July 2023 and collaborated in storytelling via text, image, and audio, as she was featured in the Thermo-staat radio show during the September heatwave. The case is still being processed, but Daisy's lawyer thinks that the Thermo-staat data can provide enough evidence to support her case.

2.2.2 Test group

To ensure that the measurements and surveys ran smoothly during the summer of 2023, we conducted an initial test among family and friends in the fall of 2022. We tested three aspects:

1. The sensors were tested in different type of houses with different building years to see how well the sensors were working in different circumstances, e.g, insulation values, building materials, amount of rooms and therewith the distance between the sensors and controllers.
2. Feedback on the measurement technology: The test group provided feedback on the clarity of the instructions, ease of set-up, and clarity and accessibility of the data (both on-device and online). This feedback was used to improve the measurement technology before it was deployed in the summer of 2023.
3. Interviews about personal experiences with summer temperatures: The test group also provided interviews about their personal experiences with summer temperatures, measures against extreme heat, and their opinions about climate in the Netherlands and climate change in general. This information was used to develop the surveys that were administered before and after the summer of 2023.

The feedback and interviews collected from the test group were crucial for the further development of the technical and scientific aspects of the project. This information helped to ensure that the measurements and surveys were accurate, reliable, and user-friendly.

2.2.3 Measurement group

We went to IJmuiden and Amsterdam several times to distribute sensorkits door-to-door and assist with the installation and set-up. In total, we distributed 60 sensorkits in IJmuiden (9 owner-occupied and 51 social-housing) and 15 in the Westerkaap (9 owner-occupied and 6 social housing). The physical recruitment strategy meant posting flyers in and around the buildings and door-to-door campaigning. This was made possible with the assistance of the tenant's council of the Housing Corporation Velsen in IJmuiden who reached out to members of the buildings' respective residents committees (*bewonerscommissies*) who gave us access to the announcements board and hallways.

Recruitment among house-owners became more difficult because we had reached out to the owners' associations (VVEs) and one of them (from Het IJkpunt in UNIC) discouraged their members to participate in our research, meaning that we were not able to recruit any house owners in that building complex. One of the motivations for not participating was that the house owners (or the VVE as their representation) would have to make changes themselves if the research indicated certain levels of heat stress, whereas for the social housing tenants the measurements could be a tool to leverage change from the housing corporation. In the Westerkaap, we set aside some of our sensor kits to get more house owners to join the project. This way, we managed to recruit several houseowners in the Nieuwe Orion and the Westerkaap, which helped us gain a 70/30 division between social housing and owner-occupied houses.

A difficulty which stemmed from our door-to-door recruitment campaign was that later on, we were not able to reach all the people who agreed to participate and had received a sensor kit. This issue was caused by combination of potential lower motivation of the recruited people compared to the Heethoofden, who had reached out to VPRO about this issue (see section 2.2.1), and the lack of contact details other than their home address. Despite support from the tenants' council who reached out to their neighbours and were able to offer technical support and intensive efforts from the research team travelling to the locations for recruitment and technical support, third of the 75 distributed sensor kits (consisting of 3 separate sensors each) never came online.

2.3 Online platforms with and for the communities

2.3.1 Kenniscloud

Kenniscloud was introduced as a community platform that connects residents, journalists and scientists, in order for the community to co-create journalistic stories. At the beginning of 2022 VPRO and Waag conducted a co-creation design session for an online open access platform (Kenniscloud) with a representative sample from the Heethoofden community (stemming from the summer of 2021). Another reason to work with Kenniscloud, was that it is partly open-source and scored high on the ethical guidelines of the Public Stack. With feedback from the test group and the Heethoofden community, the platform for our citizen scientists was made available through the Thermo-staat website in April 2023. General community management on the platform was in the hands of VPRO in close collaboration with AUAS and Waag.

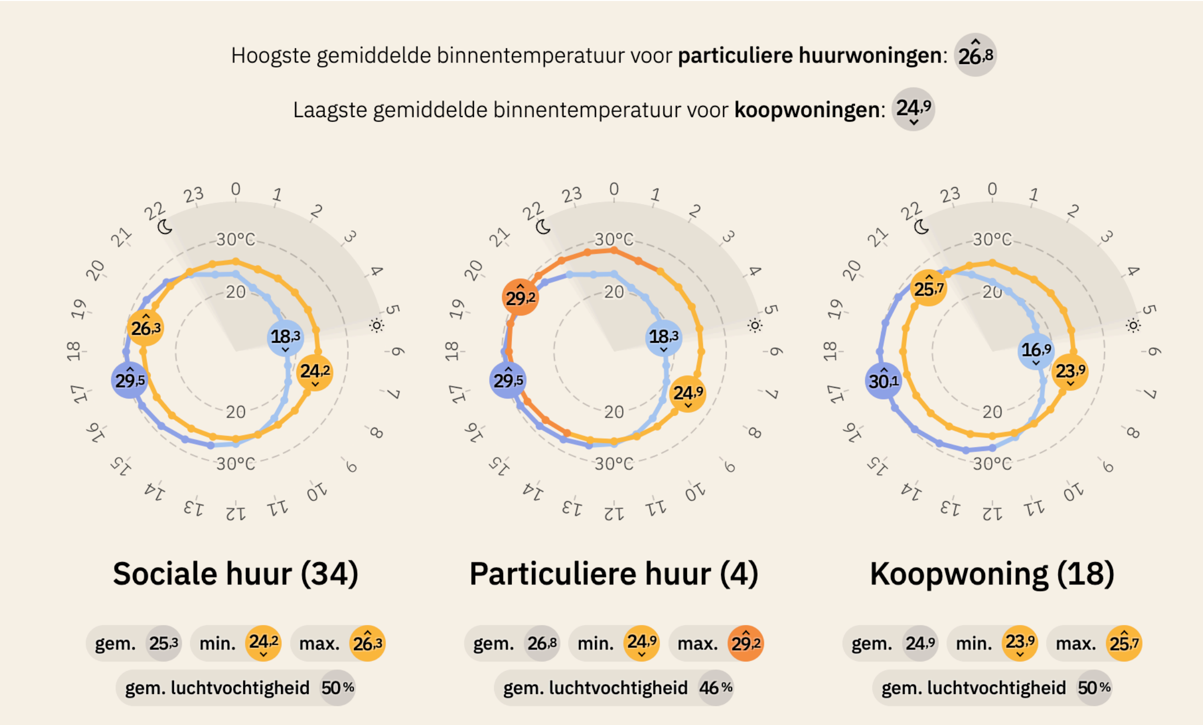
Through Kenniscloud, journalists from VPRO worked together with both the Heethoofden and the measuring community to tell stories supported by the citizen science data, see also appendix 1.

2.3.2 Website and data-visualisation

In order to enhance public access and understanding of the project's data and findings, Waag developed two comprehensive tools: a project website and a data visualisation application. The project website serves as the primary gateway for participants and the general public to gain insights into the project's objectives, updates, and outcomes. It provides a centralised hub for information dissemination, allowing individuals to stay informed about the project's progress and impact. This includes the media developed by VPRO Argos and the discussions on the KennisCloud community knowledge platform.

Complementing the project website is a data visualisation application specifically designed to empower citizens, researchers, and the general public to comprehend the vast volume of collected data, see also figure 5 for an example. This user-friendly tool enables users to delve into the data, analyse trends, and extract meaningful insights. The visualisation tool at thermo-staat.nl was co-created with some participants from the test group as well as with scientists. Participants could indicate what parameters they would like to make comparisons with between their own living situation and others. It was designed to provide insights in indoor and outdoor temperature/humidity differences between a large number of parameters (such as housing types, closeness to greenery and orientation towards the sun). The general visualisation was based on aggregated data, but we had also developed individual data dashboards for participating households.

Figure 5. Example of the Data-Visualisation Tool at the Thermo-staat website



The data visualisation application offers two distinct visualisation options:

1. Individual sensor level: Users can explore the specific data gathered from their own sensor kits, gaining a granular understanding of heat stress patterns within their homes. See thermo-staat.nl/status.
2. Aggregated visualisation: Users can manipulate an aggregated visualisation to examine heat stress conditions across various parameters, including home type, location, and room type. This empowers users to draw their own conclusions and identify trends that may not be apparent at the individual sensor level. See thermo-staat.nl/hittedata.

The website and data-visualisation are available at: thermo-staat.nl

2.4 Measurements

2.4.1 Measurement period and weather conditions

Measurements in the Thermo-staat project can be divided into two categories:

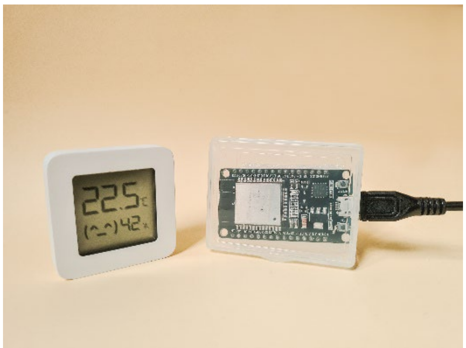
1. Measurements of temperature and humidity in the apartments. The official measurement period started in June 2023. The temperature and humidity sensors were placed in people's homes.
2. Surveys filled in before and after the summer by the measurement group. The surveys were first filled in before summer, together with placement of the measurement kits. The survey after summer was distributed amongst the general public at the beginning of October 2023 and two weeks later among the participants in IJmuiden and Amsterdam. The distribution amongst the participants was postponed till after the workshop in IJmuiden (see section 3.2.3) in order to have a better insight into the full effect of the project (including all different ways of communication) on the climate literacy.

Summer 2023 fell with an average temperature of 18.4 °C into the top-10 warmest summers since 1901 (KNMI, 2023). This was mostly due to the warmer than average June. However, July and August were average in terms of temperature, with only a few hot days in July, and many rainy days. Rainy weather then continued in August with a higher than usual precipitation rate. The only heatwave in North Holland was from 4 September till 12 September 2023. This was an unprecedentedly long heatwave for September. Nonetheless, this period was not nationally recognised as a heatwave because not all weather stations in the Netherlands measured maximum temperatures above 30°C for at least 3 days in a five-day period [reference].

2.4.2 Thermo-staat sensor kits

The criteria and placement for the used sensor kits can be found in appendix 2. Main criteria for the sensor kits were alignment with the scope of this research (e.g. ease of use for end-users and accessibility of data). Each Thermo-staat kit comprises the following components:

1. A set of thermometers (2 or 3, depending on end-user requirements): These thermometers provide accurate and reliable temperature and humidity readings.
2. A microcontroller for data collection and transmission: This microcontroller gathers data from the thermometers and sends it to the central server.
3. Adapter and cable: These components facilitate the connection between the thermometers, microcontroller, and power source.



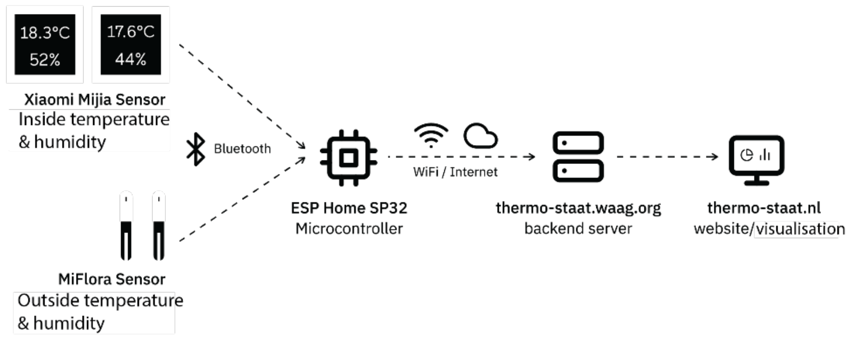


Figure 6. Sensorkits and infrastructure system used and developed in the Thermo-staat project

We conducted a pilot study involving 27 households (the test group) and both Waag office buildings to validate the effectiveness of our citizen science infrastructure. Our test group represented a diverse range of individuals in terms of age groups, cultural backgrounds, housing types (rental or owner-occupied), education levels, and familiarity with technology and heat. The test participants were instructed to install three sensor kits according to our guidelines and provide feedback through a questionnaire. The pilot study was conducted in two phases:

1. Phase 1 (10 households): During this initial phase, we identified two areas for improvement: the introductory email was overly technical, and the Bluetooth connectivity between the thermometers and microcontroller could be enhanced.
2. Phase 2 (17 households): We addressed the identified issues by revising the introductory email and providing certain households (those with multiple floors) with two microcontrollers instead of one. This additional network connectivity enabled seamless data transmission over longer distances.

General feedback received from the 27 households indicated that our technological infrastructure was highly user-friendly and accessible. This feedback validated our decision to adopt the Thermo-Staat kits as the primary measurement tool for our citizen science project. Measurement devices were left in the houses afterwards, in order to collect more data and in case of a potential follow-up project.

2.4.2.1 Measurement interval

Temperature and humidity was measured every minute and automatically backed up to the server at the same interval, depending on Bluetooth and network connection and stability. This varied per household and could even be influenced by a closed or open door. Therefore data transfer and back-ups fluctuate, and there are also gaps in the data, despite the measurement taking place every minute.

2.4.2.2 Data collection

To ensure the scientific rigour and reproducibility of our citizen science pilot, Thermo-staat meticulously collects data on a comprehensive range of parameters. This data is then processed and visualized through an intuitive interface on the project website. The parameters include outside and inside temperature, humidity based on measurements from the sensors or KNMI, as well as self-reported data of building characteristics and surroundings (see appendix 2 for the total overview).

2.5 Surveys

Climate literacy was tested based on surveys filled in among the participants (before (June) and after (October) summer 2023, see appendix 3). In addition, the same survey was distributed among the general population in October 2023 to establish a reference group, that was reached predominantly via a radio program of Argos. To investigate the aspect of climate literacy we held 10 in-depth interviews with the test group about their current level of climate literacy. The questions asked during these interviews were based on literature (Abrahamse et al., 2007; Barger and Dear, 1997). The in-depth interviews were semi-structured and topics discussed were personal background of the interviewees, their experience and perception of 'feeling' the temperature in their house, their actions and measures they take to reduce indoor temperatures and their knowledge about possible measures. Also questions about their knowledge of climate change and influence on their own environment were asked. To minimise the influence of social desirability, questions were asked openly and neutral. For example, instead of asking 'How did warmer summers influence indoor temperatures', the question was: 'How did you experience your house last summer, and has this changed compared to 10 years ago?'

The outcomes of the interviews were used as input for the in order to map the level of climate literacy before and after participating in the Thermo-staat project. In the survey respondents (both the measurement group and the reference group) were answering to 5 different groups of questions: the background information, questions about experience with heat in their apartments, about measures against heat, about their opinions, and about their knowledge of the topic. Most of the questions were in a form of multiple choice, and some additional questions were formulated as statements about which the respondents had to indicate their level of agreement.

3 Results

Results of this collaborative research between academics, journalists and citizen scientists, varies from journalistic productions, a public program and workshops, a public dataset and data analyses on indoor temperatures and climate literacy. Together these results give insight in how social-economic factors influence the perception of heat problems by the participants and how social-economic factors influence the ability of participants to act to do something about heat in and around homes. The paragraphs below describe the different results.

3.1 Journalistic productions

Throughout the measurement period the consortium worked on several journalistic productions with the measurement community and the Heethoofden community. These are published on the website of VPRO/ARGOS at: https://www.vpro.nl/argos/lees/onderwerpen/thermo-staat.html. The productions range from radio-items bringing the problem to a wider audience by elaborating on an individual story to broadcasting the research project via a radio program. See appendix 1 for an overview of the journalistic productions.

3.2 Public program and workshops

As part of the citizen science approach, two sessions have been organised in IJmuiden on participating in the project and on analysing the collected data and a public program in Amsterdam about heat stress in cities. These workshops were set up with giving information about heat stress, with an explanation of the technical concepts and language commonly used, as well as to make the voice of the participants heard. This was very valuable to identify the gap between scientific knowledge, advised practices and the lived experience, see also the following paragraphs (in order of time):

3.2.1 Information session: IJmuiden

On May 24th, we hosted an information session and informal kick-off of the measurement period in IJmuiden. Ten participants who had signed up through the flyer that we distributed in the buildings beforehand attended. We explained the project set-up, the journalistic aspect and the sensor kits. Several attendants took home multiple sensor kits to give to their neighbours as well. The main goal of the evening was to inform participants, answer their questions and also encouraged people to think about their own (research) questions. This way we could see where we could help best and focus on throughout the summer.

3.2.2 Houd je hoofd Koel: Waag Open (Amsterdam)

On August 24th the consortium hosted an evening in the Waag building in Amsterdam to talk about heat stress. This session was open to the general public and shared specifically with the measuring and heethoofden communities on KennisCloud. We talked about how heat in urban areas is constituted, what kind of maps and policies are in place to investigate hot spots and measures for adaptation. By including a thermal walk, we demonstrated how one can measure heat outdoors, and highlighted some examples of measures in the area to show what can be done to cool our cities, buildings and ourselves through changing our behaviour. We closed off with looking at the Thermo-staat data visualisation to discuss different factors that cause heat stress. More information can be found on the event page: https://waag.org/nl/event/waag-open-houd-je-hoofd-koel-verplaatstnaar-24-augustus/

3.2.3 Data workshop: IJmuiden

On the 4th of October we went to IJmuiden to host a data workshop. This event was communicated to all measuring participants beforehand via email, Kenniscloud and through flyers spread by the tenants council and residents committees in IJmuiden and Amsterdam. During this evening, seven participants, one representative from the tenants council and two from the housing corporation were present. The goal of this session was to enhance the voice of the participants: how did they experience the summer, what were their findings with the measurements and has their ability to act grown?

We discussed together the data visualisation tool (see figure 7) to learn more about heat in the homes and the possibility of drawing (scientifically relevant) conclusions based on the measurements. During the workshops it was found that, despite the relatively mild summer, temperatures above 30 degrees were measured in one of the apartments of a tenant who suggested to analyse his data live during the evening (see figure 8).

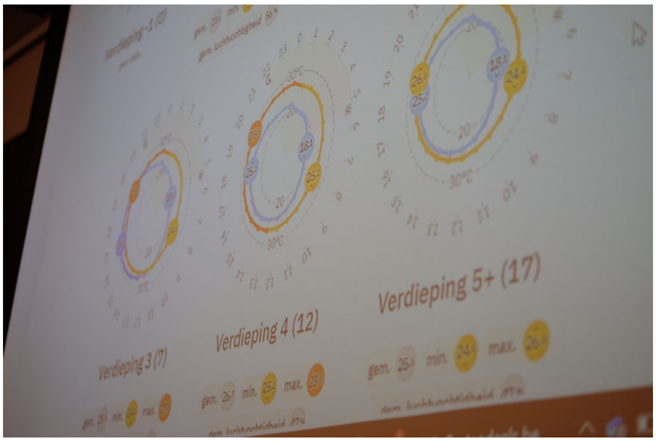


Figure 7. Presentation of data visualisation tool

Figure 8. A researcher from AUAS showing live data from a present participant

An important outcome of the session was that the participants and representatives from the housing corporation both shared the same insights and a conversation was sparked between them, moderated by the representative from the tenants' council. Some quotes from the participants in this session illustrated the impact of the Thermo-staat project as they show how awareness about indoor heat has grown (quote 1) as well as that their empowerment and credibility has increased (quote 2 and 3) (translated):

“If I hadn’t participated (in Thermo-Staat), I would never have come to the conclusion that indoor and outdoor temperatures can differ so much.”

“By participating (in Thermo-Staat) we created evidence that our heat complaints are not nonsense and I have greater credibility as a tenant.”

“I can finally prove the consistently high temperatures in the summer (in my apartment), it’s in writing (recorded) and properly measured.”

Impact Westerkaap - Amsterdam

In March 2024 one of the participants of the Westerkaap sent an email complaining about people entering his apartment to take measurements for the placement of outdoor blinds. However, a few days later (after a warm spot/spring day), he retracted his complaint and wrote that he thought it was a good idea to place outdoor blinds. Prompted by this conversation, we contacted the tenant’s council from Ymere (HYA) and asked if the placement of sunblinds was partially due to the Thermo-staat project and they confirmed this. Placement is expected in the summer of 2024.

Impact Nieuwe Orion/Unic - IJmuiden

After the data workshop in October, the participants confirmed that they felt supported by the data to continue the conversation with their housing corporation. When we checked in with the representative from the tenant’s council in April 2024, he said that they are looking forward to the results of the project in order to enter conversations with the housing corporation about the situation in the Nieuwe Orion and UNIC. The participating house owners reported that they found it interesting to participate in the research, mainly to support their tenant neighbours.

3.3 Measurement results

The data analysis and the results of the survey provide insight in how the ownership of apartments and implementation of outdoor blinds lead to lower indoor temperatures inside the same building complex. Furthermore, it has been found how participating in measuring does improve the understanding of a microclimate and which measures to take to improve thermal perception. For example, it was observed both by participants and scientists that indoor temperatures can be higher on the higher floors and that ventilation is most effective at night. For participants, some knowledge of how to act has been the outcome of insights gained from the visualisation based on measurements which has been indicated both during the workshops as well as an outcome of the surveys that were carried out as part of the climate literacy research.

3.3.1 Collected data

The main findings of the aggregated data show that temperature differences between owner-occupied apartments and social rental apartments differ significantly. Variables of floor level and outdoor blinds are also explained in further detail in this section as they show remarkable results and were often mentioned as an outstanding factor by participants. In appendix 4 a more detailed analysis of the collected data can be found.

To start with, the analysis of the available aggregated data for the full period shows that the three locations have different thermal profiles. Throughout the summer, median values for the three areas are very similar and range from 24.0 to 24.5 degrees Celsius (C). During the heat wave the differences between the three areas becomes more evident, see also figure 9. In New Orion mean hourly temperature ranges from 22C to 30.5C with a median value of 26.3C and a high number of outliers that reach up to 39C. Mean hourly temperature values in UNIC have a similar range but a lower median value around 25C, while outliers reach up to 32C. Finally, in Westerkaap mean hourly temperature values range between 22.5 and 32C with a median value of 26.4C but a low number of outliers. Generally this comparison indicates that in New Orion some of the apartments get much hotter than UNIC and Westerkaap during hot periods.

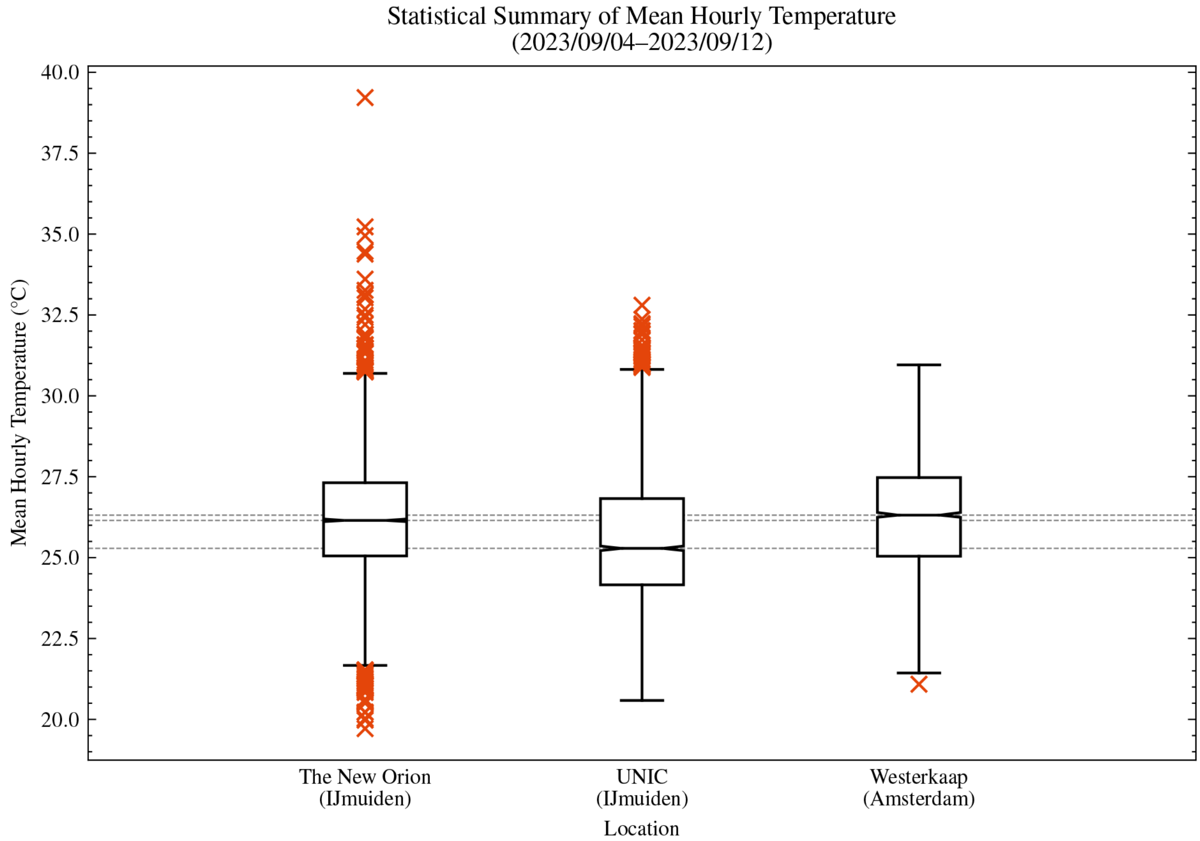


Figure 9. Mean hourly air temperature for the three locations (during a local heatwave)

3.3.2 Apartment ownership (during heat wave period)

The relation between form of living and temperatures analysed (figure 10) present a significant difference between indoor temperatures in apartments that are renter-occupied (owned by housing corporations) or that are owner-occupied, where mean hourly temperature values are generally lower in owner-occupied apartments. In New Orion and Westerkaap the median values are between 25.3C and 25.7C in owner-occupied apartments while the median values increase up to 26.5C and 26.9C in apartments for social renting. In addition to around 1 degree difference in the median of hourly temperature values, a difference of 2 degrees Celsius can be observed in the maximum mean temperature. In fact, without considering the outlier values, the maximum mean hourly temperature increases from around 29C in owner-occupied apartments to around 31Cin social rental apartments. This is expected to be related to the outdoor of the owner-occupied dwellings; a measure lacking for the renter-occupied dwellings.

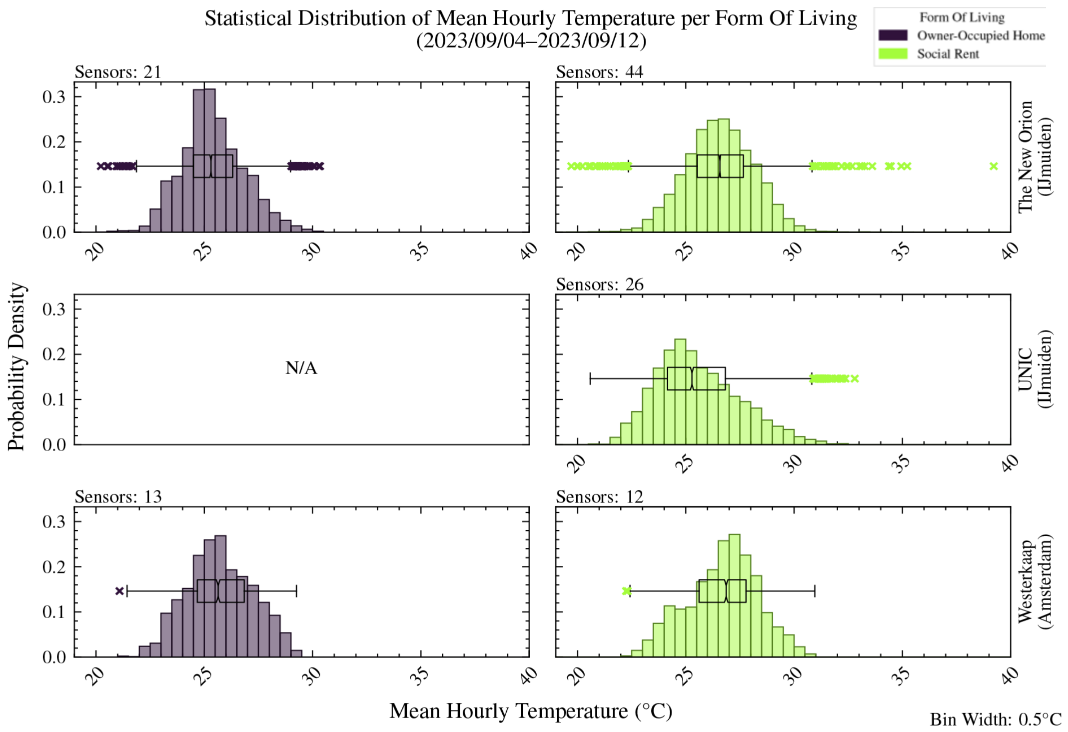


Figure 10. Frequency of mean hourly air temperatures per form of living

3.3.3 Floor level (during heat wave period)

Another factor that was mentioned by the participants is the relation between indoor temperature and the vertical position of the apartment. Participants discovered this themselves by comparing their data and experiences with other participants. Participants were able to ventilate at better times on higher floors, because the outside temperature was lower than the inside temperature there, compared to lower floors. The data analysis confirms higher temperatures and greater fluctuation on higher floors. Data are collected in apartments placed between floor 0 and 5 in New Orion, at floor 0,1,3 and 4 in UNIC and at floor 4 and 5 in Westerkaap (Figure 11). In UNIC and Westerkaap the mean hourly temperature gradually increases with height, i.e. from 24.9C on the ground floor to 26.6C on the fifth floor in UNIC and from 25.5C on the fourth floor to 26.6C on the fifth floor in Westerkaap. For the New Orion this pattern is less clear. The plotting of temperature data classified per floor (Figure 12) highlights low variability of mean temperature values at the ground floor, first and second floor except for the second floor in New Orion. A higher variability in temperature can be observed in apartments placed at floor 4 and 5 which might be explained by higher exposure to sun radiation due to different orientations of the apartments.

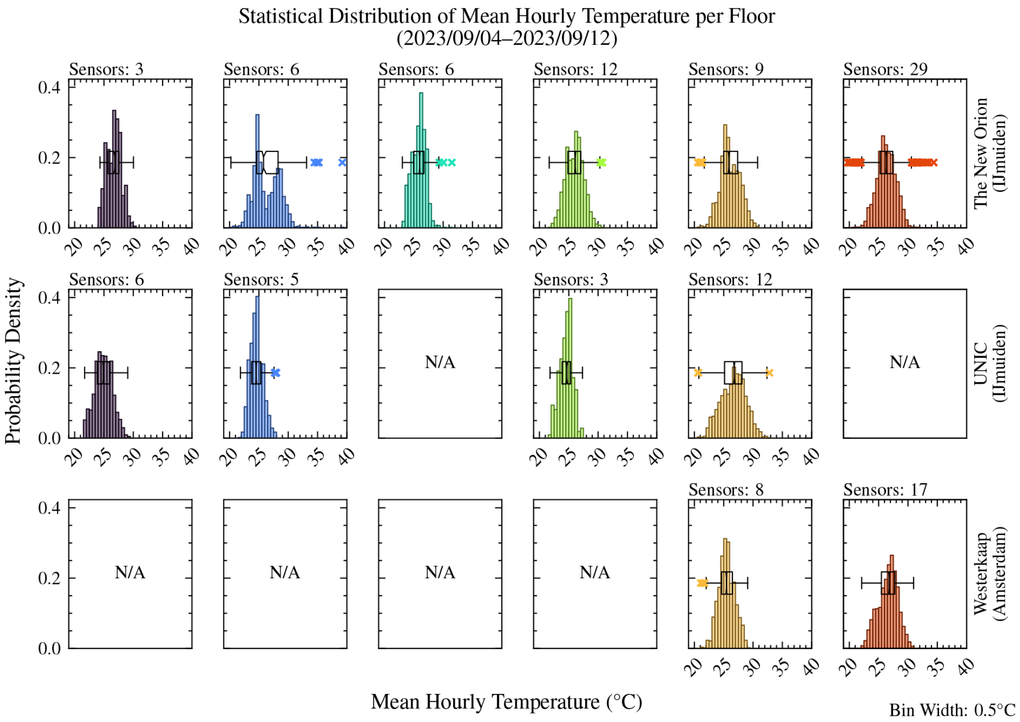


Figure 11. Frequency of mean hourly air temperature per floor (colours correspond to figure 12).

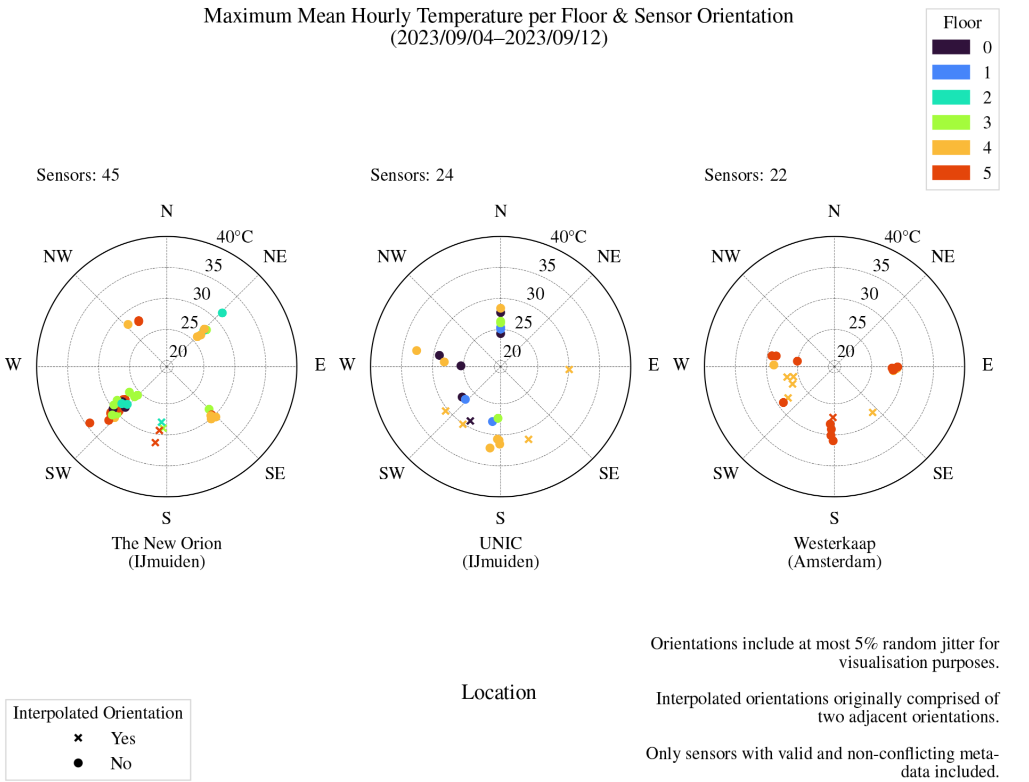


Figure 12. Mean hourly air temperature per floor plotted according to the sensor/room orientation

3.3.4 Outdoor blinds (during heat wave period)

Sunlight entering the house can significantly contribute to higher indoor air temperatures and is therefore seen as a favorable measure by the participants. Keeping the sun out can be achieved either with measures outdoors (e.g., exterior screens, awnings, blinds, or shutters) or indoors (e.g., closing the curtains), or a combination of both. In New Orion and Westerkaap, some of the apartments had outdoor blinds (in both cases around 15-20%), in the UNIC apartment blocks only indoor sun protection was reported. In all three locations over half of the measured rooms were reportedly without any form of sun protection (missing data in the image below means no sun protection) (Figure 13).

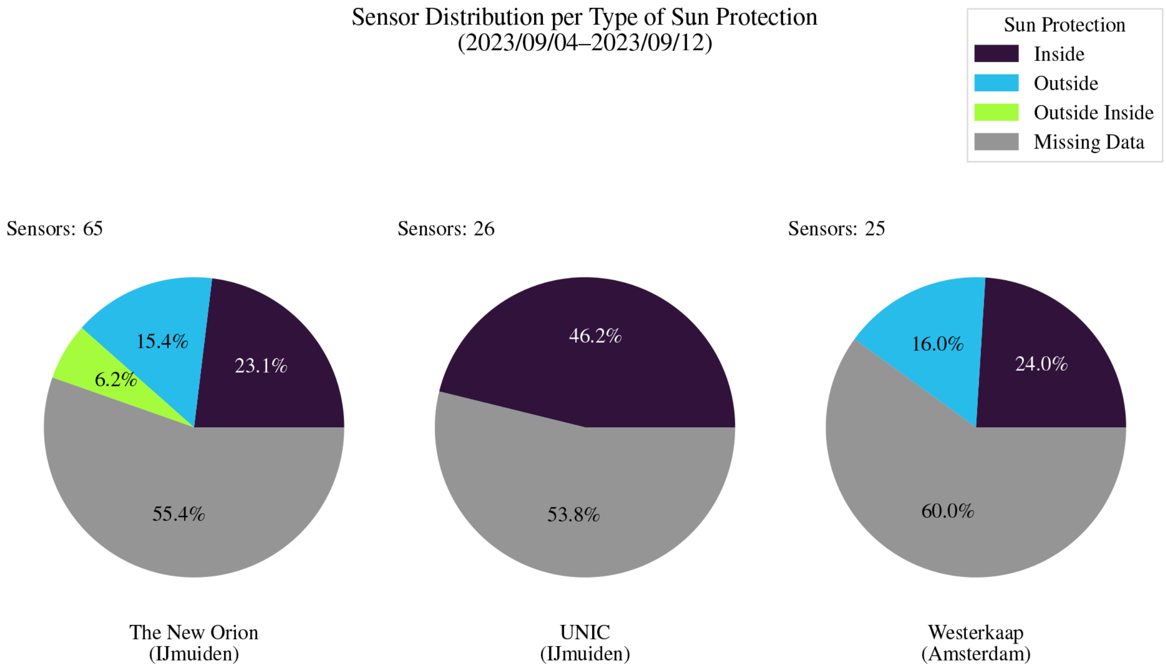


Figure 13. Proportion of sun protection measures employed per location

The relation between form of sun protection and measured temperature shows a clear pattern; a combination of outdoor and indoor sun protection yields the lowest average temperatures, followed by only outdoor blinds. Indoor sun protection yields slightly lower average temperatures than no protection (or missing self-reported data). Especially notable for the dwellings without protection (missing data) is the large scatter of values in the extreme temperatures (Figure 14).

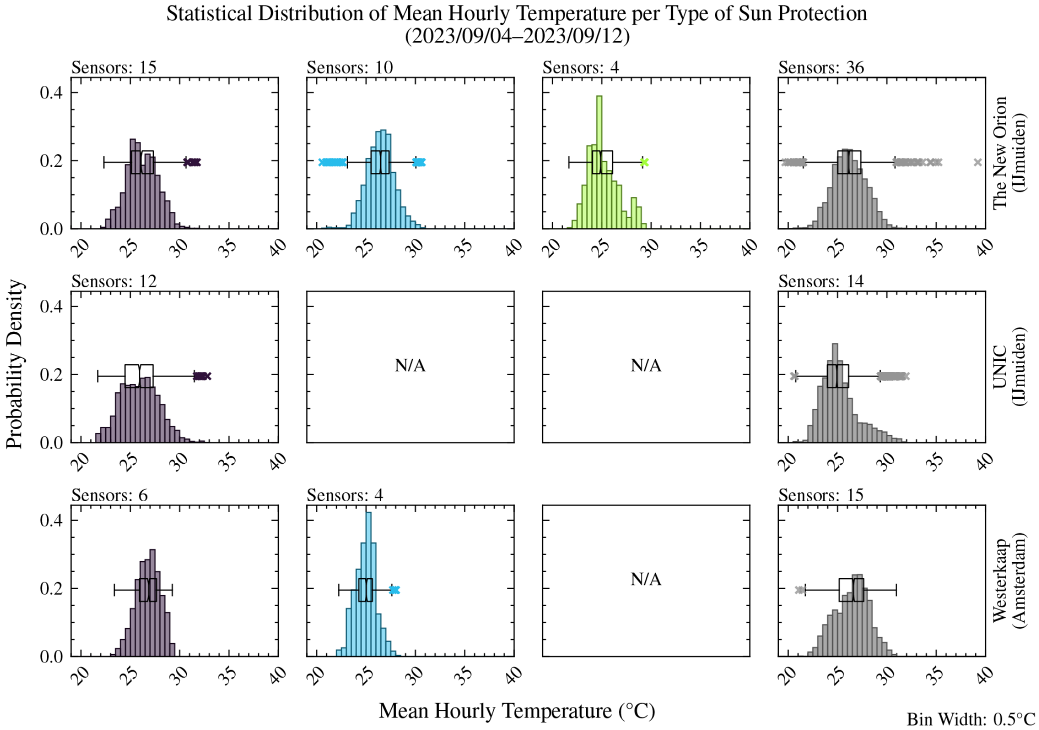


Figure 14. Frequency distribution of mean hourly air temperatures per type of sun protection measures (colors correspond with figure 13).

The pattern is most clear for the rooms in the New Orion facing southwest. In figure 15, the cluster shows the lowest mean temperatures for the rooms with shaded indoors and outdoors, increasing for those with outdoor shading, and a scatter for those with shaded indoors or not at all. The results are even more pronounced when taking into account the floor on which the sensors are located (Figure 16); those with combined shading measures are located at the third floor and still have lower mean temperatures than some with outdoor shading, which are on higher floors and can thus be expected to have lower temperatures.

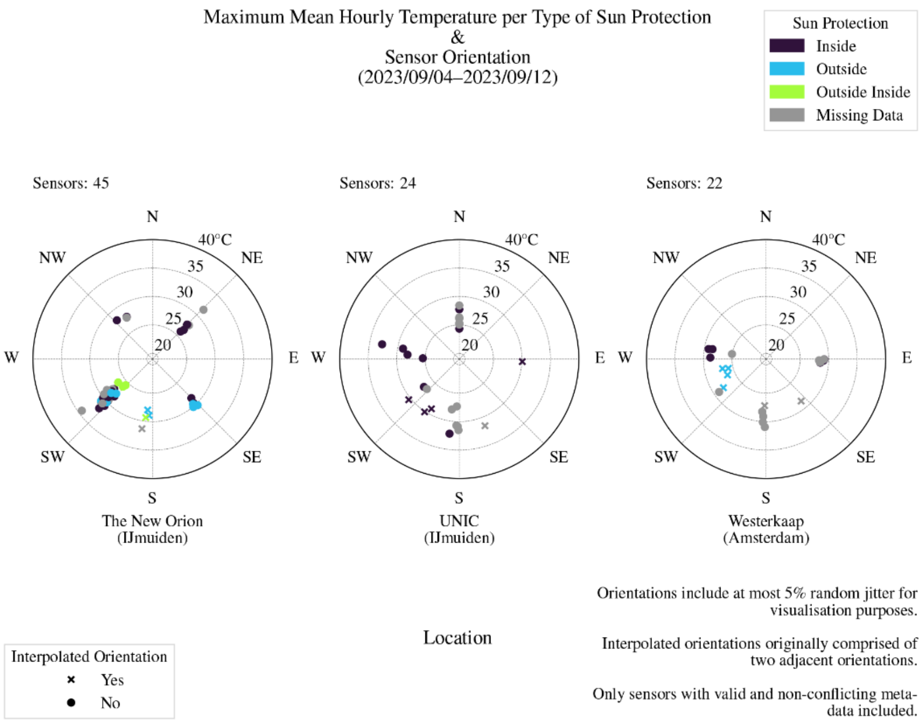


Figure 15. Mean hourly air temperature per type of sun protection measures plotted according to the sensor/room orientation

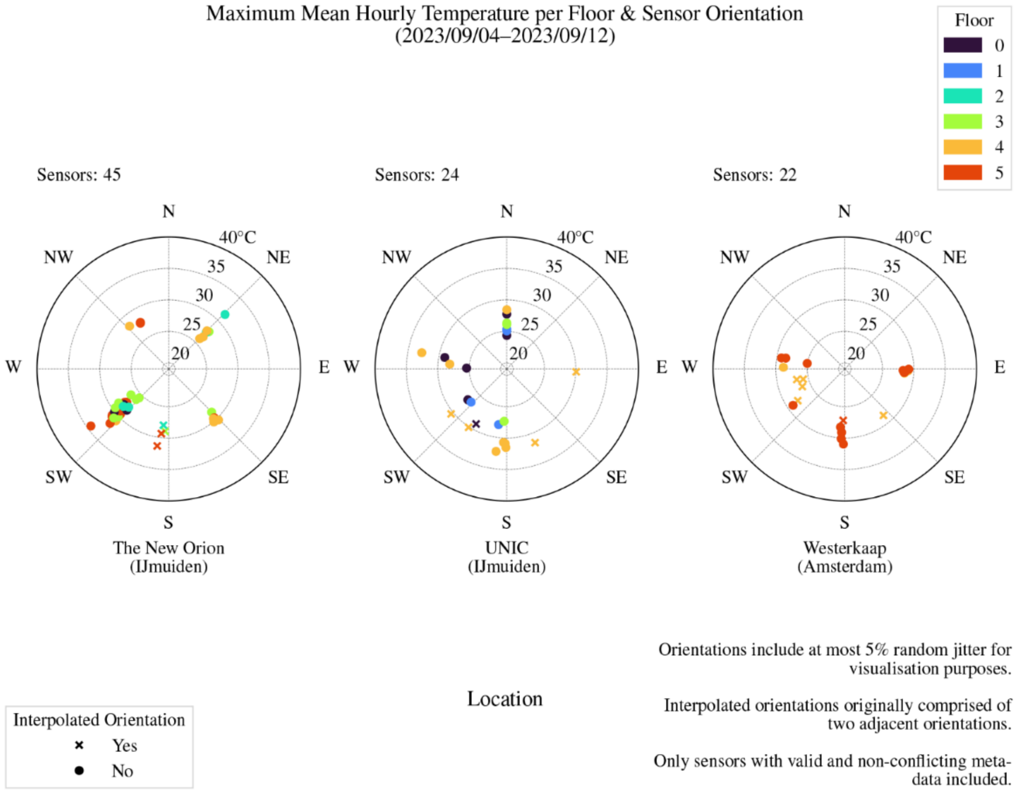


Figure 16. Mean hourly air temperature per floor plotted according to the sensor/room orientation

3.4 Climate literacy

We have collected 68 surveys from the reference group and 38 surveys (19 before summer and 19 after summer) from the measurement group. The general information about the respondents to the climate literacy survey can be found in appendix 5. It should be taken into account that the sample sizes of both the measurement group and reference group are small and not reflective of the general population in the Netherlands. Nonetheless, it provides direction and further understanding of how people with different socio-economic backgrounds perceive indoor heat and urban heat as a consequence of climate change. The demographics, as well as the type of dwellings slightly differ between the measurement group and the reference group. Besides the general information about the respondents and their dwellings, we have collected answers to questions falling into various categories (see also the subparagraphs). The categories were not known to the respondents. Particularly answers that we analyse in the category "knowledge" were spread throughout the survey.

3.4.1 Temperature

First studied category was the insight people have in temperature in their apartment. We have asked three separate questions: 1) What is the average temperature in your apartment during summer? 2) What is the maximum temperature your apartment reaches in (or "you have measured during the last") summer? 3) From which indoor temperature upwards do you feel uncomfortable in your apartment?

The answers of the measurement group about maximum temperature were very similar before and after summer (28,5C and 28,2C, respectively). Interestingly, answers before summer were slightly higher (25 - 35C) than after summer (23 - 32C). This could be attributed to a summer with less (outdoor) temperature extremes than in previous years. When it comes to average summer temperature, the answers of the measurement group were slightly lower before summer compared to the answers after summer (23,9C and 25,1C, respectively). This is an opposite trend compared to the maximum temperatures. Simply put, people expected that the average temperature of their apartment in summer would be lower than what it then turned out to be.

Third studied parameter was temperature above which people feel uncomfortable. The answer to this question stayed almost the same for the measurement group (26,5C on average before summer, 26,8C after). Interestingly, for the reference group the temperature from where they feel uncomfortable was a whole degree lower on average; 25,3C (see also figure 17). The results on the comfort levels indicate two things: 1) that the general preference considering ones comfort is relatively fixed and does not change much during one summer, and 2) that our measurement group seems to have, compared to the general public, a higher tolerance level for discomfort.

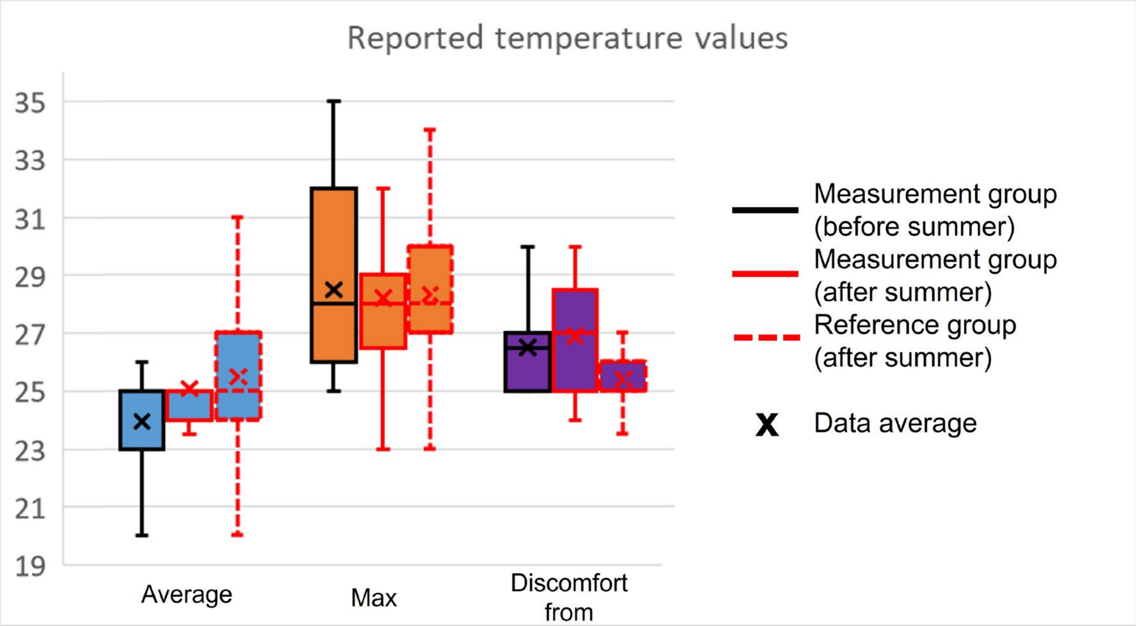


Figure 17. Reported temperature values by participants

3.4.2 Experience of heat

To a general question if one feels uncomfortable in their apartment during hot days, half of the respondents in the reference group answered yes (10 before and 9 after summer) and half no (9 before and 10 after summer). Nonetheless, more specific questions show a shift of the responses after summer towards perceiving the indoor summer temperatures as warm or very warm rather than neutral (or even cold). This is particularly visible in the data concerning night temperatures both on average summer nights and during the warmest periods of the summer. While before summer, 12 people (63%) reported that on average summer nights they feel neutral (or even cold – 1 respondent), after summer the amount of people who felt very warm quadruplet and only 8 people (42%) perceived it as "neutral". In general, the response "very warm" was more common after summer than before for all types of questions with an exception concerning average summer days. When it comes to the answers about the experiences with heat filled in by the reference group, 60% experienced their apartment as warm or very warm during the summer in general. During the warmest days of summer, 90% of the respondents reported their apartment as (very) warm, both during night and day.

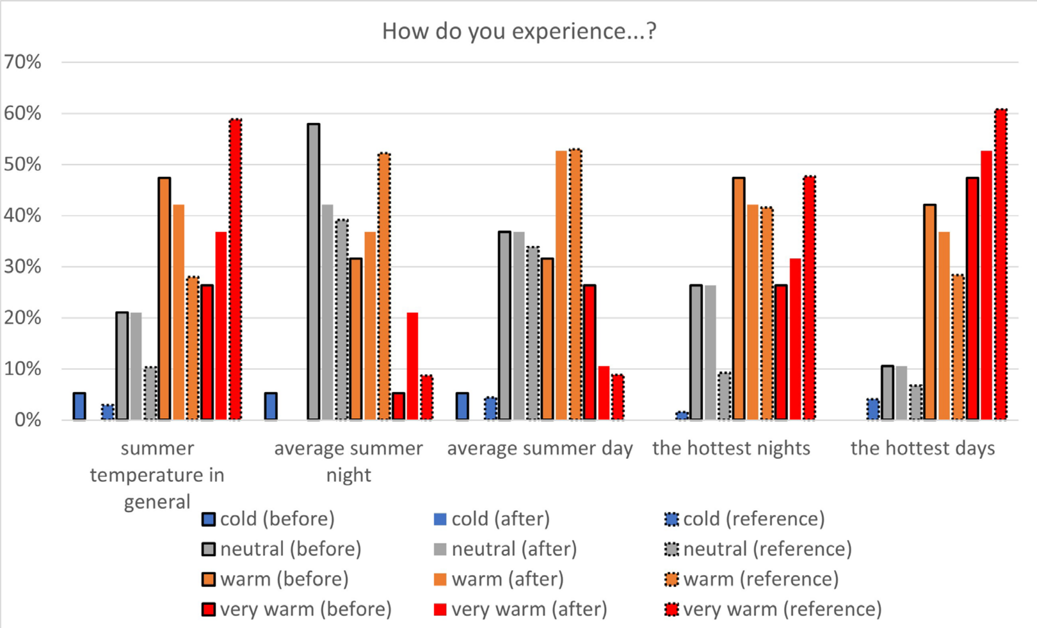


Figure 18. Experience of heat

When asked about their experience over a longer time period (the last 10 years), 85-89% (16 before and 15 after summer) of the respondents within the measurement group and 90% (60) of the reference group mentioned that their experience has changed over the last ten years. Within the measurement group, people mostly mentioned that it is in general warmer than it used to be. Besides the change in average temperature, the reference group defined the change as an increase in maximum temperature and a higher frequency of heat. Surprisingly, we see a decrease in the responses regarding the occurrence of heat waves after summer and also the reference group named it as the least prevalent effect when it comes to change in their experience of summer temperatures. This was probably caused by the lack of heat waves in 2023.

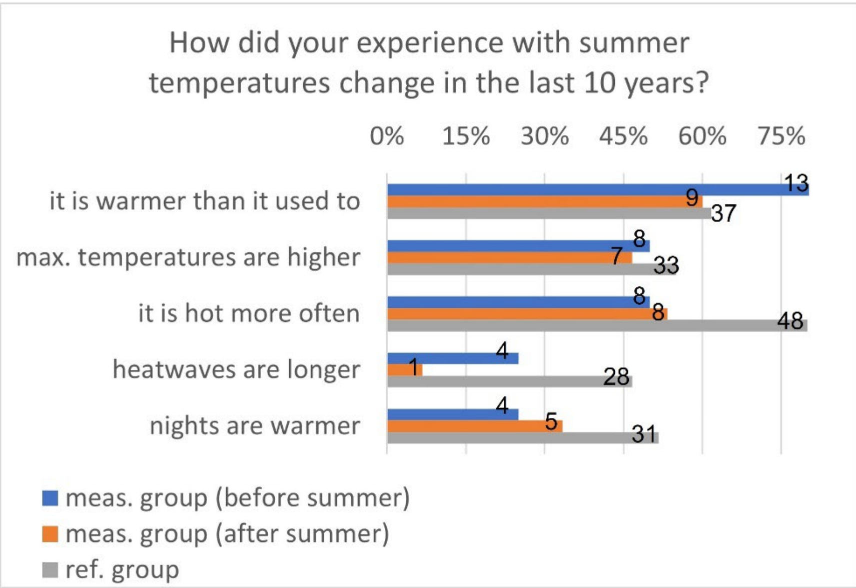


Figure 19. Experience of change summer last 10 years

3.4.3 Measures against heat

From the results regarding measures that people took during summer, we can see that in both the measurement and reference group there is some overall understanding of how to keep the house cool and how to increase one's own comfort. Although people adopted different strategies, we can see that they believe that night ventilation together with preventing the sun to warm up the apartment during a day are the most efficient strategies to keep their apartment cool. Interestingly, the amount of people that see night ventilation as the most efficient way to keep the house cool halved (from 6 before summer to 3 after) over the summer within the measurement group. This can be related either to relatively warm nights or a lower possibility to ventilate due to various factors such as noise, safety, mosquitoes, or wind (all mentioned by respondents).

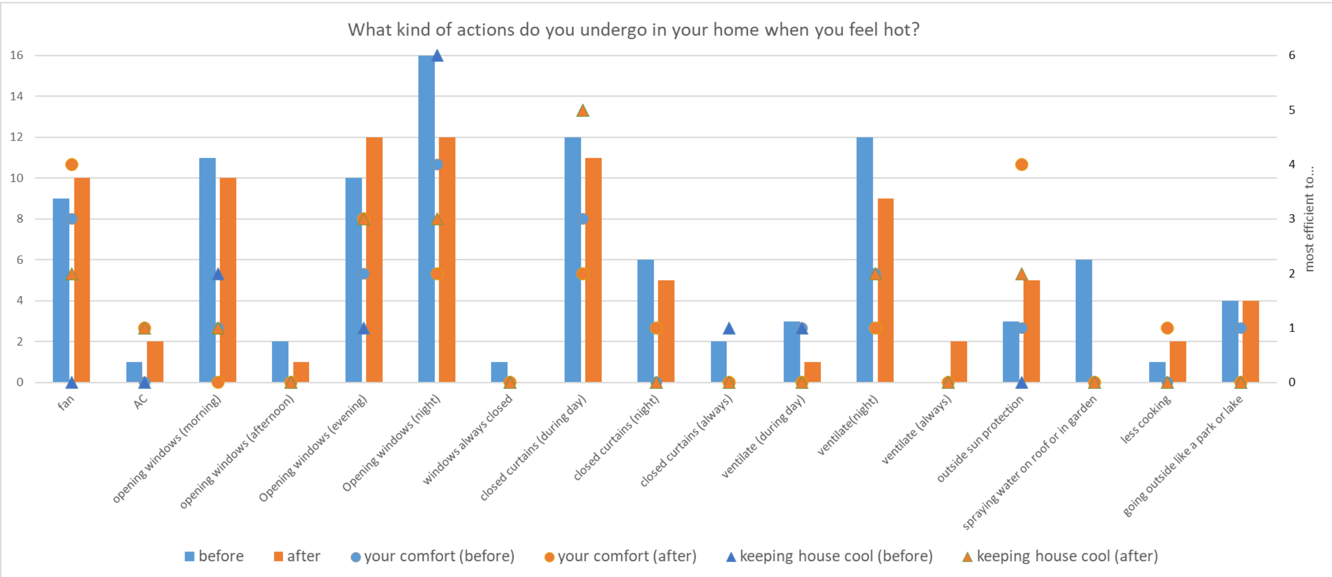


Figure 20. Actions undertaken when feeling hot inside

Understanding of the importance of night ventilation and preventing sun from entering the building is also visible in the answers to the question "Which measures could have been effective, but you can/could not implement?". Outdoor blinds was the most prevalent answer in both studied groups with almost half of the respondents from the measurement group and 74% of the respondents from the reference group choosing this option. Many respondents also wish to have more possibilities to properly ventilate their apartment during both day and night. The amount of responses regarding night time ventilation quadrupled over the summer, from 2 to 8, within the measurement group; 5 of them indicated they could not efficiently ventilate at night due to high outside temperatures.

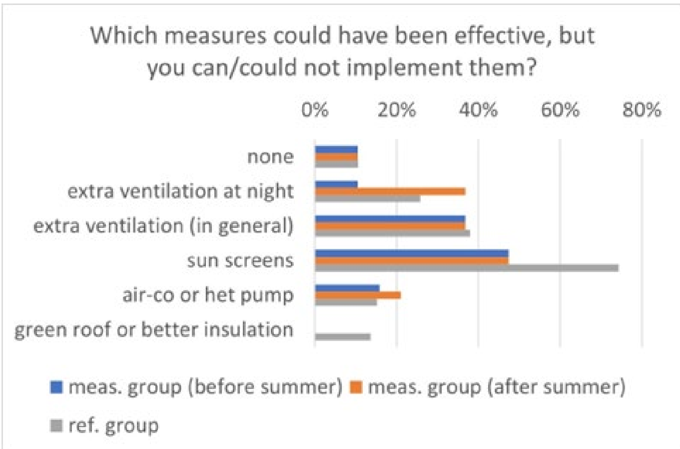


Figure 21. Mentioned effective measures that could not be undertaken

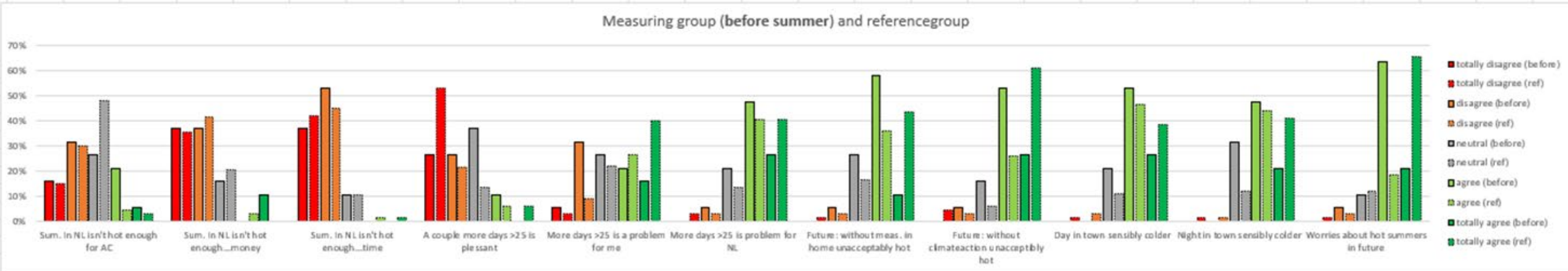
3.4.4 Perspective

The perspective of the respondents on certain topics was tested by their agreement or disagreement with different statements. Statements within the measurement group about if it is warm enough in summer to spend time or money on cooling measures yielded more neutral opinions after summer than before summer, indicating that people see less urgency after the summer than before. For example, we can see a big drop in responses that indicated that spending money (from 7 to 2) or time (from 7 to 3) on installing cooling measures is certainly necessary. During the summer the amount of respondents that worried about the hot summers in the future also dropped (from 16 (84%) to 11 (58%)). Similarly, we can see a decrease of people who agree that without an intervention in climate change the future summers will be unbearably warm (from 15 to 11). Also the opinions about if additional summer days (above 25 C) would be nice or cause more problems shifted more towards neutral. These results might be the consequence of the relatively mild summer. This is supported by the answers to the of statement "Few extra summer days would be pleasant" with which before summer 10 respondent disagreed (5 for "disagree" and 5 for "absolutely disagree") and after summer only 7 respondents (6 for "disagree" and 1 for "absolutely disagree").

Correlation coefficients indicate that the reference group was in more agreement with the measurement group before summer than after. Therefore, if the experience of the summer weather was the driving factor of the answers, we would expect more agreements between the reference group and measurement group after summer. The correlations show us a few points on which the opinion of the measurement group did not change much. Those are predominantly knowledge-related questions that have to do with climate change in the future or climate variation between cities and rural areas. All participants in the measurement group answered that it is "noticeably colder in a village both during night and day" (no disagreement at all). The majority of respondents (both reference and measurement group) believe that the "Summer time in the future will be unacceptably warm without climate action and/or cooling measures for apartments" and this opinion did not change throughout the summer.

	Sum. in NL not hot enough to use AC	Sum. in NL not hot enough...money	Sum. in NL not hot enough...time	A couple more days >25 plessant	more days >25 is a problem for me	more days >25 problem for NL	future: without measures in home unacceptably hot	future: without climate action unacceptably hot	day in village sensibly colder	night in village sencibly colder	worries about hot summers in future	
before vs. ref.	0,71	0,94	0,98	0,46	0,10	0,89	0,55	0,52	0,92	0,77	0,25	0,64449
after vs. ref	0,29	0,65	0,63	-0,16	-0,04	0,34	0,41	0,38	0,95	0,80	0,29	0,41272
before vs. after	0,64	0,50	0,73	0,77	0,45	0,68	0,97	0,95	0,99	0,88	0,76	

Table 1. Correlation table of the statements



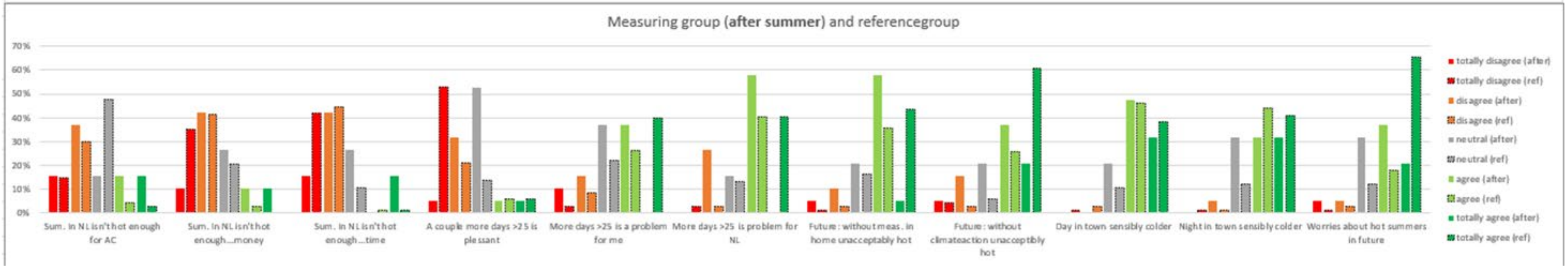


Figure 22. Perception on statements before and after summer, compared to reference group

3.4.5 Knowledge

The knowledge amongst the participants and the reference group about the topic of heat in apartments and about climate in general was tested directly and indirectly via questions. The first category of questions were stated in such a way that we directly asked the respondents about their perceived level of knowledge. In this category are questions such as "how familiar are you with the topic of heat in apartments?", "Did you learn something new last summer and from which sources?" or, if the respondents indicated that their experience with summer heat changed last 10 years "What was the cause of the change?". In the second category, we analyse the knowledge based on questions that had to do with other aspects, for example the measures taken against heat and their effectiveness ("Which measure was the most effective in increasing your comfort?"), and checking the given answers against previous research about the actual effectiveness.

When it comes to the perspective of the people on their own knowledge, 60% of the reference group mentions they do not have a lot of knowledge but do have interest in indoor heat, and close to 40 % mentions that they know a lot or consider themselves an expert. No one in the reference group considered their knowledge level as "average". The measurement group, on the other hand, chose "average knowledge" most often (42% before and 53% after summer). That the people in the reference group see themselves more as experts might be explained that they filled in the questionnaire after listening to the Argos Radio program, out of their own interest. However, when we look at the measures undertaken by both the measurement group and the reference group, all respondents seem to have a general understanding of best measures to take to reduce indoor heat. The interest in learning more about the topic dropped within the measurement group after summer. Before summer, the measurement group and the reference group had approximately same interest in learning more about heat in apartments. If we assume that this drop in interest to learn more was caused by participating in the Thermo-staat project, we might come to two contrary conclusions: 1) Either the people have now the feeling that they know enough (also visible in the increase in positive responses on the question about "sufficient knowledge", see Table 2) and anything extra they would learn would only have marginal effect, or 2) The participants were overwhelmed by participation in the project and do not wish to be further "bothered" by this topic.

Do you feel that you have sufficient knowledge about how to cool your apartment?	meas. group (before summer)	meas. group (after summer)	reference group
yes	15 (79%)	17 (89%)	45 (67%)
no	4 (21%)	2 (11%)	22 (33%)
Are you interested in learning (even) more about heat in apartments?			
yes	16 (84%)	11 (58%)	56 (85%)
no	3 (16%)	8 (42%)	10 (15%)

Table 2. Feeling of having sufficient knowledge

Looking at the answers from the 19 respondents that participated in the Thermo-staat project and filled in the survey after the summer, only 6 stated that they feel that they have "**learned something** new about heat in apartments". 4 out of those 6 stated that the new insight was because they measured temperature in their apartment, second most common answers were "from news" (2) and "by searching online/in publications" (2). The reference group was not asked to measure throughout the summer, however they were recruited by interest in this topic. In the reference group, "searching online" was the most common answer (89% of the respondents chose this option) followed by "scrawling through websites" (68%) and "measuring temperature" (by reading the thermostat for example) (63%). From the workshop held in IJmuiden we can conclude that participants have gained more insight by measuring their temperature and mostly with comparing it with the measurements from their neighbours but that participating in this project increased their agency even more.

Unfortunately, most participants reported after the summer that measuring temperature in their home did not lead to any **actions** towards keeping their home more comfortable (with exception of one participant who used it to see when to switch on the air-co). Also, only one respondent was "sometimes" active in the KennisCloud and none of the respondents took any actions as consequence of using the KennisCloud. The data visualization page was more successful. From 19 respondents, 11 reported that they used the page; mostly to see their own data (8) or to compare to other locations with similar characteristics (3). Consequently, two respondents adjusted their activities based on the visualization; both did less than planned since their location was colder than comparable other locations, and one also reported new (unspecified) measures taken. Three respondents also reported that participating in the measurements changed the way they see heat in apartments; two found the issue more pressing, one respondent additionally reported increased awareness of climate change and urban climate, and one respondent more awareness about higher chances of hot summers.

4 Conclusion

Heat stress in houses is an actual and growing problem. The aim of this project wat to investigate the following main question:

How can we use community creation and citizen science to make people more aware of and more adapted to "heat in apartments as a consequence of climate change"?

To this end we set up a research together with residents living in IJmuiden and Amsterdam. In this research the residents measured their situation and reflected on their situation and heat adaptation options and choices and investigated how these lead in potential for more effective adaptation measures, growing ability to act and awareness of this problem. In doing so, they have worked together with scientists from TU Delft and the Amsterdam University of Applied Sciences, investigative journalists from VPRO Argos and experts from Waag Futurelab in the Thermo-staat project. Purposeful collaborations and the collective capacity of academics, journalists and communities of residents themselves has led to a better understanding and insights into the threat of increasing indoor temperatures.

The sub questions to answer were

1. What are effective choices in order to build a successful community using citizen science and citizen-oriented journalism around the problem of indoor heat?
2. To what extent does the chosen approach contribute to more insight into scientific knowledge/facts (climate literacy) of the participants and of the general public?

Next to those two answers on those questions there are some conclusions to be drawn on the situation of and adaption to heat stress by residents.

4.1 Effective choices in order to build a successful community using citizen science

The main conclusion is that in order for citizen science to be valuable for participants, it should address an issue that is intrinsically felt by them. Furthermore, we learned that the tools and facilities that are meant to facilitate participating residents should be really fit to their needs in level of explanation and functioning.

At the start of the project, we were approached by a large number of residents throughout the Netherlands who were really motivated to participate, after the VPRO published about the project. However, we had to exclude many of those from our research after we decided to focus on a few specific locations in Amsterdam and IJmuiden. We made this decision in order to increase the scientific validity of the data. Participants were then largely recruited though a door-by-door campaign, which lead to 60+ participating households in IJmuiden who were not all as motivated as the original research group of Heethoofden. We learned that in order for citizen science to be valuable for participants, it should address an issue that is intrinsically felt by them. For participants who lived in relatively cool houses (for example because they were located on lower levels of the apartment blocks), heat stress turned out to be largely irrelevant. This highlights a tension between our aims to produce scientifically sound data by making our own selection of participating households, as well as to generate agency for residents through active participation both on offline as well as online platforms.

The Kenniscloud platform received little traction due to a number of reasons. First of all, our choice for a location-based community made Kenniscloud redundant to some of the participants. They already had regular communication tools and methods (such as WhatsApp or physical meetings) in place. When the platform was shared with a wider audience through the VPRO channels, it proved to be hard to keep people engaged for a longer period of time on a medium that they did not already know and/or because most of the Heethoofden were not measuring themselves in the summer of 2023. Although we were prepared for this challenge, our efforts to get a conversation going did not fully pay off. The data visualisation tool was more successful and insightful, as proved during the data analysis workshop at the end of the project. However, we also learned that instruction of the use of the tool by scientists was crucial for people to really understand the meaning of the data. Heat is a very complex matter that's defined by a large variety of variables.

4.2 Ability to act and greater understanding of climate change

The chosen approach contributed in several ways to more insight into scientific knowledge/facts (climate literacy) of the participants and of the general public.
The measured temperatures as well as the surveys showed on the one hand how residents influence their thermal comfort and well-being, and employed resources available to cope with indoor heat, and on the other hand how newly built buildings and factors outside the control of residents influence actual indoor temperatures. By visualizing the data they collected, a greater understanding of employed measures and factors was mentioned by the participants. Despite there not being prolonged periods of extreme outdoor heat (i.e. a national heat wave), the participating social rental apartments measured constant high(er) indoor temperatures throughout the summer. The use of outdoor blinds is an effective measure to lower the amount of solar radiation entering the apartments. Also, this measure has been indicated in the questionnaire after summer to be very effective for those using it, and to be desirable for those with no access to it.

The outcome of the surveys showed that participants' general knowledge about which measures to take against indoor heat is overall good at the beginning of the summer. After summer, cooling mechanisms, outdoor blinds and ventilation during night was mentioned more often with the notice that not all of these measures could be employed by participants themselves.

Questions about climate change in general show discrepancy, possibly due to a relatively mild summer and therefore a lesser sense of urgency. For example, respondents indicated that they regard more days above 25 degrees not as a problem, while at the same time there is also awareness that summers in the future will be unacceptably warm without climate action and/or cooling measures for apartments. The results of this study show a first indication how the experience of a relatively mild summer stands in the way of a long-term awareness of climate change as an underlying cause. At the same time, participants who suffer from indoor heat have the feeling that participation contributed to a better ability to act. They mentioned gaining more insights into their indoor temperatures is useful to improve communication and understanding about this topic.

This project started from the assumption that citizen science would increase agency for participants, if executed in a fully participative manner. The results of this project shows examples of this increased agency: in a co-creation session in May 2023, residents were invited to think along about research questions. Later on, during a Waag Open event, we discussed potential solutions for heat stress with citizens and finally, during a closing session, we collectively analysed data based on the data visualisation at our project website. This session was particularly fruitful for a number of citizens who were finally able to provide their housing corporation with databased insights in their problems, as expressed in the forementioned quotes. In a few cases, residents particularly experienced a sense of agency following the Thermo-staat project. For instance, a resident in Nijmegen was invited by VPRO to participate in the project after she had lost a lawsuit from her landlord. The Thermo-staat data provides her with new evidence, which she will now use to appeal. In another instance, housing corporation Ymere decided to install outdoor blinds at the Westerkaap apartment block after several residents participated in Thermo-staat.

Working collaboratively was a learning process for many involved in this project. By participating in the Thermo-staat project, the participants have gained a better understanding of indoor heat. Despite the fact that they are mostly unable to afford or implement outdoor blinds in their apartments, they are able or feel better equipped to advocate for heat-reducing solutions through participating in the Thermo-staat project. Furthermore, the research has led to first insights in how combined measuring temperature, having access to platforms and journalistic productions increases climate literacy among the participants.
The workshops with different partners played a key role in this 'citizen science' research, as during these events researchers could collect residents' stories of indoor heat, how they are coping with heat and how this might have changed over time. In return, residents felt that they were listened to and heard. It is one thing to understand how the physics of (urban) heat work, but hearing people share how they are experiencing heat often in harmful ways, was very powerful. These insights are, next to this report, published in journalistic productions where participating residents documented

their information, setting the issue into a local context that also non-experts can more easily access.

4.3 Insight in indicators for heat stress and adaptation measures

The research (measurements and questionnaires) gave insight in what influences indoor heat problems and what adaptions measures are possible and effective. From our data analysis it became clear that residents in rental apartments perceive and experience more heat problems than residents owning the apartment despite living in the same type of building. Some measures can be undertaken by tenants themselves whereas others not. This research has shown how newly built buildings and other factors outside the control of residents (e.g. installing outdoor blinds or no possibility for proper night ventilation because of building characteristics) influence actual indoor temperatures. Scientists have gained a better knowledge on how the local context is influencing the perception of urban heat. Secondly, scientists have gained a better understanding of which barriers emerge, how they are articulated by residents and other stakeholders and how this may limit processes regarding adaptation to indoor heat.

5 Discussion (Insights and advice)

5.1 Limitations

5.1.1 No heatwave

In the summer of 2023, there was no official national heatwave recorded. This might have had an influence of the felt urgency to tackle urban heat and felt consequences by (vulnerable) citizens. Also for journalistic productions, the lack of an official heatwave was perceived as limiting. The lack of official national heat waves resulted in the necessity to define warm periods, i.e. the local heatwave in September, for relevant data analyses, and storytelling. Hence, to show the impact of this project, it is suggested to gather more data during heatwaves.

5.1.2 Sample size

In addition to the relatively small data sample due to the lack of an official heatwave, the number of active sensor kits involved is rather low as well as filled in surveys among the measurement group. Combined, this yields a too small data set to perform solid statistical analysis on and provide generalizable conclusions. The study does however tie in with other studies on heat stress in dwellings, confirming the importance of specific adaptation measures such as night ventilation or use of outdoor blinds and behaviour, as well as vertical position in the building and presence of outdoor blinds.

5.1.3 Self-reported data and unsupervised sensor placement

One of the aims of the study was to relate measured data to dwelling characteristics and climate control measures, relying on self-reported information for the latter two. As this data cannot be verified, some of the data maybe false or incomplete. In addition, some information requested was not provided by the participants. Furthermore, some sensors show extreme temperature values and/or temperature ranges, which may be due to sensors placed in direct sunlight during (part of) the day, leading to incorrect measurements. Involving citizens as scientists by placing sensors is a method still under development where the balance between what you can and cannot ask of people and what you do yourself as a scientist or what you outsource. In analysing such data from citizen science this should always be considered.

5.2 Plan for future communities

1.The community of citizen scientists is very inspired by this project and its innovative method: participants remain motivated to keep measuring, illustrated by the large number of sensors remaining online after October 2023.
2.The climate literacy study would consist of a before and after measurement, with the idea that people could try out certain heat-reducing interventions in the meantime. Due to the lack of heat, this ultimately turned out differently than expected and we could not make a good follow-up measurement within the same community.
3.We were not able to make data-based journalistic productions, because the collected data did not show that much heat in comparison to previous summers in the Netherlands. We are very enthusiastic about the method, the community that has been built up and the collaboration among partners. We are well positioned to achieve the original goals as soon as things do get hot for prolonged periods of time.

Continuation of Thermo-staat, including citizens participation and reinforcement of their perspective, might advance adaptation in practice by citizens themselves, the housing corporations and municipalities. The next years we can find opportunities for more citizens involvement and to monitor the impact on heat-related public health in these communities and whether desired interventions have been successfully implemented. For the summer of 2024 Waag has acquired funding to keep the website and data visualisation running and offer technical support. This will allow for more data to be gathered and for the VPRO to create more journalistic content alongside the participants if more heat waves occur.

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7 Appendix 1: Journalistic productions

Throughout the measurement period the consortium worked on several journalistic productions by/for the measurement community and the heethoofden community. These are published on the website of VPRO/ARGOS at: https://www.vpro.nl/argos/lees/onderwerpen/thermo-staat.html. More specifically, we worked on the following items:

1. Project announcement and recruitment of Heethoofden: https://www.vpro.nl/argos/lees/onderwerpen/thermo-staat/word-heethoofd.html
2. Share your advice with dealing with extreme heat: https://www.vpro.nl/argos/lees/onderwerpen/thermo-staat/hoe-houd-jij-je-hoofd-koel.html
3. Article: Sweltering bedrooms are a blind spot in the climate approach https://www.vpro.nl/argos/lees/onderwerpen/thermo-staat/snikhete-slaapkamers-zijn-blinde-vlek-in-klimaataanpak.html
4. The battle against warm homes: buyers are cool, tenants are hot: https://www.vpro.nl/argos/lees/onderwerpen/thermo-staat/2023/verhitte-strijd-tegen-warme-woningen.html
5. Daisy suffers from heat stress: 'It can be at least 30 degrees inside my house' https://www.vpro.nl/argos/lees/onderwerpen/thermo-staat/2023/daisy-heeft-last-van-hittestress.html

The VPRO also created a radio item about Thermo-staat, which was broadcast live on September 9th during the only recorded heatwave of the summer. During the item they called with Daisy who spoke about her situation and the data she measured over summer. The item can be found online: Een koel huis als luxeproduct - HUMAN - VPRO.

Moreover, the Thermo-staat project was submitted to and nominated for the European journalism prize Prix Europa 2023 in the category of the Best European Interactive Media Project of the Year.

8 Appendix 2: Description of the measurement technology

8.1 Technical development

As part of our technical development plan, we conducted an extensive evaluation of various sensor technologies to gain proficiency in measuring temperature and humidity within households. Our research included both commercially available solutions (such as the Netatmo Smart Weather Station and the EVE Weather thermometer) and one open-source, self-developed solution. We compared these thermometers against two digital non-smart thermometers. The testing phase lasted approximately three months. Ultimately, we selected the open-source, self-developed solution, which we aptly named "Thermo-staat kits." Our decision was based on the following criteria:

1. Quality and reliability of data: The data collected by the Thermo-staat kits consistently demonstrated high accuracy and reliability.
2. Ease of use for end-users: The kits were designed to be user-friendly, allowing participants to easily install, operate, and maintain the sensors.
3. Accessibility of data: We ensured that the data collected by the kits was easily accessible to both end-users and researchers through a user-friendly interface.
4. Reliability of network technology: The kits employed robust wireless connectivity to ensure seamless data transmission between sensors and the central server.
5. Flexibility (Configuration, code, back-end): The open-source nature of the Thermo-staat kits provided extensive flexibility in customizing the technology to meet the specific needs of the project.
6. Alignment with the scope of the project: The capabilities of the kits aligned perfectly with the project's objectives, enabling us to collect comprehensive data on heat stress within different types of households.

The Thermo-staat kits outperformed all other tested solutions in terms of overall performance. A significant advantage of this technology was its adaptability to the project's scope, allowing us to deliver a solution tailored to the needs of both researchers and end-users (households).

8.2 Placement of the sensors

A correct placement of the sensors was vital for collecting representative data. For example, the height of the sensor location, the distance from walls, and direct sunlight all influence the measurements.. To have participants install the sensors correctly in their own homes, they were provided with an explanatory sensor installation guide including recommendations for placement. Each distributed Thermo-staat kit contained three thermometers of which the first two were designated to be placed in the living room and bedroom respectively. The third thermometer could be placed in another room of choice.

We gave the following guidelines for placement:

- On top of a dresser, table or in an open cupboard are good spots to measure a representative temperature for the whole room;
- Do not place the sensor on the ground;
- Do not place the sensor directly against an external wall (a few centimeters from the wall is fine);
- Do not place the sensor in direct sunlight, so not to close to a window;
- Do not place the sensor directly underneath a lamp;
- Keep the sensors out of reach from children and pets.

General recommendations were to move the sensors as little as possible and to place the microcontroller in a central, unobstructed place to ensure that all sensors could regularly send data to the server.

8.3 Parameters

1. Indoor temperature (measured in two or three rooms)
2. Indoor relative humidity (measured in two or three rooms)
3. Outdoor temperature (through KNMI data collected from the closest weather station)
4. Outdoor relative humidity (through KNMI data collected from closest weather station)
5. Indoor heat index (calculated)
6. Outdoor heat index (calculated)

Self-reported:

7. Ownership type (owner-occupied, social housing, or private rental)
8. House type (apartment, detached house, townhouse, or part of a block)
9. Energy label (indicating the overall energy efficiency of the house)
10. Building year (when the house was built)
11. Location (address or neighbourhood)
12. Orientation of the house towards the sun (north, south, east, or west)
13. Presence of objects that shade the house (trees, buildings, or other structures)
14. Type of room (living room, bedroom, kitchen, bathroom, etc.)
15. Orientation of the windows in each room (north, east, south, west, or a combination)
16. Climate control measures implemented in the house (air conditioning, fans, etc.)
17. Sun protection measures in place (window blinds, curtains, awnings, etc.)

While the majority of the parameters were self-reported, five of these were the same for most of the houses in the dataset, due to the selected locations for the measurements. These include ownership type (owner-occupied or social housing), house type (apartments/part of a block), energy label (A), building year (2008, 2018, or 2021) and location (in IJmuiden or Amsterdam).

9 Appendix 3: Survey Climate literacy

Example of the survey for the measurement group, used after summer

Living Situation:
- **Type of Residence**: Detached House, Terraced House (mid-terrace), Terraced House (end-terrace), Apartment (1 side), Apartment (2 sides)
- **Orientation**: North, East, South, West
- **Room where you spend most of your day**
- **Room where you spend most of your night**
- **Year of Construction**
- **Insulation Quality**: Good, Moderate, Poor
- **Energy Label**: A, B, C, D, E, F, G
- **Tenure**: Rental / Owner-occupied
  - **Rental**: Private vs. Social Housing

Perception and Experience:
- **How familiar are you with the topic of heat in homes?** (Expert, I know a lot, Some knowledge but interested, No knowledge or interest)
- **How did you generally experience your home last summer?** (Scale from Very Cold, Cold, Neutral, Warm, Very Warm)
  - **Warm/Very Warm**: Why do you think it was warm in your house? (Not sure, Hot outside, Windows can't open, Orientation of windows, Building materials, Lack of sunshades/curtains, Poor/Good insulation, Other: ...)
- **How warm did it get inside your home last summer (an estimate is fine)?**
  - No idea
  - Average:
  - Max:
- **What means do you use to get insight into this?** (Thermostat, Mobile App, None, Other: ...)
- **Were you home during the hottest period of the summer (heatwaves)?** (No, Hardly, Only at night, A lot)
- **How did you experience the general temperature in your home during heatwaves?** (Scale from Very Cold, Cold, Neutral, Warm, Very Warm, I did not use this room)
  - **At Night** (in the room where you mostly stay at night)
  - **During the Day** (in the room where you mostly stay during the day)
- **Did you feel uncomfortable during a heatwave in your home?** If yes, what was the temperature on the thermostat?
- **Did it become really hot in your home at any time last summer?**

  - Yes -> What did you do? (It's never that hot at my home, Go to the garden, Go to the park, Find a swimming spot, Seek a cool building (library, supermarket, etc.), Move to another room, There's nothing I can do, Other: ...)
- **How did you experience your home during the rest of the summer (regular summer days)?** (Scale from Very Cold, Cold, Neutral, Warm, Very Warm, I did not use this room)
  - **At Night** (in the room where you mostly stay at night)
  - **During the Day** (in the room where you mostly stay during the day)
- **Can you tolerate heat well?**
- **Do you feel uncomfortable during a heatwave in your home?**
  - Yes -> From what indoor temperature?
  - **What are your complaints?** (Sweating, Fatigue, Headaches, Concentration problems, Muscle pain, Nausea, Other physical complaints, Other: ...)
- **Has your experience with summer temperatures changed compared to 10 years ago?** (Yes/No/Significantly/A little)
  - **How?** (It has become cooler, It has become warmer (throughout the summer generally), The max temperature has increased, It gets hot more often (more heatwaves), Heatwaves last longer, Nights are warmer, Other: ...)
  - **For what reasons?** (I am more aware of the problem, I moved, Climate change, I've aged and can't tolerate heat as well, The city is becoming less green/pleasant, I have to do more to keep my house cool, Working more from home (e.g., due to COVID-19), Other activities, Other: ...)

Actions:
- **What actions did you take last summer when it was hot in your home?** (Fan, Air conditioner, Opening windows (day/night/evening and morning), Always keeping windows closed, Closing curtains (day/night/always), Ventilating (day/night/always), Outdoor sunshade or parasol, Green roof, Spraying water on the roof or in the garden, Less cooking, Going outside like to a park or lake, Other: ...)
- **Did it help / was it enough (all combined)?**
- **Which measure was the most efficient in helping you increase your comfort?** (Fan, Air conditioner, Opening windows (day/night/evening and morning), Always keeping windows closed, Closing curtains (day/night/always), Ventilating (day/night/always), Outdoor sunshade or parasol, Green roof, Spraying water on the roof or in the garden, Less cooking, Going outside like to a park or lake, Other: ...)
- **Which measure was the most efficient in keeping your apartment cool?** (Fan, Air conditioner, Opening windows (day/night/evening and morning), Always keeping windows closed, Closing curtains (day/night/always), Ventilating (day/night/always), Outdoor sunshade or parasol, Green roof, Spraying water on the roof or in the garden, Less cooking, Other: ...)
- **Did you adjust your daily routine during a heatwave compared to other days?**

  - Yes -> How? (Different sleeping times, Different working hours, Different tasks, Eating and drinking habits, Sleeping location, Working location, Outdoor activities (more, less, different times))
- **Did you take actions based on measuring temperatures in your home?**
  - Yes -> Which?
- **Did you take actions by participating in the knowledge cloud?**
- **Were you actively involved in the discussion on the knowledge cloud?** (No, Little, Occasionally, A lot)
- **Did you look at the page with temperature visualizations?**
  - Yes -> What did you use it for? (To see my data, To compare my data with other locations, To see what variables (orientation, rent/own, ownership, etc.) can influence the temperature, Other: ...)
- **Did the knowledge on the knowledge cloud and the visualizations influence the actions you took at home?**
  - Yes -> I implemented new measures, I changed my behavior, I did less because the indoor temperature was okay or better compared to others.
- **Did making the temperature in your home visible lead to** (more knowledge, different actions, more conversations with family/friends/acquaintances, seeking more information, Other: ...)

Knowledge:
- **Do you feel you have enough knowledge about how to cool your house?**
- **What (other) measures could be effective but you might not have been able to apply?** (Ventilating with windows open on both sides, Night ventilation by opening windows due to high outdoor temperatures, Night ventilation by opening windows due to safety concerns, Other: ...)
- **Do you feel you learned something new about heat in homes last summer?**
  - Yes -> From which sources? (By measuring the temperature, Reading on the knowledge cloud, Researching online/in publications, News, Friends/Family/Colleagues, Housing association/landlord, Municipality/government/health department newsletter, Other: ...)
- **Are you interested in learning more about the issue of heat in homes?**
- **Who do you think is most responsible for solving heat problems in your home?** (Owner, Resident, Housing Association, Homeowners' Association, Municipality, Government, ...)
- **What do you think should be done by the government to address this?** (More information about the risks, More greenery, Better house insulation, More trees, Green roofs, Nearby cool places, Different work/school hours, Water points, Reducing CO2 emissions, Other: ...)
- **What do you think should be done by the housing association/landlord to address this?** (More information about the risks, More greenery, Better house insulation, More trees, Green roofs, Nearby cool places, Different work/school hours, Water points, Reducing CO2 emissions, Other: ...)
- **What would you (still) like to do yourself?**

- **Statements**: Sliding scale from Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree:
  - Summers in the Netherlands are not warm enough to buy an air conditioner.
  - Summers in the Netherlands are not warm enough to spend my own money on cooling measures in general (e.g., buying and installing sunshades, planting a tree, installing a green roof, etc.).
  - Summers in the Netherlands are not warm enough to spend time on cooling measures in general (e.g., keeping track of the best time to ventilate, having a green garden, spraying water on the roof and walls, etc.).
  - A few extra summer days (above 25 degrees) would be pleasant.
  - More days above 25 degrees will cause problems.
  - Without additional cooling measures in homes, summers in the Netherlands will become unacceptably hot.
  - Without taking action against climate change, summers in the Netherlands will become unacceptably hot.
  - During a summer day, it is noticeably cooler in a small village than in a city.
  - During a summer night, it is noticeably cooler in a small village than in a city.

Personal Background:
- **Age**: <18, 18–25, 25–35, 35–45, 45–65, 65–75, 76+
- **Gender**: Female, Male, Prefer not to say
- ** Have you primarily lived in the Netherlands for the past 10 years? (Yes/No)

10 Full data analysis – Temperature measurements

10.1 Collected data

Temperature data were collected through indoor measurements between June 15th 2023 and September 15th 2023. Data were recorded through 65 sensors in the New Orion, 26 sensors in the UNIC and 29 sensors in Westerkaap. However, during the measurement period, the data correctly recorded accounts for the 45.9% of 267,97 hours in New Orion, 49.5% of 114,85 hours in UNIC and 28.3% of 90,23 hours in Westerkaap (Figure 23).

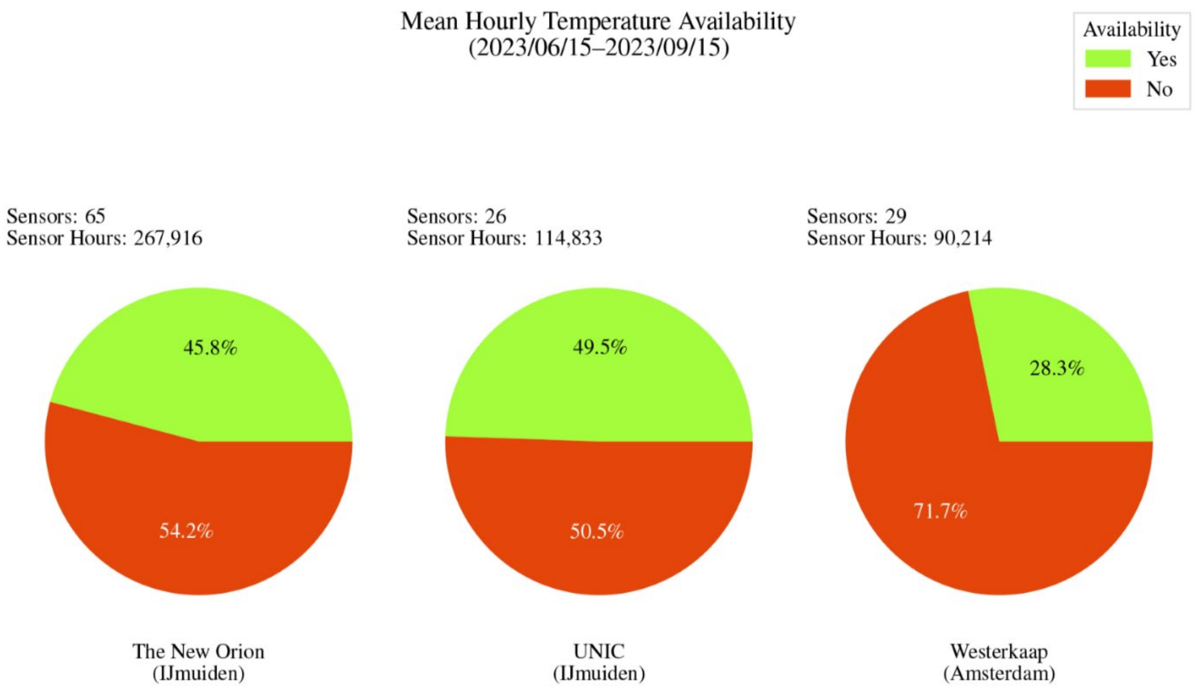


Figure 23. Indoor air temperature data availability over the full measurement period

A more detailed series of analysis have focused on a local heat wave period occurring between September 4th and 12th 2023. During this period the data correctly recorded account for the 48.2% in New Orion, 48.6% in UNIC and 42.8% in Westerkaap (Figure 24)

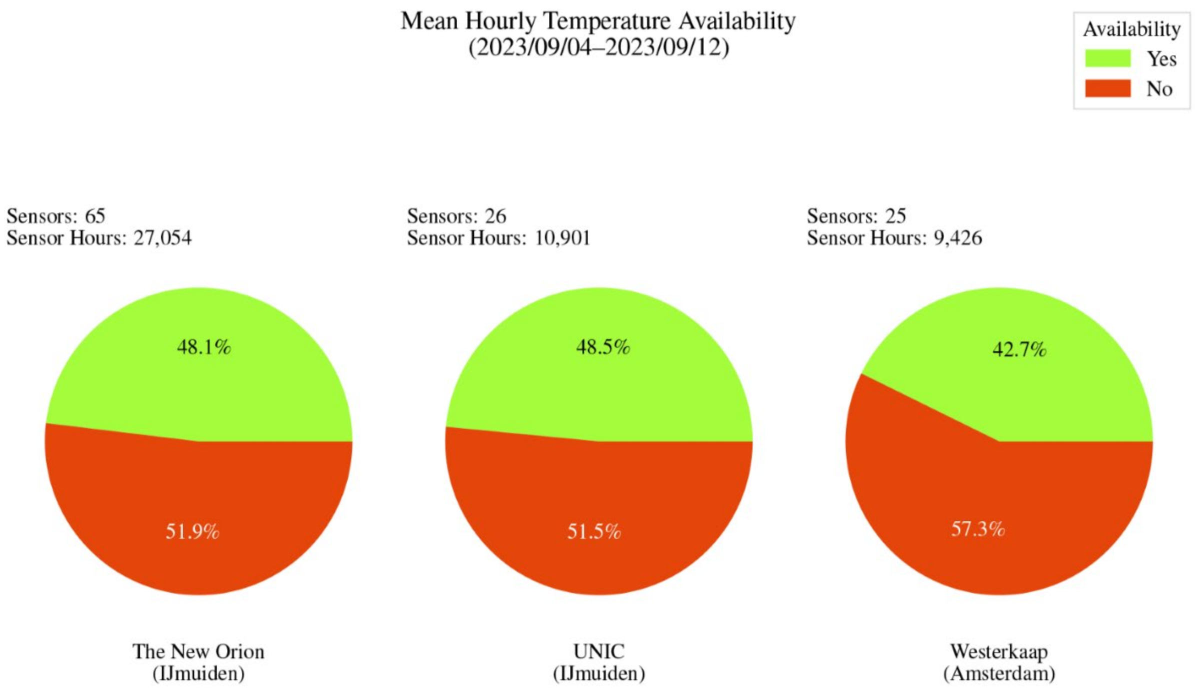


Figure 24. Indoor air temperature data availability during the local heat wave

The analysis of the available aggregated data for the full period shows that the three locations have different thermal profiles. Figure 25 presents the frequency distribution of mean hourly temperature values. Median values for the three areas are very similar and range from 24,0 to 24.5 degrees Celsius, however New Orion and UNIC have a higher number of outliers compared to Westerkaap, indicating that in the former two, there is higher thermal variability and indoor temperature can go above 31 degrees Celsius.

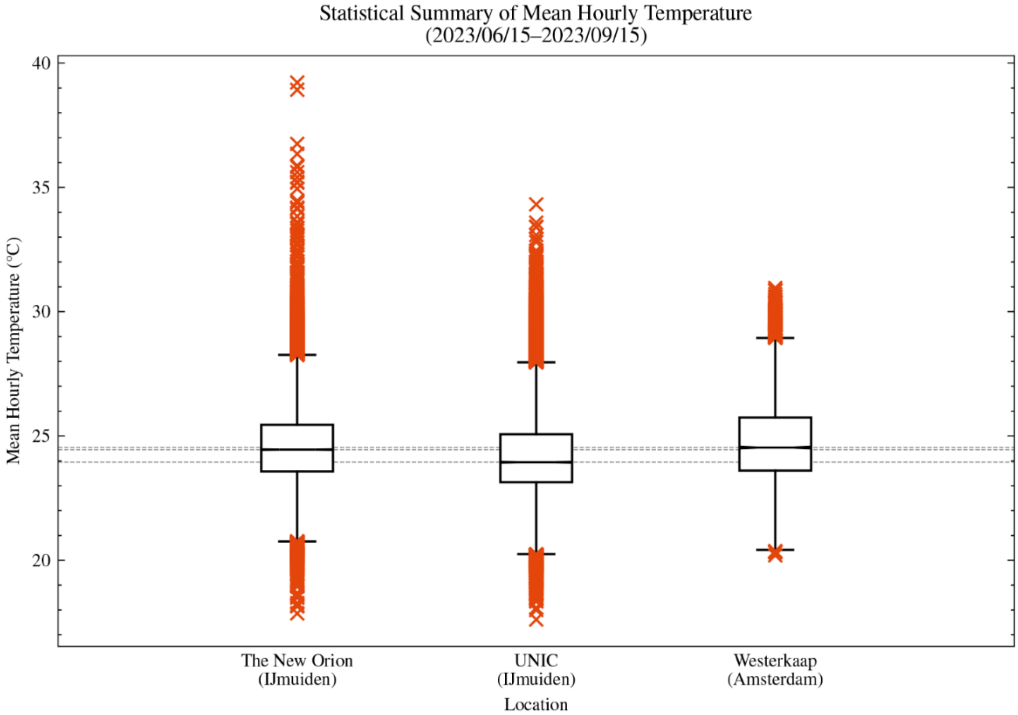


Figure 25. Mean hourly air temperature for the three locations (full measurement period)

As shown in Figure 26, during the heat wave the differences between the three areas become more evident. In New Orion mean hourly temperature ranges from 30.5 to 22.0 degrees Celsius with a median value of 26.3 Celsius and a high number of outliers that reach up to 39 Celsius. Mean hourly temperature values in UNIC have a similar range but a lower median value around 25 Celsius, while outliers reach up to 32C. Finally, in Westerkaap mean hourly temperature values range between 20.5 and 21.5 with a median value of 26.4 but a low number of outliers. Generally this comparison indicates that in New Orion some of the apartments get much hotter than UNIC and Westerkaap during hot periods.

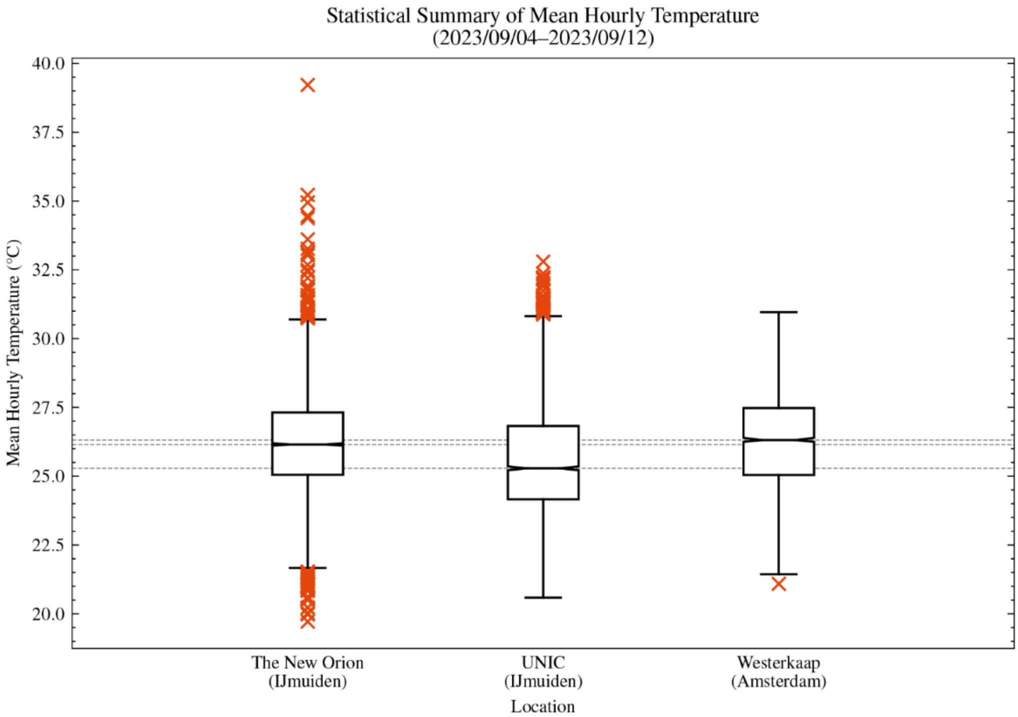


Figure 26. Mean hourly air temperature for the three locations (local heatwave)

10.2 Climate control (during heat wave period)

In the areas of analysis, three types of climate control measures are used. As shown in Figure 27 the majority of the apartments employ passive ventilation techniques (i.e. cross-ventilation, opening (all) windows). Indoor sun protection (i.e. closing curtains, shutters) and active cooling (i.e. heat pump and/or airco) is used in some New Orion and Westerkaap apartments. Data collected during the heat wave show that indoor sun protection is less effective than passive ventilation in reducing indoor hourly mean temperature. The frequency plotting (Figure 28) shows that apartments with indoor sun protection have a mean temperature of 27.2 degrees Celcius. Passive ventilation allows to keep mean temperatures around 26.1C in New Orion and Westerkaap and is particularly effective in UNIC (mean 25.4C.). Differently, apartments with active cooling systems have very diversified thermal environments that might depend on behavioural factors and occupants' decision to activate them.

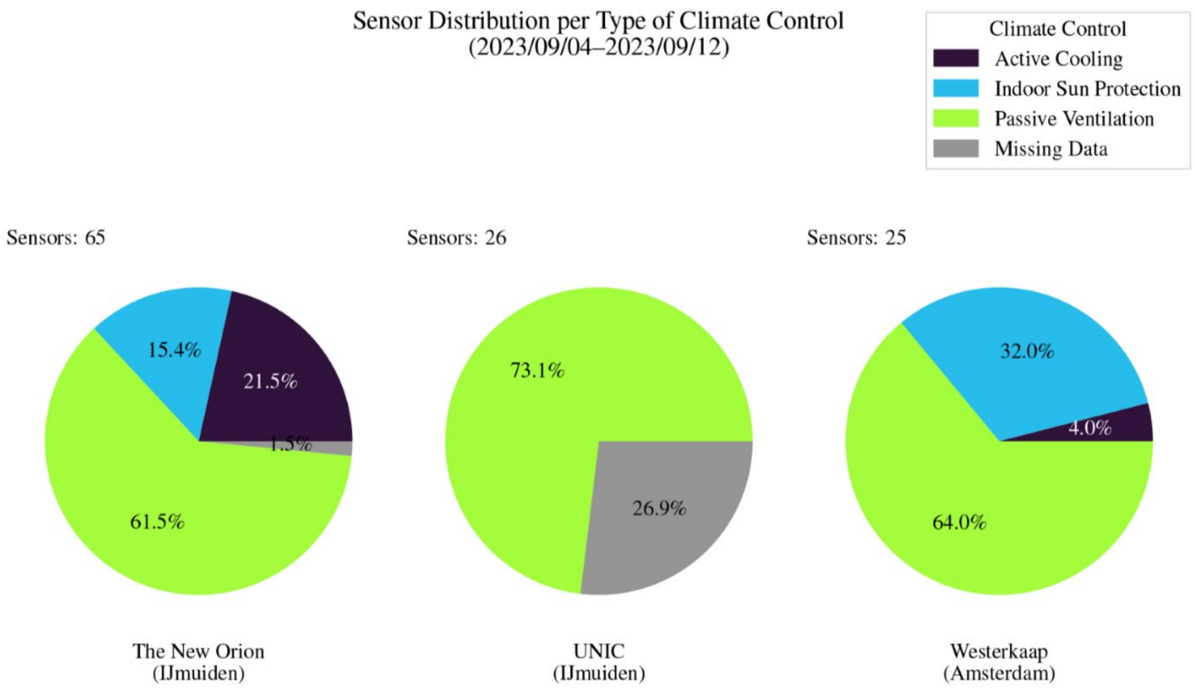


Figure 27. Proportion of types of climate control measures employed per location

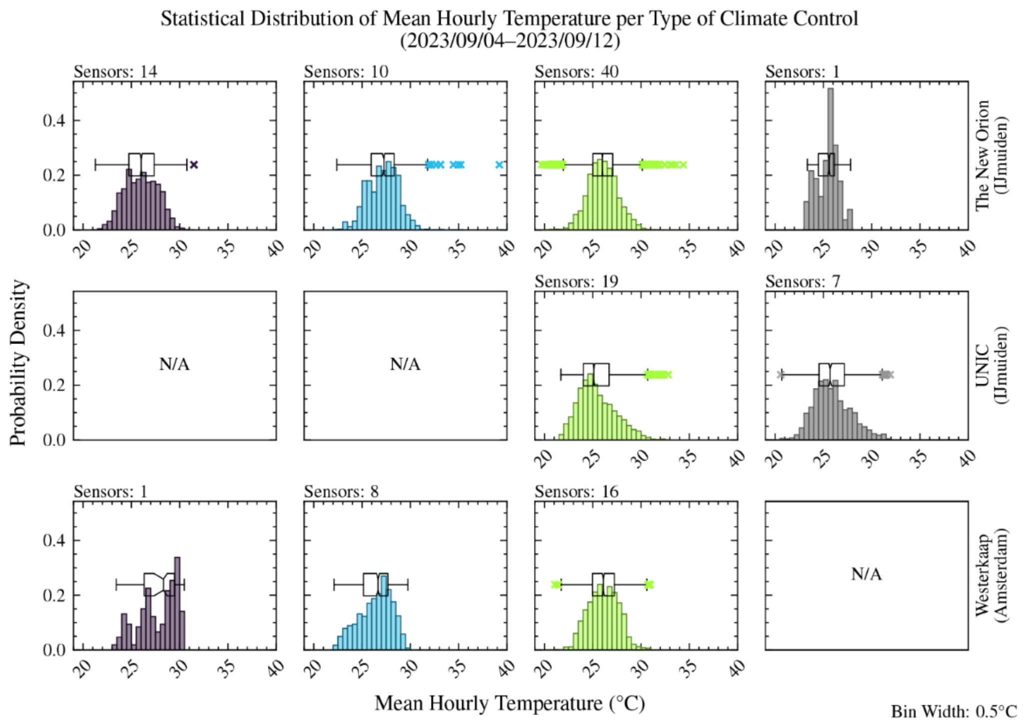


Figure 28. Frequency of mean hourly air temperatures per type of climate control measures (colours correspond to Figure 27)

10.3 Floor level (during heat wave period)

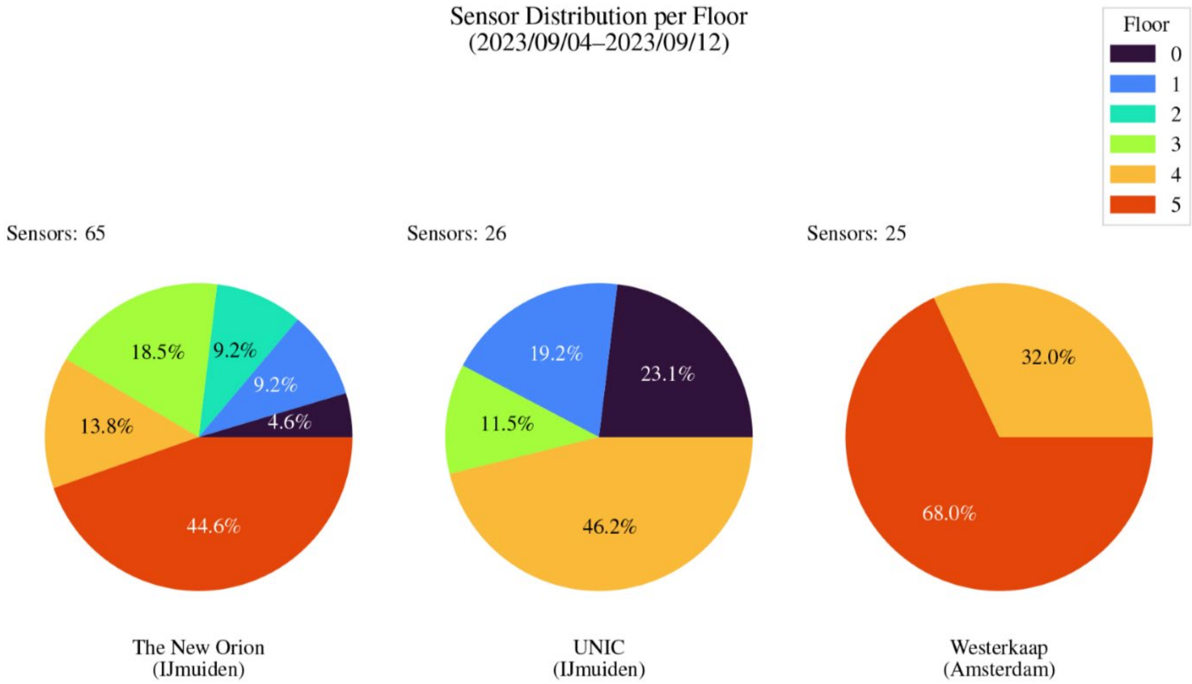


Figure 29. Sensor distribution per floor per location

Another factor that was investigated is the relation between indoor temperature and the vertical position of the apartment. Data are collected in apartments placed between floor 0 and 5 in New Orion, at floor 0,1,3 and 4 in UNIC and at floor 4 and 5 in Westerkaap (Figure 29). The plotting of temperature data classified per floor (Figure 30) highlights low variability of mean temperature values at the ground floor, first and second floor except for the second floor in New Orion. A higher variability in temperature can be observed in apartments placed at floor 4 and 5 which might be explained by the high exposure to sun radiation. Furthermore, in UNIC and Westerkaap the mean hourly temperature gradually increases with height, i.e. from 24.9C on the ground floor to 26.6C on the fifth floor in UNIC and from 25.5C on the fourth floor to 26.6C on the fifth floor in Westerkaap. For the New Orion this pattern is less clear.

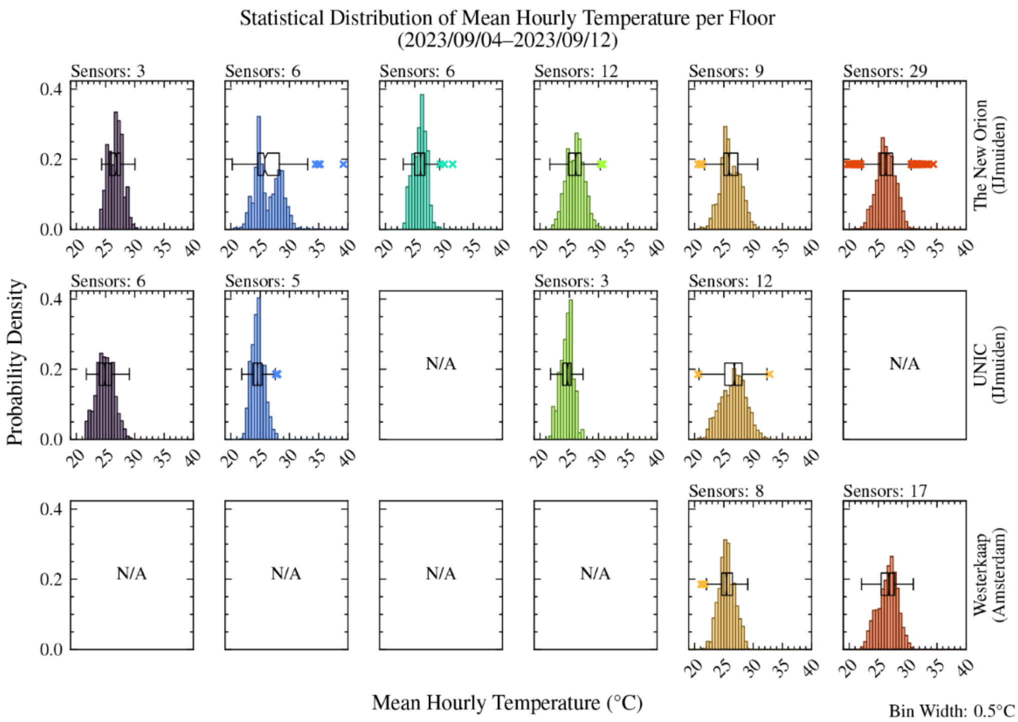


Figure 30. Frequency of mean hourly air temperature per floor (colours correspond to figure 12).

10.4 Apartment ownership (during heat wave period)

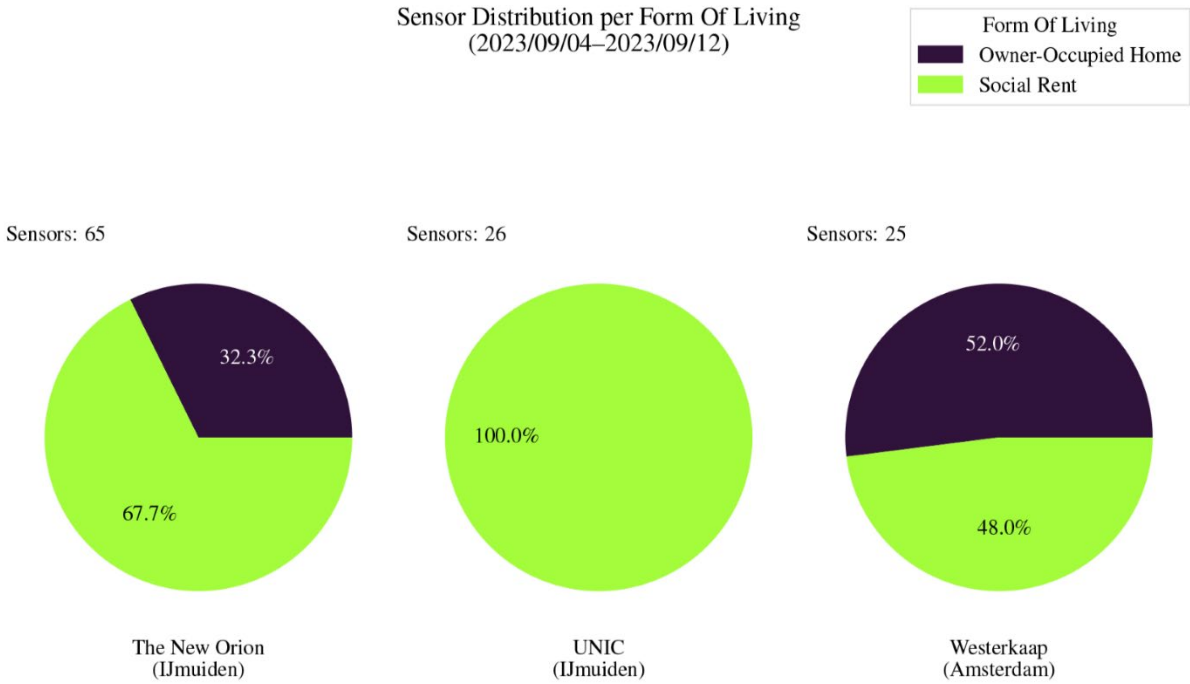


Figure 31. Proportion of sensors per form of living (ownership situation)

The apartments analysed were also classified based on the fact if the tenants owned the apartment or rented it. In New Orion 32.3% of the 65 sensors were placed in owner-occupied apartments while the remaining 67.7% were placed in social rental apartments. All the 26 sensors in UNIC were placed in apartment for social renting, while in Westerkaap, 48% of the 25 sensors were placed in apartments for social renting and 52% in owner-occupied ones (Figure 31).

The relation between form of living and temperature analysed (Figure 32) clearly shows that mean hourly temperature values are generally lower in owner-occupied apartments. In New Orion and Westerkaap the median values are between 25.3 and 25.7 degrees Celsius in owner-occupied apartments while the median values increase up to 26.5 and 26.9 degrees Celsius in apartments for social renting. In addition to around 1 degree difference in the median of hourly temperature values, a difference of 2 degrees Celsius can be observed in the maximum mean temperature. In fact, without considering the outlier values the maximum mean hourly temperature increases from around 29 degrees Celsius in owner-occupied apartments to around 31 degrees Celsius in social rental apartments. This is expected to be related to the outdoor sun protection of the owner-occupied dwellings. A measure lacking for the renter-occupied dwellings.

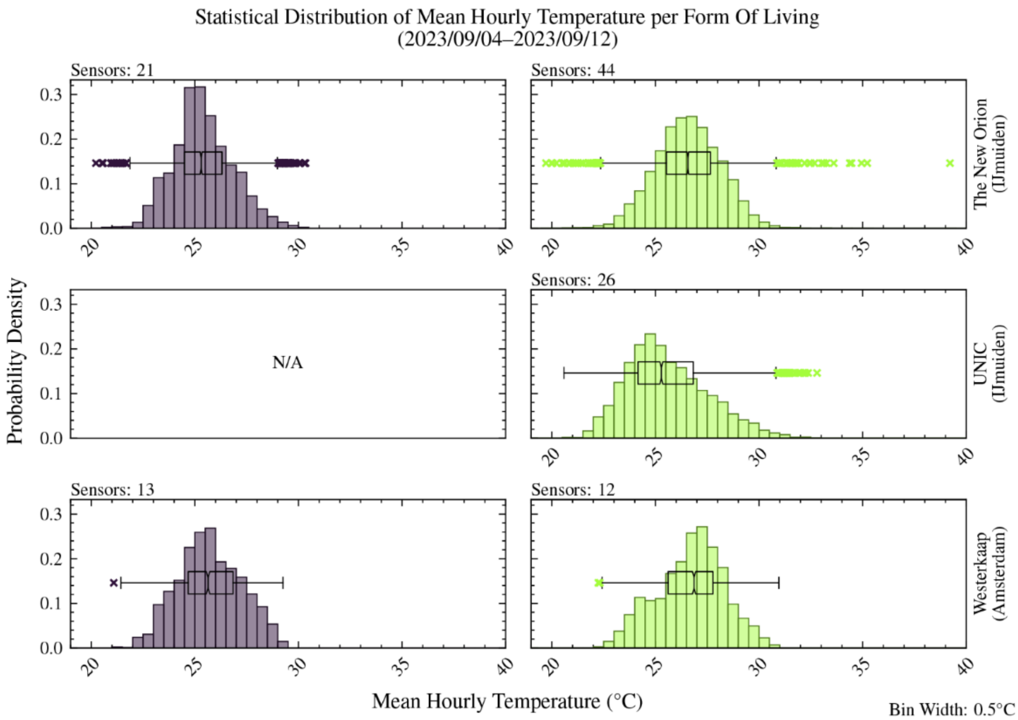


Figure 32. Frequency of mean hourly air temperatures per form of living (colours correspond to figure 14)

10.5 Sun protection (during heat wave period)

Sunlight entering the house can significantly contribute to higher indoor air temperatures. Keeping the sun out can be achieved either with measures outdoors (e.g. exterior screens, awnings, blinds, or shutters) or indoors (e.g. closing the curtains, indoor blinds, etc.), or a combination of both. In New Orion and Westerkaap, some of the apartments had outdoor sun protection (in both cases around 15-20%), in the UNIC apartment blocks only indoor sun protection was reported. In all three locations over half of the measured rooms were reportedly without any form of sun protection (missing data) (Figure 33).

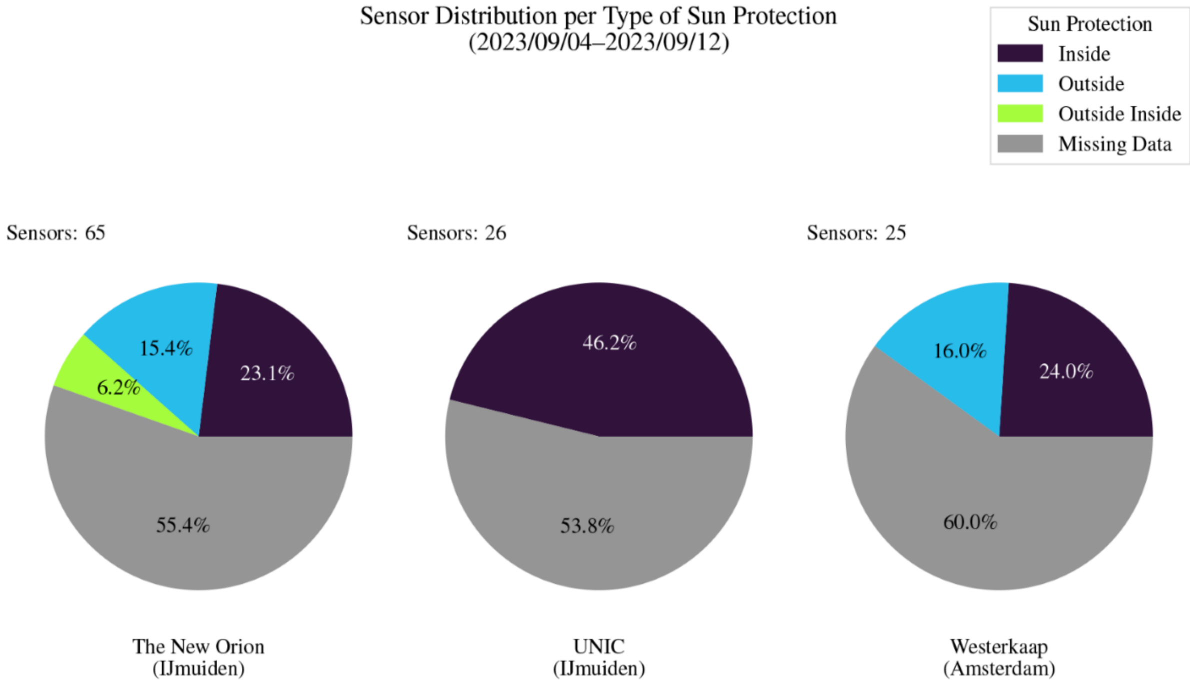


Figure 33. Proportion of sun protection measures employed per location

The relation between form of sun protection and measured temperature shows a clear pattern; a combination of outdoor and indoor sun protection yields the lowest average temperatures, followed by only outdoor sun protection. Indoor sun protection yields slightly lower average temperatures than no protection (or missing self-reported data). Especially notable for the dwellings without protection (missing data) is the large scatter of values in the extreme temperatures. (Figure 34).

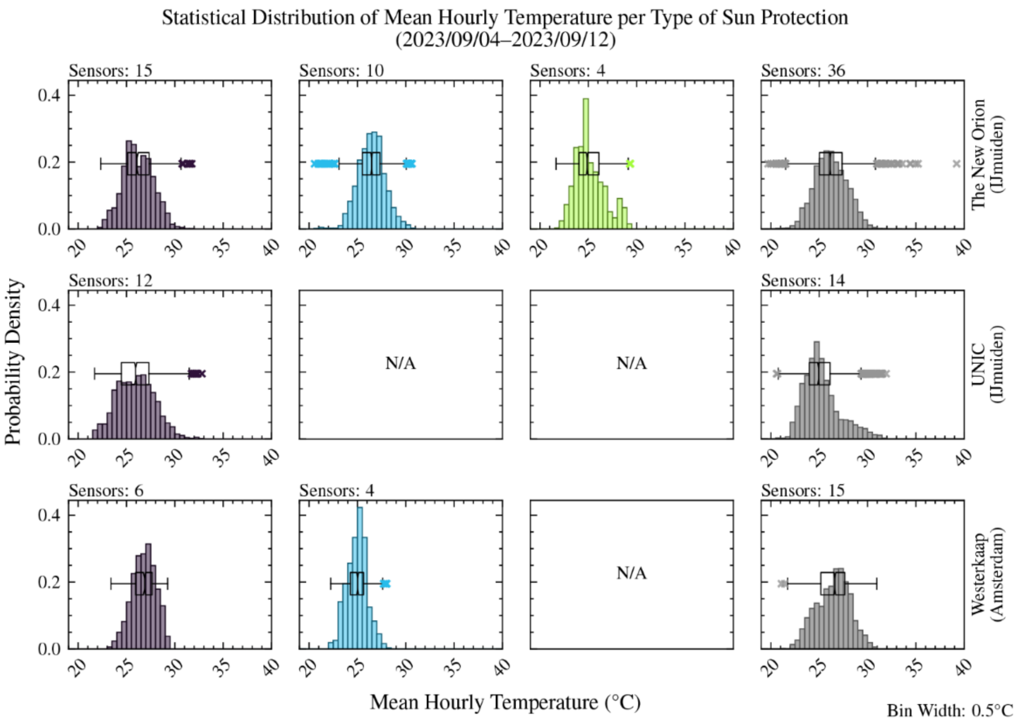


Figure 34. Frequency distribution of mean hourly air temperatures per type of sun protection measures.

The pattern is clearest for the rooms in the New Orion facing southwest, as depicted in Figure 35 ; the cluster shows the lowest mean temperatures for the sensors shaded indoors and outdoors, increasing for those with outdoor shading, and a scatter for those shaded indoors or not at all. The results are even more pronounced when taking into account the floor on which the sensors are located (Figure 36); those with combined shading measures are located at the third floor and still have lower mean temperatures than those with outdoor shading, which are on higher floors and can thus be expected to have higher temperatures.

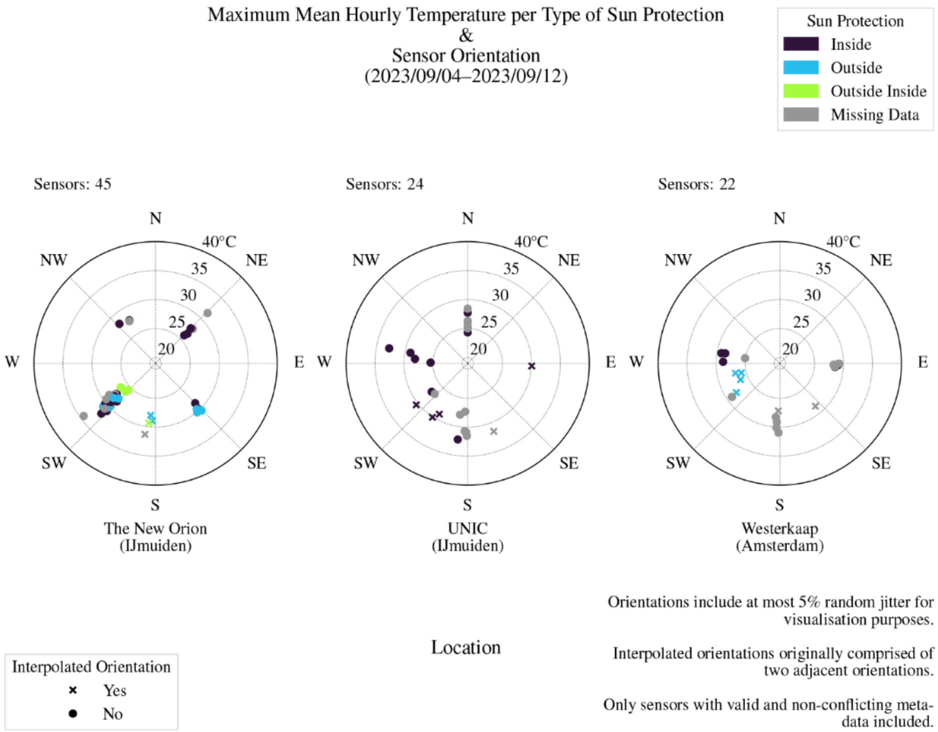


Figure 35. Mean hourly air temperature per type of sun protection measures plotted according to the sensor/room orientation

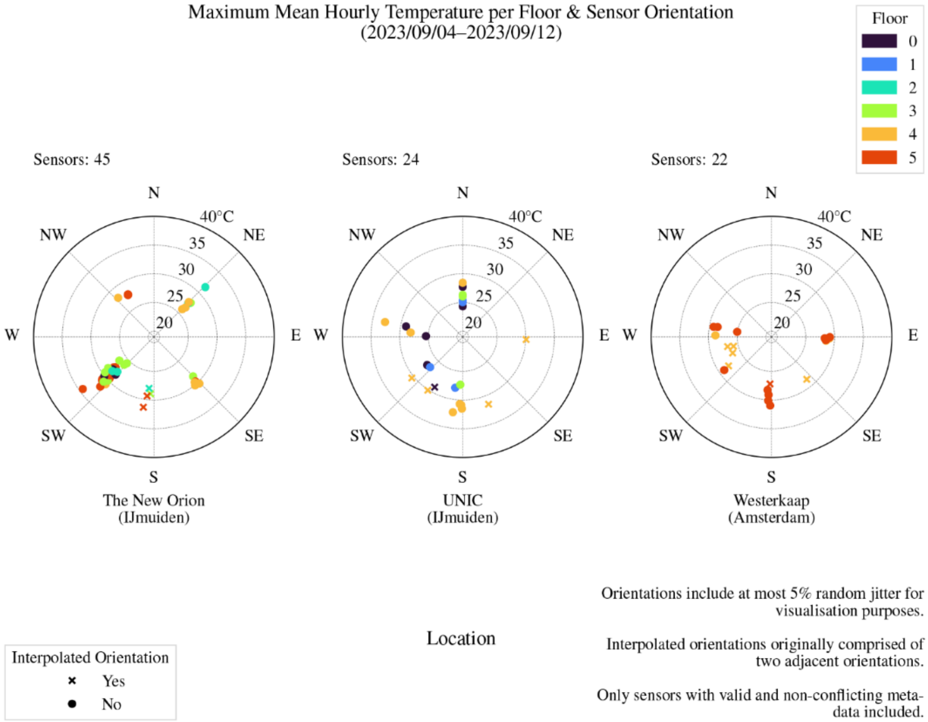


Figure 36. Mean hourly air temperature per floor plotted according to the sensor/room orientation

10.6 Type of room (during heatwave)

For all three locations participants were asked to install one sensor in their living room, one in a bedroom and one additional sensor in another room (i.e. another bedroom, workspace, etc). This request led to a sensor distribution over different types of rooms as depicted in Figure 37.

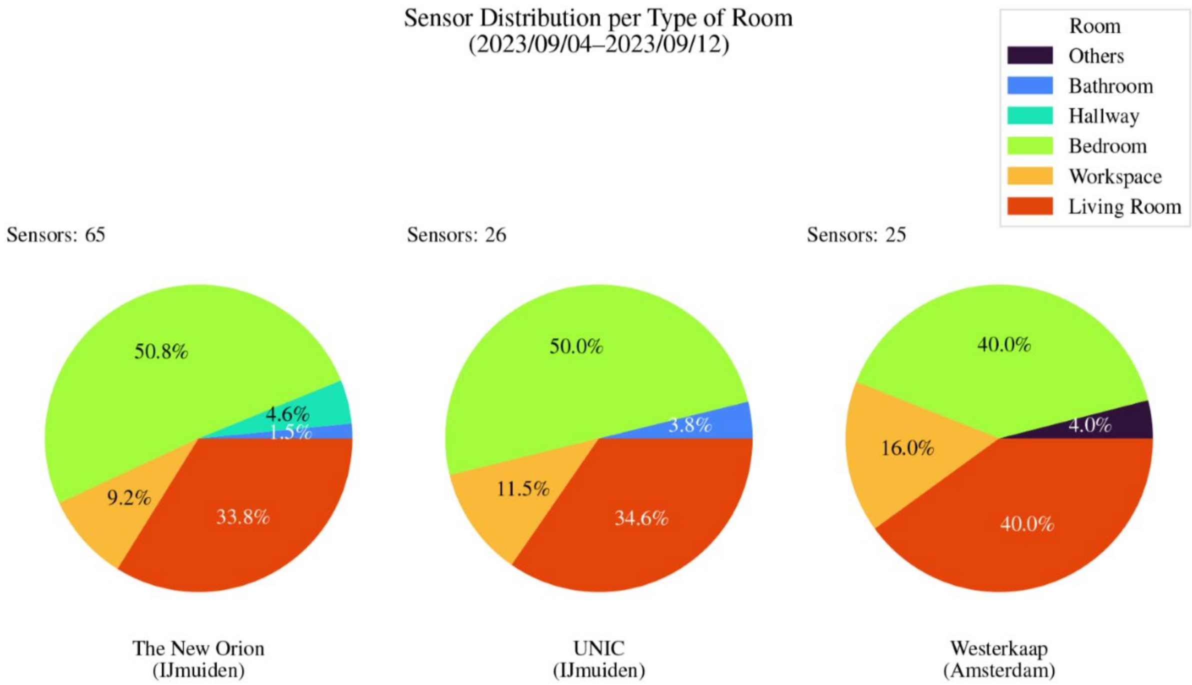


Figure 37. Proportion of sensors per room type

The measurements show that bathrooms and hallways have relatively low temperature ranges (see Figure 38). This may be explained by the small sample (2 and 3 sensors respectively), in combination with a probable low direct sun exposure. The temperature profiles of the other room types are less distinct from each other, with an exception for the UNIC buildings; here the bedrooms and workspaces have a lower average temperature than the living rooms, which is presumably due to their orientation; most of the bedrooms and workspace face north, while most living rooms face south (Figure 39).

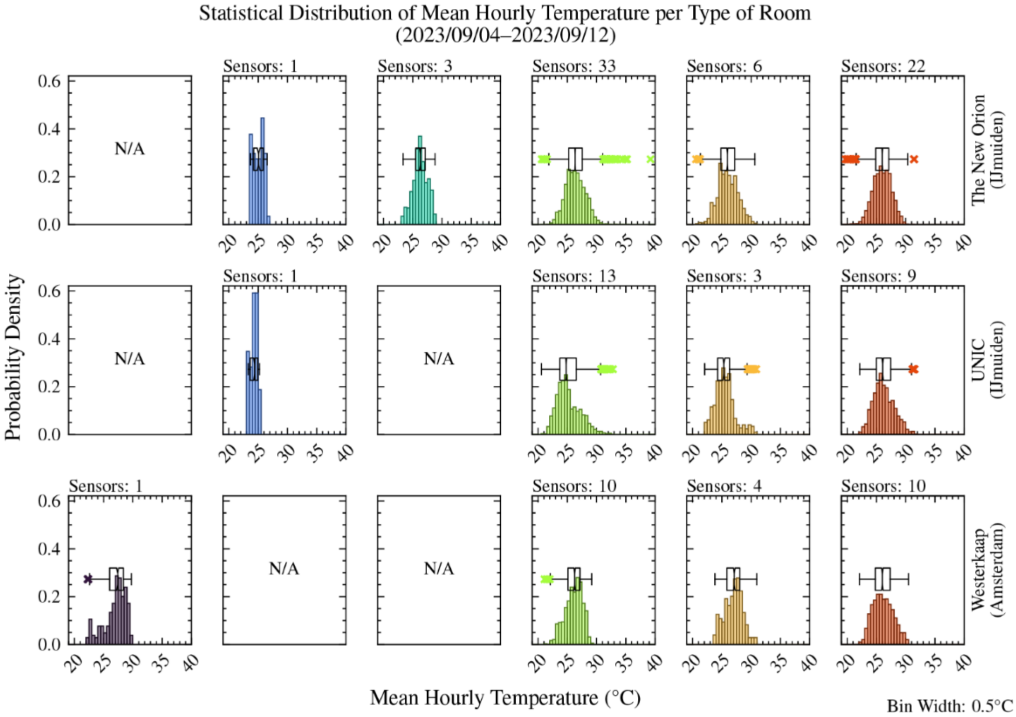


Figure 38. Frequency distribution of mean hourly air temperatures per type of room

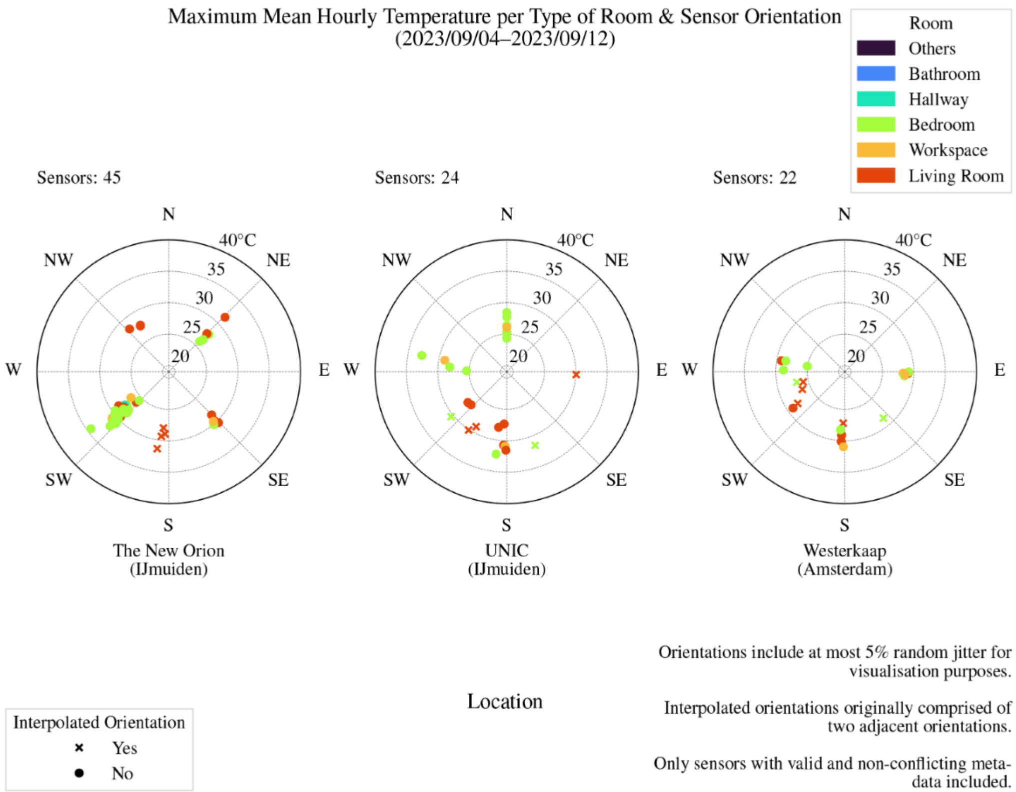


Figure 39. Mean hourly air temperature per type of room plotted according to the sensor/room orientation

11 Appendix 5: Appendix 5: Full data analysis – Climate literacy

For analysing the data that came out of the surveys, two different groups were analysed: the group of people that participated in the measurements (further "the measurement group") and the general public (further "the reference group") that was reached predominantly via a radio program of Argos. We have collected 68 surveys from the reference group and 38 surveys (19 before summer and 19 after summer) from the measurement group. The general information about the respondents to the climate literacy survey can be found in Table 1 below. It should be taken into account that the sample sizes of both the measurement group and reference group are small and not reflective of the general population in the Netherlands. Nonetheless, it provides direction and further understanding of how people with different socio-economic backgrounds perceive indoor heat and climate change.

The surveys were filled in by the measurement group before summer (in the month June) and after summer (in the month October). The reference group has filled in one survey, in the beginning of October, just after the Argos radio program. The surveys had the same questions, with some small changes for the reference group as they have only filled in the survey once (after summer). The demographics, as well as the type of dwellings slightly differ between the measurement group and the reference group. The majority of participants were people living in an apartment reaching from one side of the building to the other (further referred to as "2-façade apartment") with a good to average insulation. However, the measurements were taken in newly constructed buildings, while the construction years of the dwellings of the reference group is evenly distributed throughout the last 100 years. Also the demographics differ in some aspects, most noticeably age and gender. The respondents from the measurement group were predominantly elderly men. Both groups were highly educated; in the measurement group almost 60% of the respondents stated to have higher education, in the reference group this was more than 80% of the respondents. This high percentage of highly educated respondents in the reference group is probably caused by the demographics of listeners to Argos radio programs and visitors of their website.

Type of house	apartment (1 facade)	apartment (2 facade)	terraced house	detached		
Before	4 21%	12 63%	2 11%	1 5%		
After	4 21%	15 79%	0 0%	0 0%		
Reference	15 25%	31 51%	12 20%	3 5%		
Construction year	**Before 1945**	**1975 to 1985**	**1985 to 1995**	**1995 to 2005**	**2005 to 2015**	**2015 or later**
Before	2 11%	1 5%	1 5%	1 5%	6 32%	8 42%
After	0 0%	0 0%	1 6%	0 0%	7 39%	10 56%
Reference	16 29%	7 13%	6 11%	10 18%	7 13%	9 16%
Isolation	**Good**	**Mediocre**	**Bad**			
Before	14 78%	1 6%	3 17%			
After	18 95%	1 5%	0 0%			
Reference	43 65%	18 27%	5 8%			
Age	**18 - 25**	**26 - 35**	**36 - 45**	**46 - 65**	**66 - 75**	**76+**
Before	1 5%	1 5%	0 0%	8 42%	4 21%	5 26%
After	0 0%	1 5%	0 0%	4 21%	8 42%	6 32%
Reference	0 0%	9 13%	6 9%	28 41%	20 29%	5 7%
Anual income	**<15.000**	**15.000-25.000**	**25.001-40.000**	**40.001-60.000**	**60.000+**	
Before	2 13%	3 19%	6 38%	4 25%	1 6%	
After	2 12%	2 12%	7 41%	5 29%	1 6%	
Reference	10 16%	19 30%	15 24%	14 22%	5 8%	

Orientation living room	South	East	North	West
Before	11 39%	7 25%	1 4%	9 32%
After	14 58%	5 21%	1 4%	4 17%
Reference	36 54%	10 15%	11 16%	10 15%
Orientation bedroom	**South**	**East**	**North**	**West**
Before	5 24%	4 19%	8 38%	4 19%
After	5 23%	8 36%	5 23%	4 18%
Reference	29 43%	13 19%	16 24%	10 15%
Gender	**Male**	**Female**	**No comment**	
Before	13 68%	6 32%	0 0%	
After	15 79%	4 21%	0 0%	
Reference	31 46%	34 50%	3 4%	
Course/study	**Primary school, VMBO, MBO1, HAVO (first 3 years)**	**HAVO, VMBO, MBO**	**HBO, wo bachelor, wo master, doctor**	
Before	1 6%	6 38%	9 56%	
After	6 35%	2 12%	10 59%	
Reference	1 2%	14 22%	51 81%	

Table 3. Basic details of measurement (before and after) and reference group

Besides the general information about the respondents and their dwellings, we have collected answers to questions falling into various categories (see also the subparagraphs). The categories were not known to the respondents. Particularly answers that we analyse in the category "knowledge" were spread throughout the survey.

11.1 Temperature

First studied category was the insight people have in temperature in their apartment. We have asked three separate questions: 1) What is the average temperature in your apartment during summer? 2) What is the maximum temperature your apartment reaches in (or "you have measured during the last") summer? 3) From which indoor temperature upwards do you feel uncomfortable in your apartment?

The results show that people have a good insight into the maximum temperatures that their apartment reaches. The answers of the measurement group about maximum temperature were very similar before and after summer (28,5 C and 28,2 C, respectively). Interestingly, answers before summer ranged slightly higher (25 - 35 C) than after summer (23 - 32 C). This could be attributed to either a summer with less (outdoor) temperature extremes than in previous years, or to potentially different composition of the respondents before and after summer.

When it comes to average summer temperature, the answers of the measurement group were slightly lower before summer compared to the answers after summer (23,9 C and 25,1 C, respectively). This is an opposite trend compared to the maximum temperatures. Simply put, people expected that the average temperature of their apartment in summer would be lower than what it then turned out to be. Also the range of the responses was very narrow in the answers of the measurements group after summer, from the 19 respondents 15 answered that the average temperature was between 24 and 25 C. In the reference group, there was a bigger range in how warm it got indoors during last summer, the answers varied from 19 to 34 degrees (outliers not shown in figure) with an average of 25,5 C.

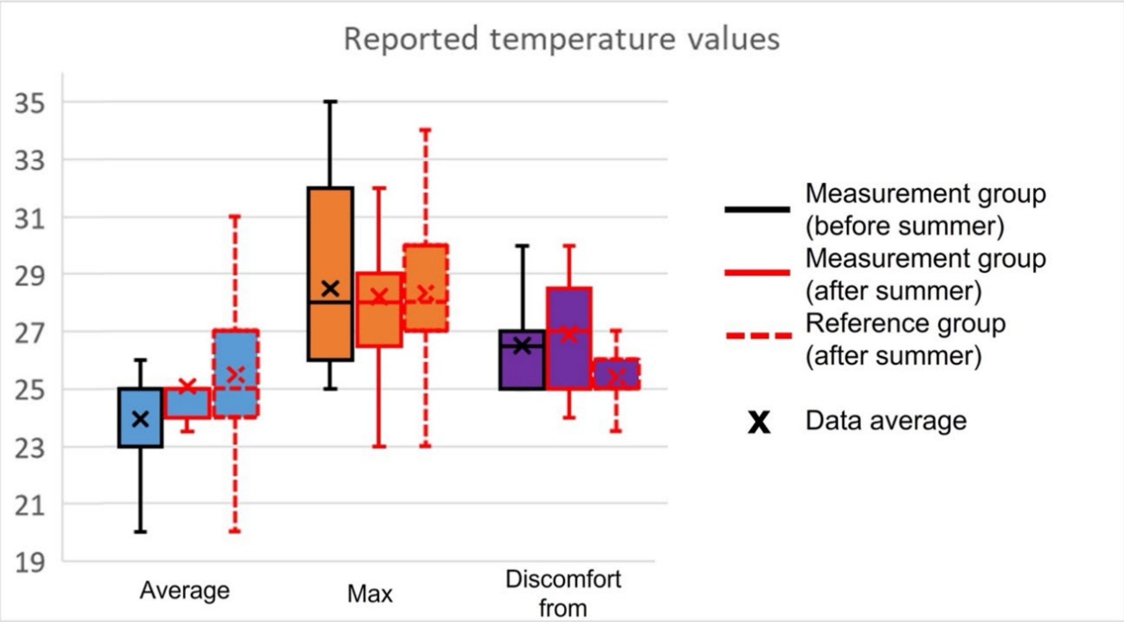


Figure 40. Reported temperature values by participants

Third studied parameter was temperature above which people feel uncomfortable. The answer to this question stayed almost the same for the measurement group (26,5 C on average before summer, 26,8 C after). Interestingly, for the reference group the temperature from where they feel uncomfortable was a whole degree lower on average; 25,3 C. The results on the comfort levels indicate two things: 1) that the general preference considering ones comfort is relatively fixed and does not change much during one summer, and 2) that our measurement group seems to have, compared to the general public, a higher tolerance level for discomfort.

11.2 Experience of heat

To a general question if one feels uncomfortable in their apartment during hot days, half of the respondents in the reference group answered yes (10 before and 9 after summer) and half no (9 before and 10 after summer). Nonetheless, more specific questions show a shift of the responses after summer towards perceiving the indoor summer temperatures as warm or very warm rather than neutral (or even cold). This is particularly visible in the data concerning night temperatures both on average summer nights and during the warmest periods of the summer. While before summer, 12 people (63%) reported that on average summer nights they feel neutral (or even cold – 1 respondent), after summer the amount of people who felt very warm quadruplet and only 8 people (42%) perceived it as "neutral". In general, the response "very warm" was more common after summer than before for all types of questions with an exception concerning average summer days.

When it comes to the answers about the experiences with heat filled in by the reference group, 60% experienced their apartment as warm or very warm during the summer in general. During the warmest days of summer, 90% of the respondents reported their apartment as (very) warm, both during night and day.

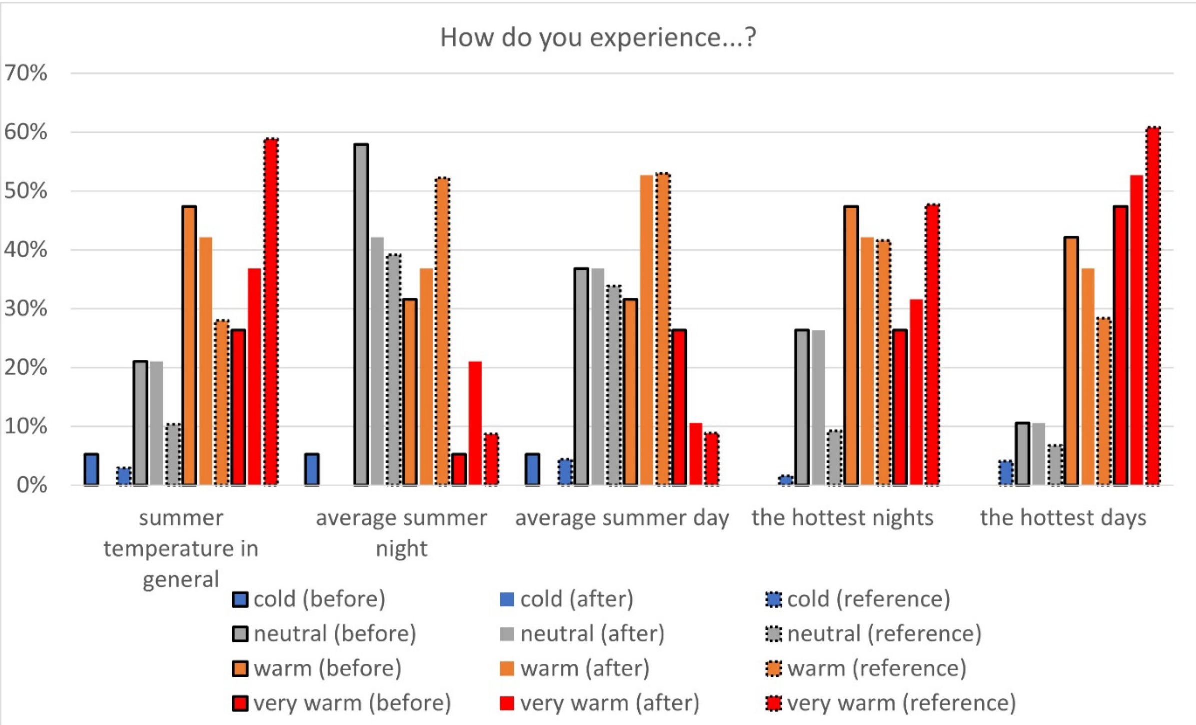


Figure 41. Experience of heat

When asked about their experience over a longer time period, 85-89% (16 before and 15 after summer) of the respondents within the measurement group and 90% (60) of the reference group mentioned that their experience has changed over the last ten years. Within the measurement group, people mostly mentioned that it is in general warmer than it used to be. Besides the change in average temperature, the reference group defined the change as an increase in maximum temperature and a higher frequency of heat. Surprisingly, we see a decrease in the responses regarding the occurrence of heat waves after summer and also the reference group named it as the least prevalent effect when it comes to change in their experience of summer temperatures. This was probably caused by the lack of heat waves in 2023. Nonetheless, the reference group mentioned longer heat waves and warm nights much more often than the measurement group.

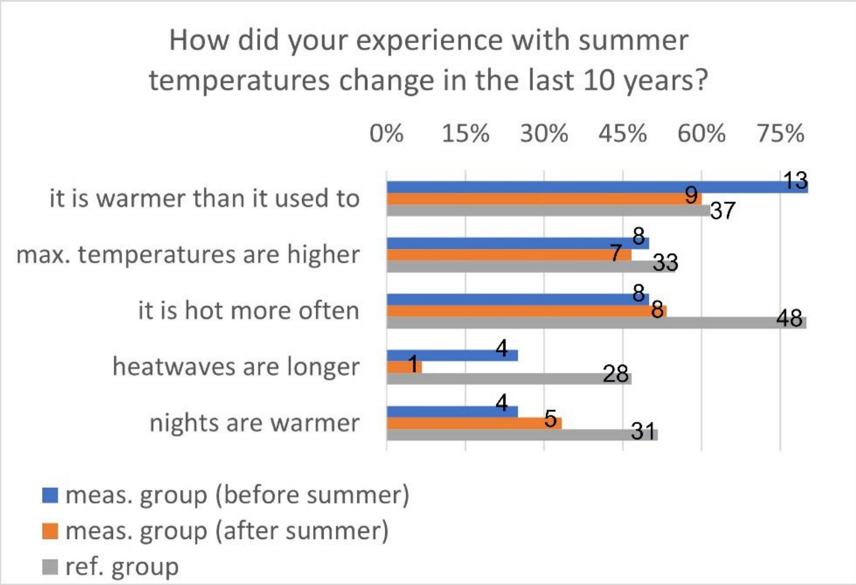


Figure 42. Experience of change summer last 10 years

11.3 Measures against heat

From the results regarding measures that people take/took during summer, we can see that in both the measurement and reference group there is some overall understanding of how to keep the house cool and how to increase one's own comfort. Although people adopted different strategies, we can see that they believe that night ventilation together with preventing the sun to warm up the apartment during a day are the most efficient strategies to keep their apartment cool. Interestingly, the amount of people that see night ventilation as the most efficient way to keep the house cool halved (from 6 before summer to 3 after) over the summer within the measurement group. This can be related either to relatively warm nights or a lower possibility to ventilate due to various factors such as noise, safety, mosquitoes, or wind (all mentioned by respondents).

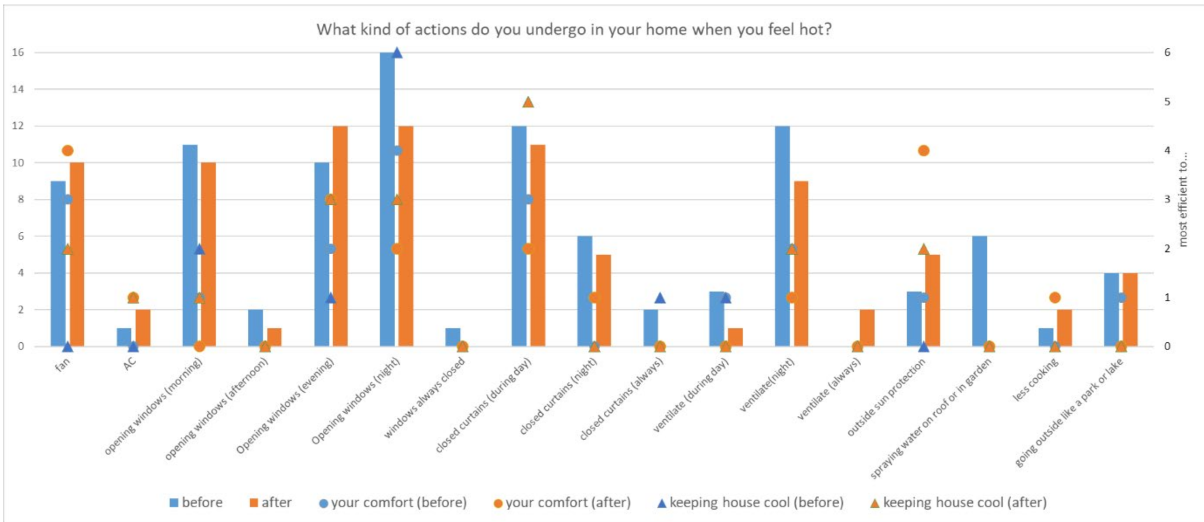


Figure 43. Actions undertaken when feeling hot inside

Understanding of the importance of night ventilation and preventing sun from entering the building is also visible in the answers to the question "Which measures could have been effective, but you can/could not implement?". Outdoor blinds was the most prevalent answer in both studied groups with almost half of the respondents from the measurement group and 74% of the respondents from the reference group choosing this option. As indicated in the previous paragraph, many respondents also wish to have more possibilities to properly ventilate their apartment during both day and night. The number of responses regarding night time ventilation quadrupled over the summer, from 2 to 8, within the measurement group; 5 of them indicated they could not efficiently ventilate at night due to high outside temperatures.

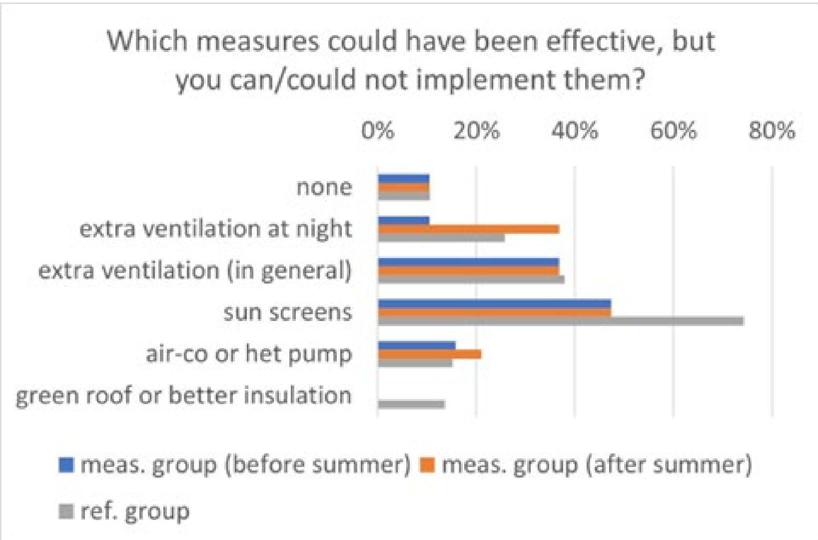


Figure 44. Mentioned effective measures that could not be undertaken

When it comes to increasing one's comfort, there is less clarity among the respondents in the measurement group about which measure is the most efficient. Physiologically, the most effective way to increase one's comfort would be a ventilator or other way of creating a breeze through the apartment (alternatively, other active cooling measure such as air-conditioning). Ventilator was, indeed, chosen relatively often, but so were measures that by definition prevent sun from entering (closing the curtains over day or outdoor blinds) and therefore are meant to keep the house cool. Four times more respondents from the measurement group chose this option after summer than before summer. It is not clear if those measures were so effective that people also perceived the colder indoor temperatures and consequently higher comfort, or if there are other reasons that lead to these answers.

In the reference group, 43 (65%) of the respondents used a ventilator and 6 an air-conditioning unit. All of the respondents using air-conditioning indicated it also as the most efficient measure to increase their comfort. The ventilator was the prevalent answer as the most effective way to increase the personal comfort. Neither the ventilator or air conditioning was very frequently mentioned among the answers about cooling one's apartment. This shows a good understanding of the reference group when it comes to which measures are effective for which goal. The importance of feeling a breeze was clearly perceived as an improvement for comfort.

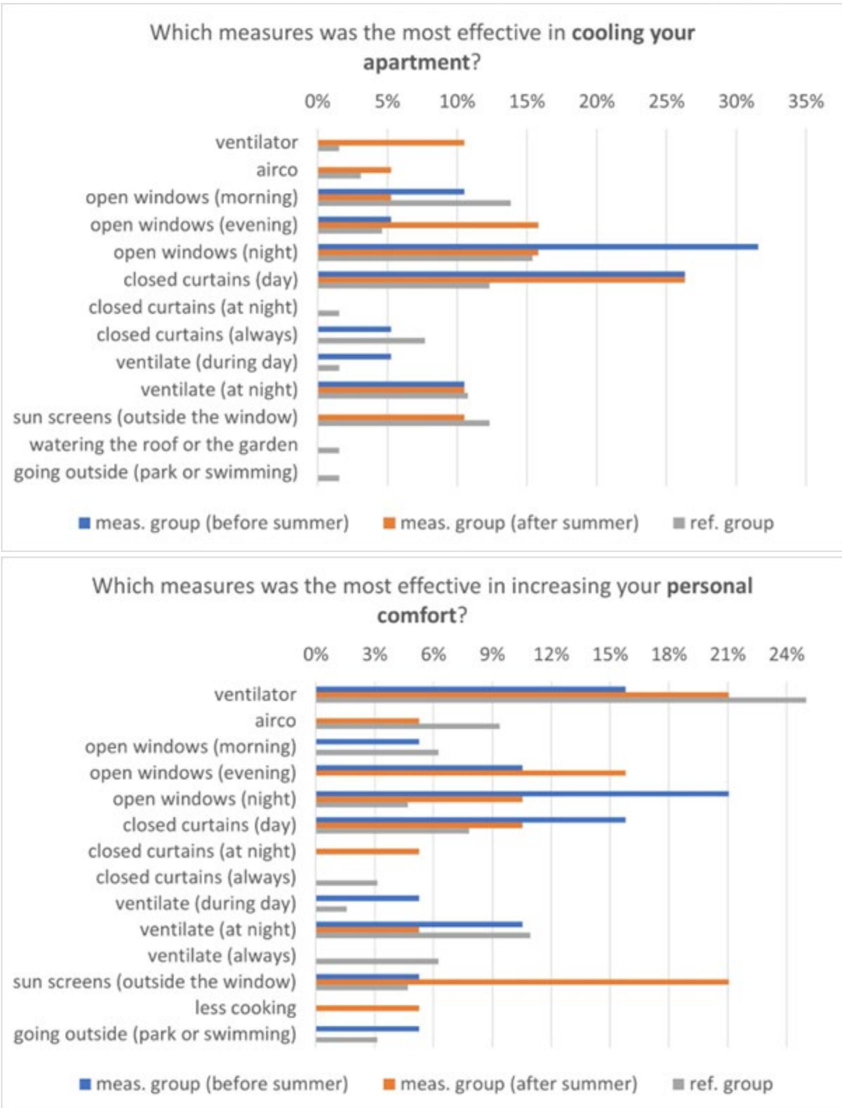


Figure 45. Measures undertaken to cool apartment and to increase personal comfort

Additional outdoor blinds are often seen as a potentially effective measure that was not possible to implement for both the reference and measurement group. From conversations with the participants and the housing corporation representatives it became clear that it is not allowed to place any installation on the façades of the building. As mentioned before, additional night ventilation was another desired measure that was not possible to implement, often due to high night time temperatures or building characteristics. This strengthens the need for local climate adaptation and the need for well-designed windows that can stay open without reducing the feeling of safety or comfort because of noise and/or mosquitoes. Third group of measures that the respondents wished to implement was the possibility to create a breeze by opening windows on both sides of the building. Surprisingly, the hinder was not related to respondents with only 1-façade apartments (only one respondent within the measurement group and circa 35% of the reference group with 1-façade apartment reported this problem), suggesting that the problem is rooted in other issues (like safety, noise, wind, or mosquitoes). Unfortunately, the reasons for why the measures were not possible were not examined in this survey.

Another way of dealing with extreme heat is to adjust activities or change location. Before summer, 11 people from the measurement group reported that they use such measures during heat waves. After summer, the number dropped slightly to 9. One interesting result emerged from the comparison of the answers before and after summer: the willingness to do outdoor activities. Before summer, people assumed that they will limit their outdoor activities (8 out of 11) and no one answered that they would do more. After summer, only 3 people reported that they limited their outdoor activities and 4 people mentioned an increase in outdoor activities. We could not find any similarities between those 4 people, the reported average and maximum temperatures in their apartments varied, as well as their answers about comfort. Surprisingly, two out of those 4 people reported that they have an air conditioning system at home (one already had it, other installed it as a result of the measurements). Going outside for activities was the most mentioned behavioural change by the reference group (35%), as well as changing their drinking and eating behaviour secondly mentioned. With these results, we see on the one hand that activities undertaken outdoors is more similar after summer between the measurement group and the reference group. On the other hand, we can still see a clear difference in the answers given by the reference group and the measurement group after summer which might indicate a difference in knowledge and or interest. This will be discussed in the section below.

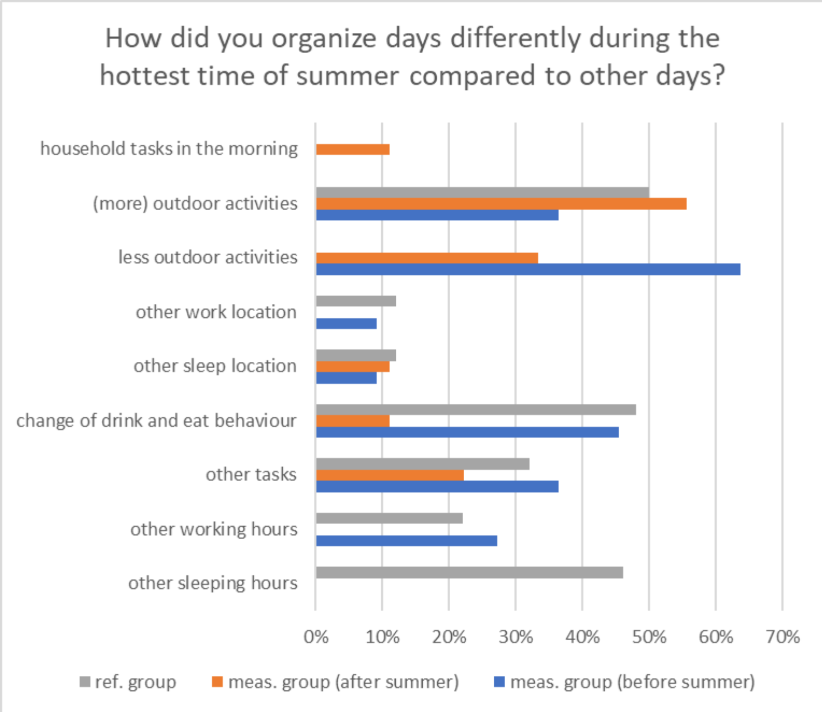


Figure 46. Taken different day activities during hot weather

When comparing the measures taken by the measurement group and the reference group it is important to take into account the type of the dwelling they inhabit. People that live in a 1-façade apartment have different possibilities when it comes to heat adaptation measures than people who live in a 2-facade apartment. Therefore, correlation coefficients have been calculated for two types of apartments that are present in the measurement group. We see a strong correlation between the measures taken by the reference group and the measurement group after summer as well as within the measurement group before and after summer (see also figure 30 and table 2). These correlations are even stronger for residents living in 2-façade apartments. This result suggests that there is a set of measures that is standard taken by residents living in such apartments. The lower correlation with respondents with apartments with just 1-façade suggests a need for other measures, possibly due to the lower possibility of ventilation, a well-known measure by the participants. On top of that, 87% of the respondents from the reference group and 75% of the respondents from the measurement group live in a rental apartment and therefore also have less options in installing other structural measures (e.g., outdoor blinds).

Table 4. Correlation table of activities undertaken by people living in 1 or 2 facade apartments

	app 1 facade	app 2 facade	total
Before vs. Reference	0.63	0.67	0.71
After vs. Reference	0.65	0.90	0.88
Before vs. After	0.52	0.90	0.88

Figure 47. Activities undertaken by people living in 1 facade or 2 facade appartments

11.4 Perspective

The perspective of the respondents on certain topics was tested by their agreement or disagreement with different statements. Statements within the measurement group about if it is warm enough in summer to spend time or money on cooling measures yielded more neutral opinions after summer than before summer, indicating that people see less urgency after the summer than before. For example, we can see a big drop in responses that indicated that spending money (from 7 to 2) or time (from 7 to 3) on installing cooling measures is certainly necessary. During the summer the number of respondents that worried about the hot summers in the future also dropped (from 16 (84%) to 11 (58%)). Similarly, we can see a decrease of people who agree that without an intervention in climate change the future summers will be unbearably warm (from 15 to 11). Also the opinions about if additional summer days (above 25 C) would be nice or cause more problems shifted more towards neutral. These results might be the consequence of the relatively mild summer. This is supported by the answers to the of statement "Few extra summer days would be pleasant" with which before summer 10 respondent disagreed (5 for "disagree" and 5 for "absolutely disagree") and after summer only 7 respondents (6 for "disagree" and 1 for "absolutely disagree").

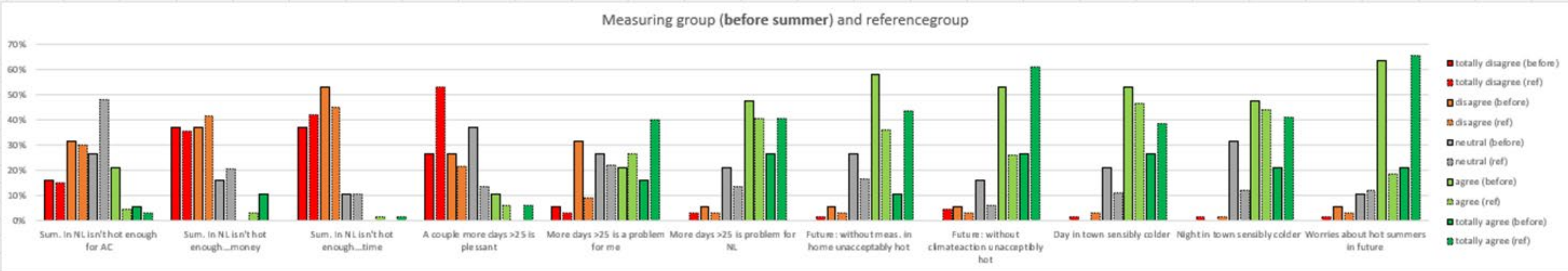
When comparing these results with the answers from the reference group, which were filled in after the same relatively mild summer, a different image arises. 97% responded negative or neutral that the summers are (now) warm enough to invest money and time in reducing the temperatures inside. Concerning the statements about future summers the respondents answered positively that extra cooling measures will be needed to sustain a comfortable living environment indoors (77%). Second, respondents are aware that if, without doing anything, summers will become unbearable hot and that they are worried about the future summers.
A comparison between the results of the "Statements" (Stellingen) for the measurement group and the reference group can indicate how participating in a measurement campaign changes people's perspective. Correlation coefficients indicate that the reference group was in more agreement with the measurement group before summer than after. This is an interesting result, particularly because the reference group answered the questions after summer only. Therefore, if the experience of the summer weather was the driving factor of the answers, we would expect more agreements between the reference group and measurement group after summer. This is particularly visible for statements about the climate in the Netherlands (as discussed in the previous paragraph). Before summer, the measurement group predominantly disagreed with statements that "The summers in NL are **not** warm enough to invest money/time to cooling measures"; the same general opinion can be found in the reference group. However, after summer, the opinion of the measurement group shifted more towards agreement or neutral and therefore lower willingness to spend time or money (the shift is stronger in case of money). Similarly (probably connected), the perspective on if "more days above 25 degrees would be problematic for NL" shifted from agreement (1 no, 4 neutral, 9 yes, 5 absolutely) before summer to more neutral stand after summer (5 no, 3 neutral, 11 yes).

On two points the correlations of the reference and measurement group were always low (both before and after summer): 1. The reference group tend to see the possibility of more days above 25 degrees as something that would cause a problem for them more often than our measurement group. This is quite surprising, as our measurement group consisted predominantly of elderly – potentially vulnerable – people. Nonetheless, this is in agreement with the higher comfort threshold reported by the measurement group compared to the reference group 2. The reference group also showed more worries about the warm summers in the future. This is consistent with the previous point.

From the differences between before and after summer responses of the measurement group, we can see how the participation in the measurement campaign influenced the opinions of people. The correlations show us a few points on which the opinion of the measurement group did not change much. Those are predominantly knowledge-related questions that have to do with climate change in the future or climate variation between cities and rural areas. All participants in the measurement group answered that it is "noticeably colder in a village both during night and day" (no disagreement at all). The data even show that the respondents are more certain (less "neutral") for daytime than for night-time. This is, however, not true. Measurements show that the daytime temperatures are comparable (1-2 degrees difference) in a city and in a village, while at night, the temperature difference can reach 5-10 degrees difference (KNMI). The majority of respondents (both reference and measurement group) believe that the "Summer time in the future will be unacceptably warm without climate action and/or cooling measures for apartments" and this opinion did not change throughout the summer.

	Sum. in NL not hot enough to use AC	Sum. in NL not hot enough...money	Sum. in NL not hot enough...time	A couple more days >25 plessant	more days >25 is a problem for me	more days >25 problem for NL	future: without measures in home unacceptably hot	future: without climate action unacceptably hot	day in village sensibly colder	night in village sencibly colder	worries about hot summers in future	
before vs. ref.	0,71	0,94	0,98	0,46	0,10	0,89	0,55	0,52	0,92	0,77	0,25	0,64449
after vs. ref	0,29	0,65	0,63	-0,16	-0,04	0,34	0,41	0,38	0,95	0,80	0,29	0,41272
before vs. after	0,64	0,50	0,73	0,77	0,45	0,68	0,97	0,95	0,99	0,88	0,76	

Table 5. Correlation table of the statements



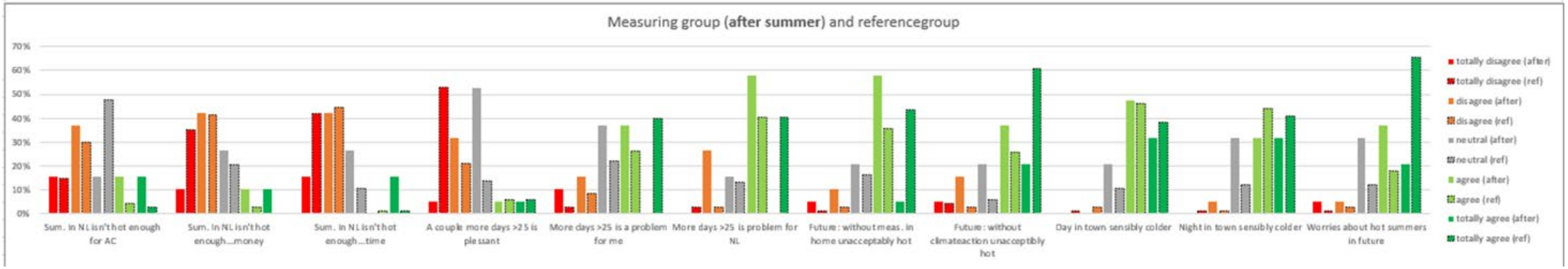


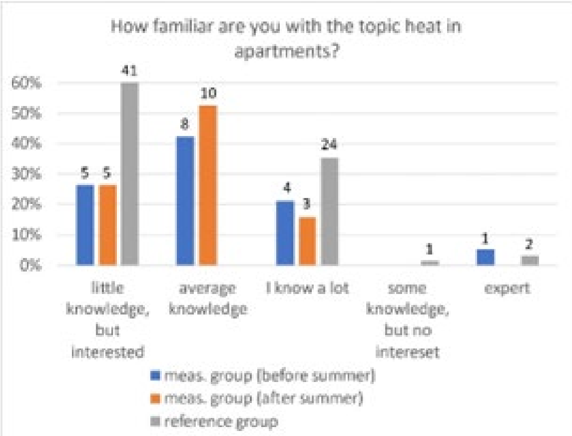
Figure 48. Perception on statements before and after summer, compared to reference group

11.5 Knowledge

The knowledge about the topic of heat in apartments and about climate in general was tested directly and indirectly via questions. The first category of questions were stated in such a way that we directly asked the respondents about their perceived level of knowledge. In this category are questions such as "how familiar are you with the topic of heat in apartments?", "Did you learn something new last summer and from which sources?" or, if the respondents indicated that their experience with summer heat changed last 10 years "What was the cause of the change?". In the second category, we analyse the knowledge based on questions that had to do with other aspects, for example the measures taken against heat and their effectiveness ("Which measure was the most effective in increasing your comfort?"), and checking the given answers against previous research about the actual effectiveness. The analysis within the second category was already discussed in the previous sub-chapters and will only be summarized here.

When it comes to the perspective of the people on their own knowledge, 60% of the reference group mentions they do not have a lot of knowledge but do have interest in indoor heat, and close to 40 % mentions that they know a lot or consider themselves an expert. No one in the reference group considered their knowledge level as "average". The measurement group, on the other hand, chose "average knowledge" most often (42% before and 53% after summer). That the people in the reference group see themselves more as experts might be explained that they filled in the questionnaire after listening to the Argos Radio program, out of their own interest. However, when we look at the measures undertaken by both the measurement group and the reference group, all respondents seem to have a general understanding of best measures to take to reduce indoor heat.

The interest in learning more about the topic dropped within the measurement group after summer. Before summer, the measurement group and the reference group had approximately same interest in learning more about heat in apartments. If we assume that this drop in interest to learn more was caused by participating in the Thermo-staat project, we might come to two contrary conclusions: 1) Either the people have now the feeling that they know enough (also visible in the increase in positive responses on the question about "sufficient knowledge", see Table 4) and anything extra they would learn would only have marginal effect, or 2) The participants were overwhelmed by participation in the project and do not wish to be further "bothered" by this topic.



Do you feel that you have sufficient knowledge about how to cool your apartment?	meas. group (before summer)	meas. group (after summer)	reference group
yes	15 (79%)	17 (89%)	45 (67%)
no	4 (21%)	2 (11%)	22 (33%)
Are you interested in learning (even) more about heat in apartments?			
yes	16 (84%)	11 (58%)	56 (85%)
no	3 (16%)	8 (42%)	10 (15%)

Figure 49. Knowledge about heat in apartments

Table 4. Feeling of having sufficient knowledge

From the workshop held in IJmuiden we can conclude that people have gained more insight by measuring their temperature and mostly with comparing it with the measurements from their neighbours, see also paragraph 3.2.3. Looking at the answers from the 19 respondents that participated in the Thermo-staat project and filled in the survey after the summer, only 6 stated that they feel that they have "**learned something** new about heat in apartments". 4 out of those 6 stated that the new insight was because they measured temperature in their apartment, second most common answers were "from news" (2) and "by searching online/in publications" (2). The reference group was not asked to measure throughout the summer; however, they were recruited by interest in this topic. In the reference group, "searching online" was the most common answer (89% of the respondents chose this option) followed by "scrawling through websites" (68%) and "measuring temperature" (by reading the thermostat for example) (63%).

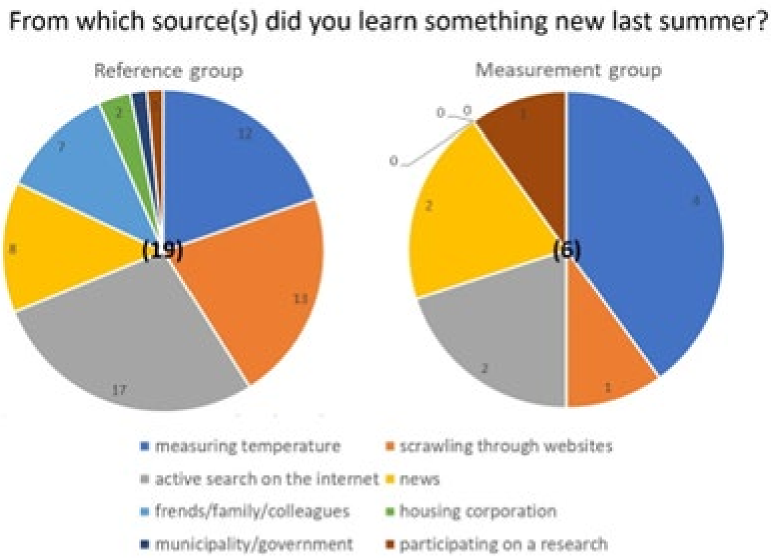


Figure 50. Piecharts of sources learned from

Unfortunately, most participants reported after the summer that measuring temperature in their home did not lead to any **actions** towards keeping their home more comfortable (with exception of one participant who used it to see when to switch on the air-co). Also, only one respondent was "sometimes" active in the KennisCloud and none of the respondents took any actions as consequence of using the KennisCloud. The data visualization page was more successful. From 19 respondents, 11 reported that they used the page; mostly to see their own data (8) or to compare to other locations with similar characteristics (3). Consequently, two respondents adjusted their activities based on the visualization; both did less than planned since their location was colder than comparable other locations, and one also reported new (unspecified) measures taken. Three respondents also reported that participating in the measurements changed the way they see heat in apartments; Two found the issue more pressing, one respondent additionally reported increased awareness of climate change and urban climate, and one respondent more awareness about higher chances of hot summers.

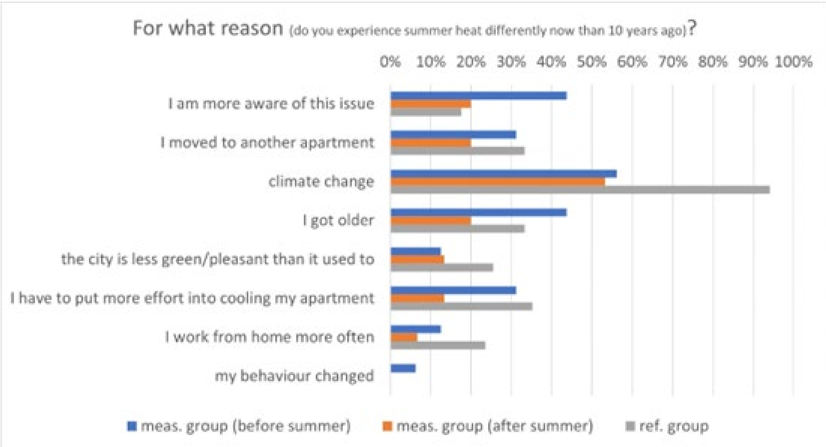


Figure 51. Difference experience of summer compared to 10 years ago