Exploring probable futures of summer comfort in Dutch households

Dr. Lenneke Kuijer

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PHASE 1

Anticipating the Role of Smart Technologies in the Dynamics of Everyday Life

TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

COLOPHON

Contact
Dr. Lenneke Kuijer
Future Everyday Group
Department of Industrial Design
Eindhoven University of Technology
Eindhoven, The Netherlands
S.C.Kuijer@tue.nl
Editors
Dr. Lenneke Kuijer
Phillip Gangan
Infographics
Brigitte van der Lugt
Graphic Design
Volle-Kracht
Photography
Lenneke Kuijer
Shutterstock
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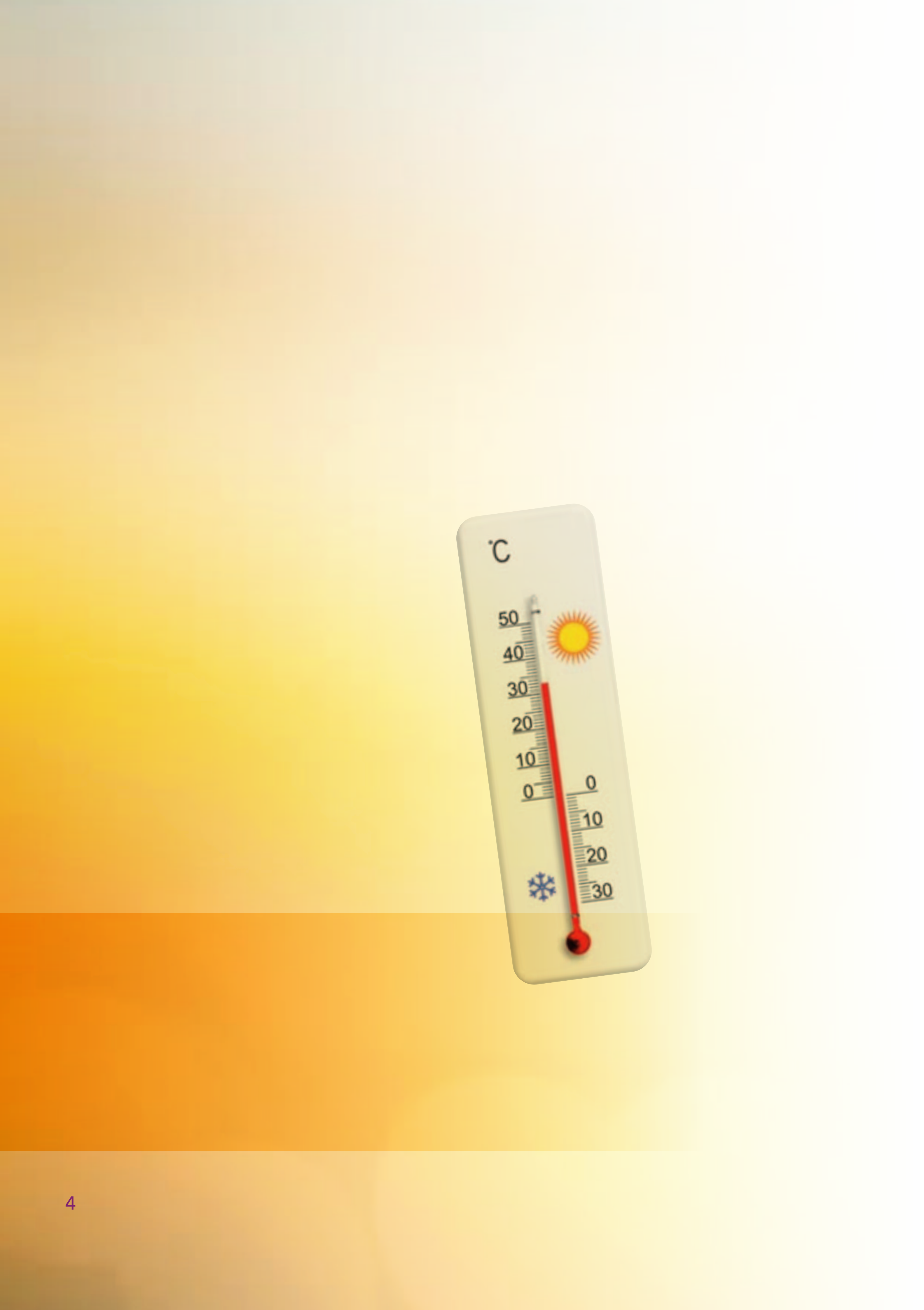

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SUMMARY

Due to climate change, the frequencies, temperatures, and durations of heatwaves and levels of solar gain in the Netherlands are expected to increase. How Dutch households will adapt to this change is still uncertain. At this crossroad, it is important to ask where Dutch practices of summer comfort are heading and whether and how they can be steered in desirable directions. This report is the first in a series of three and focuses on the first part of the question: where are Dutch practices of summer comfort heading?

The study was conducted as part of a research project[1] into the role of interactive technology[2] design in shaping future everyday life. The project takes a social practice perspective. Social practice theory views everyday life in the home as a collection of related practices (i.e. cooking, eating, sleeping) that change over time in co-evolution with broader changes such as climate, demographic, and technological change – for example, cooking has changed over the past century due to changes such as globalisation and the introduction of the microwave. To identify and extrapolate current trends and developments in and around summer comfort, ten experts and 21 households were interviewed.

The report concludes that overheating in dwellings is a growing problem likely to lead to (unequally distributed) discomfort and harm, and an increase in domestic energy demand. The inclusion of the risk of overheating in the new Nearly Energy Neutral Buildings[2] (NENB) requirements indicate that the problem is being taken seriously. However, they focus on new buildings, while particularly older apartment buildings in cities heat up to levels that render them practically unliveable by occupants. Coupled with this is the finding that most occupants experience discomfort well below the NENB overheating norm, particularly in the practices of working from home and sleeping.

Passive cooling[3], summer night ventilation, and shading[4] can prevent or reduce overheating through low-energy means, but several barriers stand in the way of their full potential. First, practices of shading and summer night ventilation require the active involvement of residents, but clash with their historically formed relation with the sun in the Netherlands. A cultural shift is needed to better integrate these practices into household responses to hot weather. Second, both shading and summer night ventilation compete with cooling—shading and cooling compete on the level of investments in comfort, and summer night ventilation and cooling compete during use.

Seeing as even well-equipped, highly skilled households in this study did not manage to maintain comfortable indoor temperatures during the August 2020 heatwave, it seems likely that artificial cooling will make its way into many Dutch households in the coming decades. This can further hamper the development of shading and ventilating practices.

When speculating how cooling practices may develop, the difference between water-based and air-based cooling systems emerged as important. Water-based systems such as radiant floor cooling can be highly energy efficient, or even energy positive when they cool to store heat. They do invite routines of continuous cooling, while air-based systems such as air conditioners induce on-demand cooling routines. More research is needed on the implications for levels of comfort and energy demand of different types of cooling.

Along with expected increases in demand for artificial cooling, the study identifies possible health- issues accompanying this development. Because artificially cooled dwellings further reduce occupant motivation to go outside and increase their tendency to use the car, issues may arise with levels of exercise and Vitamin D intake during hot spells. Other areas in which increases in energy demand could arise are in cooled food storage—appliances that, in turn, directly contribute to overheating in dwellings—as well as increases in shower frequencies and barriers for syncing laundering with solar electricity production.

Looking ahead to the next phase of the project, opportunities for interactive technology designers to enable low-energy health and comfort during hot weather were identified in three related categories:

- **ACCLIMATISING**
  Support and enhance bodily strategies of acclimatising to higher temperatures through sweating, adaptation, ways of dressing, and person-oriented forms of cooling.
- **SHADING AND VENTILATING**
  Develop practices of shading and ventilating to develop in the Dutch cultural and material context (i.e., modified relations with the sun, matching household rhythms, and adjusted to the built environment).
- **INTEGRATION**
  Envision ways in which routines and technologies of shading, ventilating, and cooling can complement each other rather than compete.

Finally, the report calls for specific attention to lower-income households in city apartments. The study indicates that this group is likely to disproportionately experience harmful consequences of a warming climate. Their dwellings show high levels of overheating, they have little resources to take up measures to mitigate these effects, and they spend a relatively large amount of time at home.

[1] Technologies that, due to their equipment with sensors, processing power and actuators can act in response to specific situated circumstances; also referred to as 'smart' technologies.

[2] Part of the EU Energy Performance of Buildings Directive (BENG in Dutch), introduced on 1 January 2021.

[3] Ground based heat-pumps provide floor cooling 'for free' in summer as a side effect of regenerating their source.

[4] Ventilating, shading and cooling in this report refer to the sum of activities performed by both residents and technologies.to refresh the indoor air at cooler times of day (generally 23:00-5:00h), keep solar heat from entering the dwelling and cool down spaces or bodies.

SAMENVATTING

Door klimaatverandering zullen naar verwachting de frequentie, temperatuur en duur van hittegolven, en ook de hoeveelheid zoninstraling in woningen in Nederland stijgen. Hoe Nederlandse huishoudens zich aan deze veranderingen zullen aanpassen is nog onduidelijk. Momenteel staat Nederland op een kruispunt van verschillende routes richting toekomstig zomercomfort. Het is daarom belangrijk om na te gaan waar deze routes naartoe gaan, en of en hoe eventuele onwenselijke ontwikkelingen kunnen worden bijgestuurd. Dit rapport is de eerste in een serie van drie en focust op de vraag: hoe ontwikkelen Nederlandse huishoudens zich op het gebied van zomercomfort?

Het onderzoek is uitgevoerd als onderdeel van een groter onderzoeksproject naar de rol van ontwerpers van interactieve technologieën[5] in het vormen van het dagelijks leven. Het project gebruikt een gedragspraktijkenperspectief. Dit is een stroming in de sociologie die het dagelijks leven benadert als een geheel van sociaal gedeelde gedragspraktijken (bijv. koken, eten, slapen). Deze gedragspraktijken veranderen over de tijd in samenspel met veranderingen in klimaat, demografie en technologie – bijvoorbeeld, koken is de afgelopen eeuw veranderd onder invloed van onder andere globalisering en de introductie van de magnetron. Voor het identificeren en extrapoleren van huidige trends en ontwikkelingen rond zomercomfort zijn tien experts en 21 huishoudens geïnterviewd.

Het rapport concludeert dat oververhitting in woningen een groeiend probleem is dat waarschijnlijk tot (onevenredig verdeeld) ongemak, en een toename in energieverbruik in huishoudens zal leiden. Het opnemen van het risico op oververhitting in de Bijna Energie Neutrale Gebouwen (BENG)[6] richtlijnen wijst erop dat het probleem serieus wordt genomen, maar het is momenteel onduidelijke hoe deze richtlijnen kunnen worden toegepast in de bestaande bouw, terwijl juist oudere appartementencomplexen in steden opwarmen tot niveaus die ze praktisch onleefbaar maken. Daarbij komt de bevinding dat de meeste bewoners hun woning (ruim) onder de BENG norm al oncomfortabel warm vinden, vooral bij het thuiswerken en slapen.

Passieve koeling[7], zomernachtventilatie en zonwering[8] kunnen oververhitting voorkomen of sterk verminderen met weinig energieverbruik, maar verschillende barrières verhinderen hun ontwikkeling. Ten eerste vereisen buitenzonwering en zomernachtventilatie actieve betrokkenheid van bewoners, maar botsen ze met de historisch gevormde relatie die veel Nederlanders hebben met de zon. Een verandering op cultureel niveau is nodig op deze praktijken beter te integreren in de manier waarop huishoudens omgaan met heet weer. Ten tweede concurreren zowel zonwering als zomernachtventilatie met koeling. Zonwering en koeling concurreren op het niveau van investeringen in het wooncomfort en zomernachtventilatie en koeling concurreren tijdens gebruik.

[5] Met interactieve technologieën wordt in dit rapport verwezen naar technologieën die door hun sensoren, processoren en actuatoren kunnen reageren op lokale omstandigheden; deze worden ook wel 'slimme' technologieën genoemd.

[6] Voorgekomen uit de EU Energy Performance of Buildings Directive. Geïntroduceerd op 1 januari 2021

[7] Warmtepompen met bodenenergie leveren 'gratis' vloerkoeling wanneer ze in de zomer hun bron regenereren.

[8] De termen ventileren, zonweren en koelen refereren in dit rapport naar de som van activiteiten uitgevoerd door zowel bewoners als technologieën voor het verversen van de binnenlucht op koelere momenten

Gezien het feit dat zelfs goed voorbereidde en geïnformeerde huishoudens in de studie er tijdens de 2020 hittegolf niet in slaagden om hun binnentemperatuur op een comfortabel niveau te houden lijkt het waarschijnlijk dat actieve koeling zich de komende jaren verder zal verspreiden. Dit zal naar verwachting de verdere ontwikkeling van buitenzonwering en zomernachtventilatie als gedragspraktijken vertragen.

In speculaties over de verdere ontwikkeling van koeling in de studie komt het verschil tussen water-gebaseerde en lucht-gebaseerde systemen naar voren als belangrijk. Water-gebaseerde systemen, zoals vloerkoeling kunnen zeer energiezuinig zijn, of zelfs energiepositief als ze koelen als bijeffect van het opslaan van warmte. Ze stimuleren wel continue vormen van koelen, terwijl lucht-gebaseerde systemen zoals airconditioners eerder alleen bij behoefte gebruikt worden. Meer onderzoek is nodig naar de implicaties van deze verschillende vormen van koeling voor comfort en energiebehoefte.

Parallel aan de toename in de vraag naar koeling identificeert de studie gezondheidsrisico's van het gebruik van koeling in woningen. Omdat koeling de motivatie om naar buiten te gaan lijkt te verlagen en autogebruik stimuleert zouden lichaamsbeweging en vitamine D inname kunnen verminderen. Andere mogelijke effecten op de energievraag zijn in gekoelde voedselopslag – waarbij ook weer extra warmte wordt geproduceerd in huis –, een toename in douchefrequenties, en barrières voor het afstemmen van wasmachinegebruik op de productie van zonne-energie.

Vooruitkijkend naar de volgende fasen van het project presenteren zich een aantal kansen voor ontwerpers van interactieve technologieën om bij te dragen aan een energiezuinig, gezond zomercomfort. Deze kunnen worden samengevat in drie categorieën:

- **ACCLIMATISEREN**
  Ondersteun en stimuleer strategieën voor het acclimatiseren aan hogere temperaturen door zweten, lichamelijke aanpassing, manieren van kleden en persoons-georiënteerde manier van koelen;
- **ZONWERING EN VENTILEREN**
  Zonwering en ventileren: ontwikkel gedragspraktijken voor zonwering en ventileren voor de Nederlandse culturele en materiele context –aangepaste relaties met de zon, passend bij levelsritmes en aangepast aan de gebouwde omgeving;
- **INTEGRATIE**
  Ontwikkel manieren waarop routines en technologieën voor zonwering, ventilatie en koeling elkaar aanvullen in plaats van met elkaar concurreren.

Tot slot roept het rapport op tot extra aandacht voor huishoudens met lagere inkomens in stedelijke appartementencomplexen. Het onderzoek wijst erop dat deze groep onevenredig te lijden heeft onder de schadelijke gevolgen van opwarming. Deze woningen zijn gevoelig voor oververhitting, de bewoners hebben weinig middelen om hier iets tegen te doen, en brengen relatief veel tijd thuis door.

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I want to thank all households for generously sharing their everyday lives and welcoming me into their homes despite the COVID-19 circumstances, and experts that helped me tremendously in getting some grip on the highly complex area of summer comfort and its future developments. In particular, I thank the members of my User Committee for their help, support and valuable feedback. A special thanks to Maria Kluijtenaar for helping in participant recruitment.

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Permanently adopting highly energy-intensive, air conditioning-dependent practices of summer comfort that exist in countries like Australia could still be prevented if well-informed decisions are taken today.

1

INTRODUCTION

The climate in the Netherlands is getting warmer. Due to climate change, the likeliness, severity, and duration of heatwaves is increasing. Dutch dwellings have long been built with a focus on keeping warm during winter, resulting in large windows and high levels of insulation and airtightness. Other factors contributing to overheating issues are urbanisation and urban heat islands, and an ageing society[9].

Dutch households are becoming more aware of the consequences of climate change in their everyday lives and are beginning to adjust their lives and homes to these new circumstances. At this point in time, Dutch practices of summer comfort can still go in many directions. Some of these directions are undesirable from health, inclusivity, and environmental points of view. When no measures are taken, some homes will (and already are) reaching unhealthy temperatures for parts of the year. When taking the position that everyone in the Netherlands, regardless of income, should have access to a healthy and comfortable private space all year round, action is necessary.

For those who can afford it, mitigating discomforts and health risks of hot weather are within reach, but tend to require high amounts of energy. Essent, one of the main energy providers in the Netherlands, reported a 30% increase in energy demand during the August 2020 heatwave[10]. This growth was attributed to the rising sales and use of ventilators and air conditioners. This increased household energy demand is worrying because it could jeopardize achieving national and international CO^2 reduction targets[11], and instead further contribute to climate change.

[9] As people age, they become more vulnerable to heat due to reduced sweat response and thirst sensation (Foster et al., 1976, Kenney and Chiu, 2001).

[10] Essent. 30 procent stijging energieverbruik tijdens hittegolf. LINK

[11] Rijksoverheid. Klimaat-beleid. LINK

This report presents a qualitative exploration of the future of domestic summer comfort in the Netherlands. In line with the Future Cone Model (Figure 1), this exploration of 'probable' futures will be followed by a study into possible and then preferable futures of domestic summer comfort. By identifying and extrapolating current trends and developments in domestic summer comfort, this report identifies relevant questions, challenges, and points of friction. Subsequent studies will focus on answers, solutions, and directions for healthy, equitable, and sustainable practices of summer comfort.

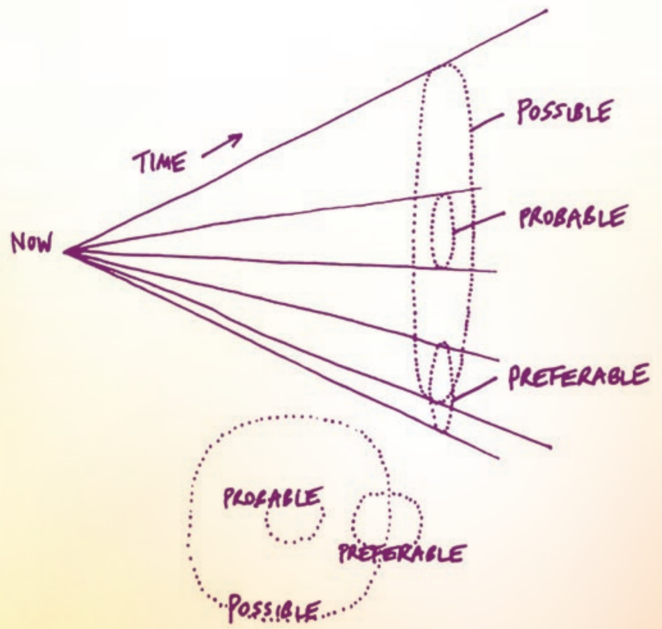


Figure 1: The "future cone"-adapted from Hancock and Bezold (1994) by Candy (2010).

These studies are conducted as part of the NWO VENI project 'Anticipating the Role of Smart Technologies in the Dynamics of Everyday Life' (2019-2023). The overall aim of this project is to develop a new theory to better understand the changing role of computational technologies in everyday life and help technology developers anticipate future opportunities and risks during the design process. Summer comfort forms a case through which this theory is developed. The research project is conducted within the Future Everyday Group of Eindhoven University of Technology.

The report begins by exploring the motivations and theoretical foundations behind the study. This is followed by a description of the approach taken and an overview of the data collected. The Findings Section presents the detailed results of the analysis of this data, which form the basis for the conclusions and recommendations of this study. The report closes with implications for a diversity of stakeholders and further research.

The intended audience for the series of reports on the future of summer comfort are decision makers who play a role in shaping the future of domestic summer comfort. A range of key stakeholders was involved in the study as a User Committee[12]: Het Klimaat-verbond, Royal Auping, Itho Daalderop, Havensteder Rotterdam, and Romazo. As part of the results, the study identifies an additional set of stakeholders. While the focus of the report is on the Netherlands, its outcomes may be relevant beyond this context, particularly in countries where artificial cooling has been mostly absent in households, but is currently on the rise due to global warming.

[12] These organisations are involved as advisors to the project. The study and researcher are financially independent from these parties. See Table 2 for more details on the UC members.

2

BACKGROUND

Climate change is beginning to affect everyday life in Dutch households. When daytime temperatures rise above 25°C for five days in a row, with at least three of the five days reaching maximum temperatures above 30°C, the Dutch Meteorological Institute (KNMI) defines this as a heatwave. In the Dutch context, heatwaves are considered to be extreme weather events. These events disrupt everyday life; it gets too warm for 'business as usual'. Local governments put heat plans in action to protect vulnerable groups. But what happens inside the mainstream Dutch household during such events?

This question is becoming highly relevant now that temperatures are predicted to rise and heatwaves are expected to become longer warmer and more frequent (KNMI 2015). The Netherlands is at a crossroad when it comes to summer comfort. Permanently adopting highly energy-intensive, air conditioning-dependent practices of summer comfort that exist in countries like Australia (ref) could still be prevented if well-informed decisions are taken today. 'Solving' overheating in dwellings with mechanical air conditioning is not the only possible way forward; summer comfort in the Netherlands could still go in a variety of directions. Decisions made in the present–adopting policies, proposing standards, erecting infrastructure, designing technologies, passing on instructions and communicating visions –live on into the future and shape it in particular ways. But not just in any direction.

Where Dutch summer comfort might go depends on where we currently stand. This raises questions like: To what extent are mainstream Dutch households equipped and able to equip themselves to deal with longer, warmer, and more frequent heatwaves? Which strategies do households apply and aspire towards to achieve comfort in times of hot weather, and which currently not? What are possible consequences of these strategies for levels and patterns of energy demand? What are developments outside of these households that may affect these strategies?

Since they pertain to the future and therefore cannot be directly studied, these questions are challenging to answer. To come to these answers, this study draws on theories and methods from social practice theory, which is a group of theories from sociology that approach everyday life as a collection of practices (refs). Practice theories are useful for the challenge at hand because they are particularly good at studying large scale societal changes while still considering the details of everyday life (Kuijer 2014).

Summer comfort is a so-called dispersed practice (Schatzki 1996), a practice that is part of many other practices. Part of the challenge is to identify these so-called integrative practices. Within social practice theory, the study builds on earlier work that explored dispersed practices (of winter comfort) historically (Kuijer and Watson 2017). What this earlier work highlighted, besides the importance of including a range of integrative practices, is the importance of including broader changes outside the household in the analysis (i.e. practices of domestic comfort co-evolve with changing indoor climate technologies and were affected by government policies such as the increased age of compulsory education).

In line with the project's overarching focus on 'smart', interactive technologies, the study draws on the concept of co-performance. Co-performance is a modification of social practice theories that places automated technologies—such as thermostats—next to people as co-performers of practices (Kuijer 2019). The idea behind this shift is that automated technologies increasingly take over tasks from people. Sensors, processing power (matching sensor values to pre-set thresholds), connectivity (to weather predictions, mobile phones) and actuators (connected to power sources, usually the electricity network) allow these devices to act relatively independent of the inhabitants. Their 'behaviour', alongside that of humans, affects the development of everyday practices, which also makes explicit the role of the designers of these technologies into these processes. For example, the actions of an automated sunscreen are based on a judgment—*'it is too sunny now, this sunshine should be prevented from entering the home, wind speeds are low enough: go down'*. As such, it, and by implication the designers who designed the judgment into the device, become performers of this judgment in everyday life. The actions of the sunscreen, reflecting judgments about 'good' and 'bad' sunshine, 'strong' and 'mild' winds, are experienced by inhabitants and passers-by who see the action. This in turn influences their ideas of appropriate shading behaviour. A co-performance perspective therefore takes into account the combined behaviour of people and automated devices when considering practices and how they change.

These theoretic starting points: (1) summer comfort as a dispersed practice, (2) social change as a co-evolution of practices and wider developments, and (3) automated technologies and their designers as co-performers of practices alongside people form the basis for the methodology used to answer the main research question: where are Dutch households currently heading in terms of summer comfort?

Methodology

The study consisted of a set of interrelated research activities. These included a research visit to Australia, a fair visit, internet scoping, expert interviews, household interviews, field observations, and a media scoop. Ethics approval for the studies involving human participants (household interviews and expert interviews) was obtained through the Eindhoven University of Technology Ethics Board under reference ERB2020ID18 and ERB2020ID140 respectively.

The core element of the study was the 21 interviews with a diverse set of Dutch households conducted during the time of the 13-day heatwave that took place from 5-18 August 2020. The focus of these interviews were the current and aspired ways of dealing with hot weather in everyday life. To design these interviews in a way that they would capture all relevant practices, background research was conducted to identify which practices are affected by and involved in summer comfort. Since dealing with hot weather is relatively new for the Netherlands, a research visit to Australia was used to gain more insight into living in hot weather. During this visit, informal conversations with experts[13], personal observations, a visit to the Melbourne Museum, and watching several instruction videos on how to deal with hot weather in Australia[14] brought forward. See Table 1.

13 Alan Pears, Senior Industry Fellow at RMIT, and dr. Yolande Strengers and dr. Larissa Nicholls, Emerging Technologies Research Lab. LINK

14 The temperature in Australia. LINK How to Survive an Australian Heatwave. LINK 12 Ways to Escape the Heat. LINK How to keep your house cool. LINK

PRACTICE	RATIONALE
Cooking and eating	Cooking and eating produce heat in the home and in the body. Staying hydrated is important in hot weather and preserving food can become more difficult.
Personal care and clothing	Taking a shower can cool the body down, but also create humidity and heat in the home. Clothing can cool and protect, but can also retain heat on the body.
Laundering and cleaning	Doing laundry is a physically-intensive activity that can lead to overheating. Washing machines and dryers in particular produce heat in the home. Hot weather may create more or fewer loads of laundry. Cleaning and tidying up are also physically active and can require heat-generating appliances.
Home working	Working at home (including homework) is a temperature-sensitive activity. In higher temperatures, it is more difficult to focus. Devices used can create additional heat.
Free time	Relaxation can reduce or prevent bodily overheating by reducing physical activity, keeping out of the sun, and consuming cool drinks. Additional people and using appliances on the other hand can create additional heat in the house.
Sleeping	Hot weather hampers sleep. Sleeping is a temperature-sensitive practice. Bedrooms tend to be separated from other spaces and may have a different indoor climate.
Ventilation, shading, and cooling	These activities are explicitly focused on managing indoor climate in the dwelling and are therefore of core importance for summer comfort. They are relatively new to Dutch households and are therefore relatively open in their development. They are expected to be interwoven with the other practices.

Table 1: overview of focal practices relating to summer comfort.

While households are experts on their own current ways of dealing with hot weather, they are less able to predict their future options. Working from the range of everyday practices identified in the background research, a set of domain experts was consulted to gain an overview of near-future trends and developments related to these practices. Inspired by Dahlgren et al. (2020), these broader changes were divided into three categories:

1. Climate change
2. Demographic change
3. Technological change

In combination with the current and aspired strategies of the households, a picture could thus be painted of a co-evolution of everyday practices and relevant developments outside of the home.

2030 and 2050 were taken as milestones for these futures. One nearer-future and one further-future. These are timeframes that are often mentioned in strategy documents by government and industries and are therefore expected to match decision-making practices among these important stakeholders that form the primary audience of the report.

Details on the data collected during the expert interviews, household study, and media scoop are included below, followed by an overview of the data analysis approach and a discussion of the limitations of the data for the goals of the study.

Expert interviews

Ten expert interviews were conducted between March and December 2020, four before the household interviews and six after. An overview of the experts interviewed is offered in Table 2.

E1	9-3-2020	Itho Daalderop, Tiel	Elbert Stoffer	Innovation manager renewables, Itho Daalderop
E2	9-3-2020	Royal Auping, Deventer	Geert Doorlag	Researcher and product developer, Royal Auping BV
E3	30-3-2020	Microsoft Teams	Jan Engels	Projectleider Koeltebeleid, Klimaatverbond Nederland
E4	20-5-2020	Microsoft Teams	Pepijn van Lobenstein	Programma manager Energie Transitie, Havensteder Rotterdam
E5	16-nov	Microsoft Teams	Pauline van Dongen	Wearables specialist, fashion designer
E6	17-nov	Utrecht, J2O Architects	Johan Boogerd	architect with special focus on energy neutral
E7	19-nov	Microsoft Teams	Pieter Nuiten	W/E adviseurs
E8	20-nov	Microsoft Teams	Frank van der Linden, Eddy Hillebrand, Vincent Zacht	Ambiance zonwering
E9	8-dec	Microsoft Teams	Boris Kingma	human physiology expert at TNO
E10	11-jan	Microsoft Teams	Mireille Folkerts	human physiology expert at VU

Table 2: overview of experts interviewed for the study.

These interviews were tailored to the expertise of each interviewee and included preliminary results of the study where possible. The interviews lasted approximately 30 minutes to 1,5 hours. All experts were offered the chance to read and comment on a concept version of this report.

Household study

The set-up for the household study consisted of a workbook and an interview. The workbook (available upon request) was designed to prime participants on the topics to be discussed in the interview and collected systematic data that is difficult to collect in an interview, such as the number of times the household does their grocery shopping or how often different categories of laundry are washed. A flyer and application form were made to recruit participants (see Appendix B). The recruitment message was spread through the social media accounts of the members of the User Committee via Twitter, LinkedIn, and via email.

To recruit more participants from lower-income groups with practical education levels and migration backgrounds, a letter was sent out to 188 pre-selected households in the Havensteder portfolio[15], along with a printed copy of the flyer. When this did not result in additional participants, a door-to-door recruitment effort was executed in consultation with Havensteder. Three housing complexes were visited on Thursday, 30 July. During this visit, informal conversations with 25 residents from various households and complexes and one neighbourhood manager led to one additional participant. During the day, notes on conversations and observations led to additional data on the experiences and thoughts of this group regarding hot weather.

Since the door-to-door recruitment did not result in a sufficient number of applications, Havensteder then brought the study to the attention of tenants filing complaints about heat. These participants were offered a slimmed down version of the study without the workbook component. This eventually resulted in the desired balance of owner and tenant participation. At 66%, ownership is slightly overrepresented in the population compared to the national average of 60%. Despite recruitment efforts in this direction, private/free sector rent is not represented in the sample. It comprises 12% nationally.

While planning the study, it was uncertain whether there would be a heatwave. 'Luckily', a major heatwave occurred well in-sync with the planned study from 5 to 18 August. According to KNMI, August 2020 was the warmest August since 1901, after 1997. Exceptional to this heatwave was the high minimum temperature, with three tropical nights (temps above 20°C), which, on average, occur less than once a year, and nine tropical days (max 30°C or above) which normally occur once a year on average[16]. A few interviews took place before the heatwave, the rest during and after. Household 2 (H2) sent additional information after the heatwave.

15 Havensteder is a social housing provider with a stock of 4.500 dwellings in the city of Rotterdam.

16 KNMI, Maand en seizoens-overzichten 2020. LINK

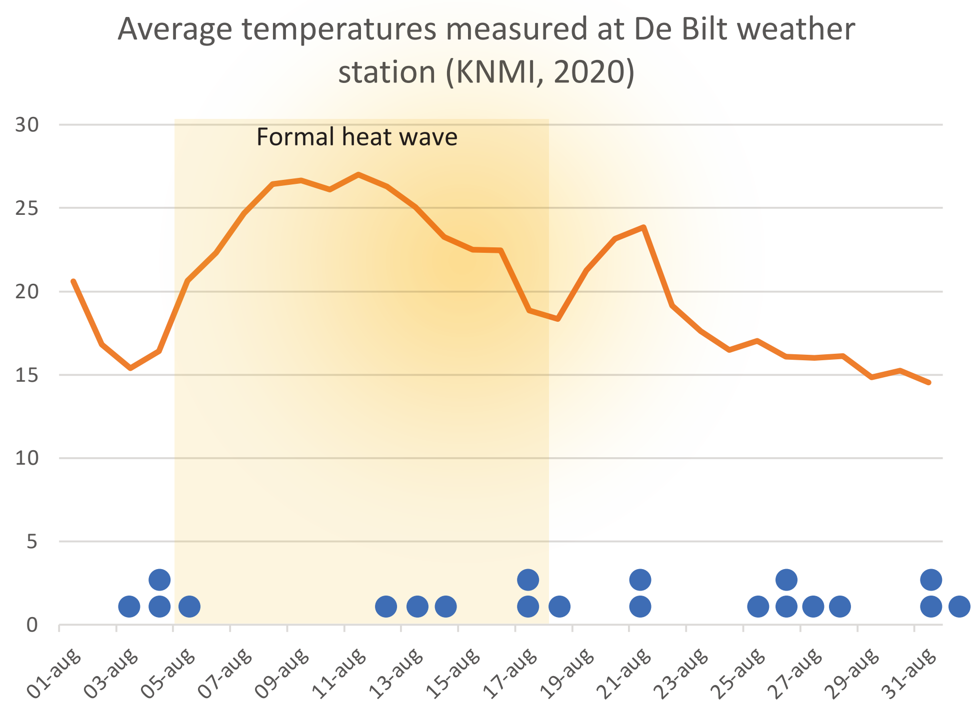


Figure 2: Timing of the interviews in relation to the August 2020 heatwave (Interview 21 was conducted on 15 September).

Eventually, 15 households completed the workbook and interview, while six were only interviewed. A total of 21 hours of interview material was collected. Since two participants were interviewed simultaneously in some of these interviews, there were 25 interviewees in total. All-in-all, the study covered 60 residents. Figure 3 shows an overview of the sizes of participating households. At only 24%, single-person households are under-represented in the sample.

Figure 3: Number of occupants in participating households and number of interviewees per household.

The study covered a variety of types of dwellings that roughly reflect the national figures as illustrated in Figure 4. At 29%, apartments are overrepresented in the sample. Representation of terraced houses is just slightly under the national average. At 19%, free standing houses are also slightly underrepresented, as are semi-detached ('2-onder-1-kap') with 14% representation versus the 20% national average (CBS 2020).

Figure 4: division of types of dwellings in sample.

Figure 5 illustrates the geographic coverage of the study and the range in ages of dwellings included. The ages of interviewees varied from early 20s to early 70s. Including the passive participants within the households, the age range was a slightly wider, including children of which the youngest was just a few months old.

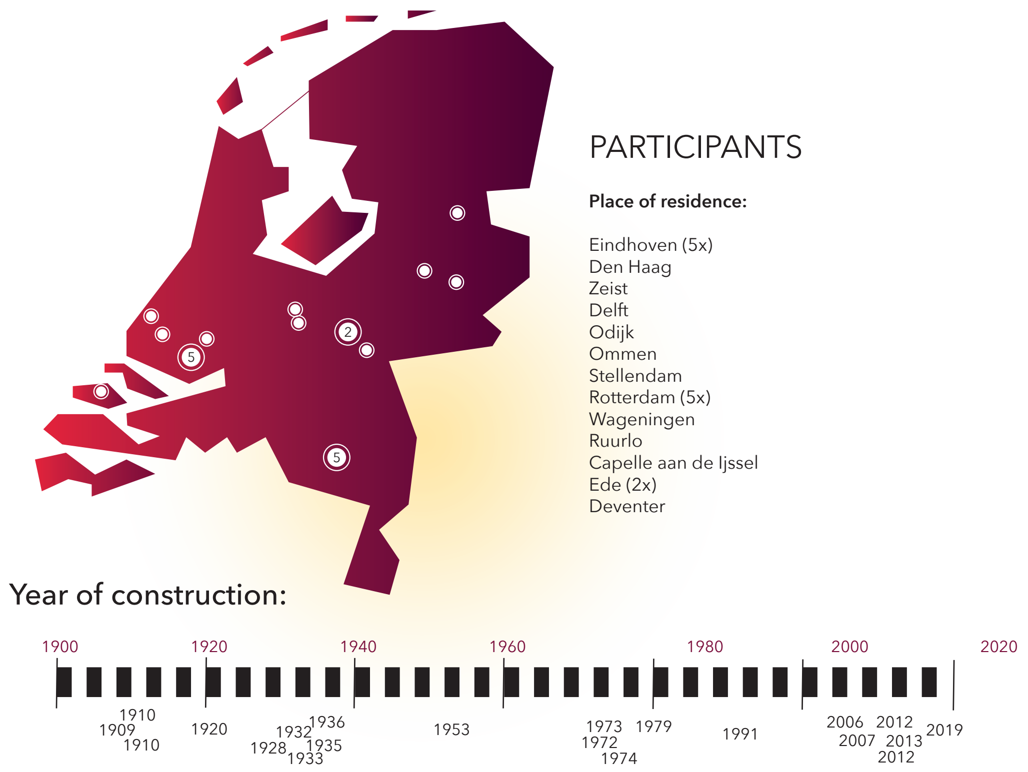


Figure 5: Locations and building years of the dwellings in the sample.

Households are referred to in this study with a code (e.g. H1, H2, etc.). If more than one member of the household participated then they each received a code (e.g. H1a, H1b), starting from the person that initiated the interview.

Media scoop

During the August 2020 heatwave, a small-scale media scoop was conducted. The purpose of this news scoop was to get a rough idea of how the heatwave was discussed in popular media. In the scoop, a total of 19 online news items were collected on 12 August. Over the following days, several articles were added. These articles were obtained via Google News search function and by snowballing from relevant articles to related articles promoted on the various news websites. Search terms used were 'hittegolf', 'heet weer', 'hitte,' and 'air-conditioning'. The articles included are dated between 24 June and 17 August. They were compiled into one document and analysed in NVivo using the same coding scheme as the household interviews.

Data analysis

Analysis of the household interview data used the following main steps:

1. Theoretic framework and approach to topic, also embedded in workbook and interview set-up, leads to initial coding frame (activities)
2. Coding I: Transcripts are all coded according to these nodes > additional nodes emerge from the first coding process, transcripts are only read scanning
3. Coding II: Nodes are analysed more in-depth and tables per participant are made that summarize according to subthemes per node, some additional coding is done, transcripts are read carefully
4. Counts are made where possible and relevant
5. Table overview is used to write aggregate text for each node/theme into report
6. Questions that arise are noted down
7. Additional information is gathered through literature, internet search, and expert interviews
8. Findings per practice are summarized in overview table including current situation, prognosis and risks/opportunities (see Appendix C).

This process is not fully linear. For example, in the case of cooking and eating, the report text was roughly written before the Coding II process and then gradually revised after Coding II and additional information gathering.

Since only one researcher analysed the data, the information offered in this report is elaborate and detailed. As such, any reader becomes a co-analyst and maximum openness is achieved in the link between data and eventual conclusions.

Limitations

No actual measurements of indoor temperatures were made, so conclusions regarding temperatures are based on self-reported values. The use of workbooks, which primed participants to notice their indoor temperatures and summer comfort habits in the week before the interview, partly compensated for this. Six of the 21 households did not fill out the workbook.

The interview focused on a selection of practices. Other relevant practices that were not included specifically were pet care, parenting, hygiene/cleaning practices, and do-it-yourself activities.

The sample is not fully representative of the Dutch population. Relevant caveats are low-income households, households with a migration background, and age groups above 70. For healthy adults, strong discomfort relates to health effects. My conversations with physiologist Mireille Folkerts taught me that this is less so for the elderly and very young children. While still experiencing a feeling of comfort, circumstances can already be unhealthy for these groups. This is mainly due to their reduced capacity to sweat and thus dissipate heat. These health risks were not included in the study. Even if it was representative, the range of diversity in the full population is much larger than in the sample due to the small sample size. These representation issues were addressed where possible through expert interviews, studies conducted by others, and explicit speculation based on available information.

Decisions made in the present live on into the future and shape it in particular ways. But not just in any direction.

3

MAIN FINDINGS

Broader context

This study focuses on the future of summer comfort in Dutch households. It therefore delves into everyday life and developments inside households. These developments do not occur in isolation from the broader context within which these households are situated. This section outlines a rough picture of trends and developments.

Climate change

The macro trend that lies at the basis of this report is climate change. In 2014, the Dutch National Meteorological Institute (KNMI) modelled future climate scenarios for the Netherlands (KNMI 2015). The report contains scenarios for 2030, 2050, and 2085, offering a range of indicators such as temperature, humidity, solar gain, and rainfall per year and per season.

The scenarios are based on four possible futures: moderate-to-high temperature rise and low-to-high changes in worldwide air flow patterns. Modelling these scenarios leads to estimates of minimum and maximum changes in the indicators compared to the average values from the reference period 1981-2010.

The scenarios show a rise in average temperatures. Table 3 shows an overview of predicted temperature rise and average temperatures for the relevant seasons. What is striking in this overview is the relatively high temperature rise in Autumn.

	2030		2050	
	Predicted rise	Predicted average temperature	Predicted rise	Predicted average temperature
Spring	0,56-1,04	10,06-10,54	0,9-2,1	10,4-11,6
Summer	0,65-1,15	17,65-18,15	1,0-2,3	18,0-19,3
Autumn	0,73-1,27	11,33-11,87	1,1-2,3	11,7-12,9

Table 3: predicted temperature rises compared to 1981-2010 and average temperatures for 2030 and 2050 (data from [KNMI, 2015]).

For the summer months, the report specifies changes in maximum temperatures, humidity, and number of warm days and tropical nights. Warm days have a maximum temperature above 25°C. Tropical days have their maximum temperature above 30°C. Tropical nights have their minimum temperature above 20°C. Five warm days in a row, of which three are tropical, constitutes a heatwave[17].

By 2050, the maximum temperature on the hottest day is predicted to increase by 1.4-3.3°C compared to the benchmark years. During this time, the number of warm days is predicted to increase from 21 days to 25,6-35,7 days per year and the number of tropical nights by 0.5 to 2.2%. This means that the probability of heatwaves increases. Summers between 2030 and 2050 are predicted to have slightly lower humidity. The scenarios for 2085 show further increases in these indicators and further drops in humidity levels.

Other environmental changes that have a bearing on domestic settings are increases in solar gain[18], increased problems in water shortages caused by drought in certain times of the year alternated with more severe rainfall in others[19].

Demographic change

The Dutch National Bureau for Statistics (CBS) reports a total population of 17.3 million people in 2019 with an average age of 42 (CBS 2020)[20]. Towards 2030, this number is expected to grow to 18.5 million and 19.3 million in 2050[21]. Currently, the Netherlands has 7.9 million registered households (of which 38% are one-person households) with 23% of households having a migration background. Over the past decades, the population has been growing in cities and decreasing in rural areas. The average age is predicted to rise and rural areas are expected to see the most ageing. Eight percent of Dutch households (appr. 630.000) are reported to live on a low income (defined as 2.000 euro per month or less for a family with two children). For 3,3% of the total number of households, this situation lasts more than four years (CBS 2019)[22]. No clear predictions are offered for these numbers. Policy efforts are directed at reducing this percentage.

The CBS distinguishes four types of dwellings: detached (vrijstaand), terrace (tussen-woning / hoekwoning), semi-detached (2-onder-1-kap), and apartment. Viewed across the Netherlands, apartments comprise the smallest group with 15%, 23% are detached, and the largest group is terrace or semi-detached with 42% (CBS 2016)[23]. In the Netherlands, 60% of households live in the house they own, 28% live in the social housing sector, and 12% in the free rental sector. The number of dwellings increased by approximately 61.000 per year between 2012 and 2018 (CBS). The net number of owner-occupied dwellings increases by 46.000 per year, resulting in a growth of the percentage of owner-occupied dwellings. Newly built dwellings must adhere to building norms, as discussed in the next section. While much improvement can be expected from these building norms, it is predicted that by 2050, 85% of dwellings will comprise dwellings that are already built today (VSK notes 2020).

17 KNMI, uitleg hittegolf. LINK

18 Amount of sunlight/warmth that enters the home because of expected increases in clearness of the atmosphere (KNMI 2015).

19 Intensiteit van extreme neerslag in een veranderend klimaat. LINK

20 CBS, accessed July 2020, Bevolking; kerncijfers. LINK

21 CBS, Statline, accessed 28 July 2020. LINK

22 CBS, Armoede en sociale uitsluiting 2019. LINK

23 CBS, Vier op de tien huishoudens wonen in een rijtjeshuis, 28 July 2020. LINK

Technological change

As of the first of January 2021, a new set of requirements for energy performance of the built environment was instigated. The EU Energy Performance of Buildings Directive[24] requires all new buildings to be Nearly Energy Neutral Buildings (NENB) from this date. To implement this policy, the NENB norm was designed to replace a range of norms and calculation methods so far used for energy performance of existing and new buildings. Relevant to this study is the limitation of risk of overheating that is now included as a requirement for new buildings (RVO 2021, W/E 2018). The risk of overheating is expressed as the TO^{July} value, which should stay below 1.2. This value is calculated with designated software. A simplified calculation that can be used as an alternative to assess the risk of overheating gives insight into the factors at play.

The calculation is rooted in Fanger's (1970) Predicted Mean Vote (PMV) model. In a situation of light domestic activity, light summer clothing, 50% humidity, average airflow, and outside of direct sun exposure, the PMV model expects people's comfort zone to lie between 24,3°C and 27,2°C. The simplified method focuses on the weighted number of hours per year that the average indoor temperature in a modelled dwelling exceeds a PMV of 0,5. This corresponds with a temperature of 27°C (W/E 2018). The unit used is the Weighted Temperature Encroachment (WTE: GTO in Dutch). Roughly, the indicator multiplies the time in hours with the number of degrees above 27°C. Above 33°C, a multiplier of 10 is used[25]. Calculations are made for different zones in the dwelling, with distinctions between the living room, kitchen, and bedrooms on different sides (and floor levels when relevant) of the dwelling. To calculate the risk of overheating of the dwelling, the average area of used living spaces is taken. Overheating is defined as a GTO of 450 hours yearly (W/E 2020). Table 4 presents a fictive, rough example calculation of what this might mean in terms of temperature patterns in a 2-bedroom, open plan dwelling. This example falls well within the maximum of 450 hours. A dwelling with active cooling is automatically considered to adhere to the GTO requirement.

	GTO	27-28°C	28-29°C	29-30°C	30-31°C	31-32°C
Living room/kitchen	162	10d*8h	5d*5h	2d*4h	1d*2h	
Bedroom front (SE)	314	15d*8h	10d*5h	5d*4h	3d*2h	1d*2h
Bedroom back (NW)	49	5d*5h	3d*3h	1d*2h		
Average	**175**					

Table 4: Example calculation of risk of overheating in 2-bedroom open-plan dwelling.

24 European Commission, Nearly zero-energy buildings. LINK

25 Regeling Bouwbesluit, bijlage VII. See also LenteAkkoord (2021). LINK

W/E consultants summarize current and emerging technologies to prevent overheating in dwellings[26] Next to passive measures such as building orientation, overhang, shading, passive cooling and passive ventilation, they list a range of active cooling technologies ranging from ventilators, ventilation systems with passive cooling, and air conditioning units currently available in the market to technologies still in early development such as thermo-acoustic cooling and heat storage in phase changing materials. Within artificial cooling systems, important distinctions can be made between air-based cooling and water-based cooling. The first is possible with mobile air conditioners, split unit air conditioners, and the less well-known (direct and indirect) evaporative coolers. Water-based, (mostly) radiant underfloor cooling is possible with heat-pumps and through district cooling. An important difference in energy demand exists between air-based heat pumps that provide active cooling, and water-based heat pumps that provide passive cooling as a side effect of regenerating their source.

A related technological development that has a bearing on the home and everyday life is the energy transition. The switch to renewable energy has already led to a growing proliferation of solar panels[27] and electric vehicle ownership. The Dutch government's commitment to scale down dependence on natural gas has implications for homes[28]. Today, most households still make use of gas for central heating, water, and cooking. The rise in district heating and (slow) spread of heat pumps and solar water heaters indicate ongoing developments in this direction[29].

As observed at the VSK2020 fair[30], the energy transition and particularly the phasing out of natural gas is a dominant theme in the building installation sector. Heat pumps are omnipresent and exist in many variants, of which water-to-water, air-to-water, and air-to-air systems are the main categories. While heat pumps traditionally offer low temperature heating, some companies are promoting high-temperature systems. Both these and adaptations to hydrogen are presented as potential plug-and-play replacements of the dominant central heating unit, but their technical and economic viability are still under investigation. The installation sector is widely opposed to district heating, but in national and local government planning, this form of heating plays a large role for urban areas (expert consultations). Most heat-pumps and district heating systems can also cool or be made suitable to do so. High-temperature systems generally do not.

The dominant form of cooling systems in the Dutch market are air-to-air heat pumps. The Dutch trade organisation for cooling technology (NVKL) has seen its split unit air conditioner sales increase over the past years with a 30% increase in 2019 (resulting in 123.000 units sold) and expected sales of around 185.000 units in 2020[31]. Bol.com, a Dutch version of Amazon reported a 3000% increase in the sale of ventilators and air-conditioners compared to 2019 and MediaMarkt saw a near fourfold in their sales during the August 2020 heatwave compared to the same month in the previous year[32]. These increases are attributed to the high number of tropical nights and home working due to the COVID-19 pandemic. According to the Essent article, about 20% of Dutch people say they use an air conditioner (mostly mobile) and another 15% are considering buying one[33].

26 TKI Urban Energy, factsheets koudetechnieken. LINK

27 Rijksoverheid, According to WoON2018, 13% of family houses have solar panels on their roof. LINK

28 NOS, Over drie jaar geen traditionele cv ketel meer. LINK

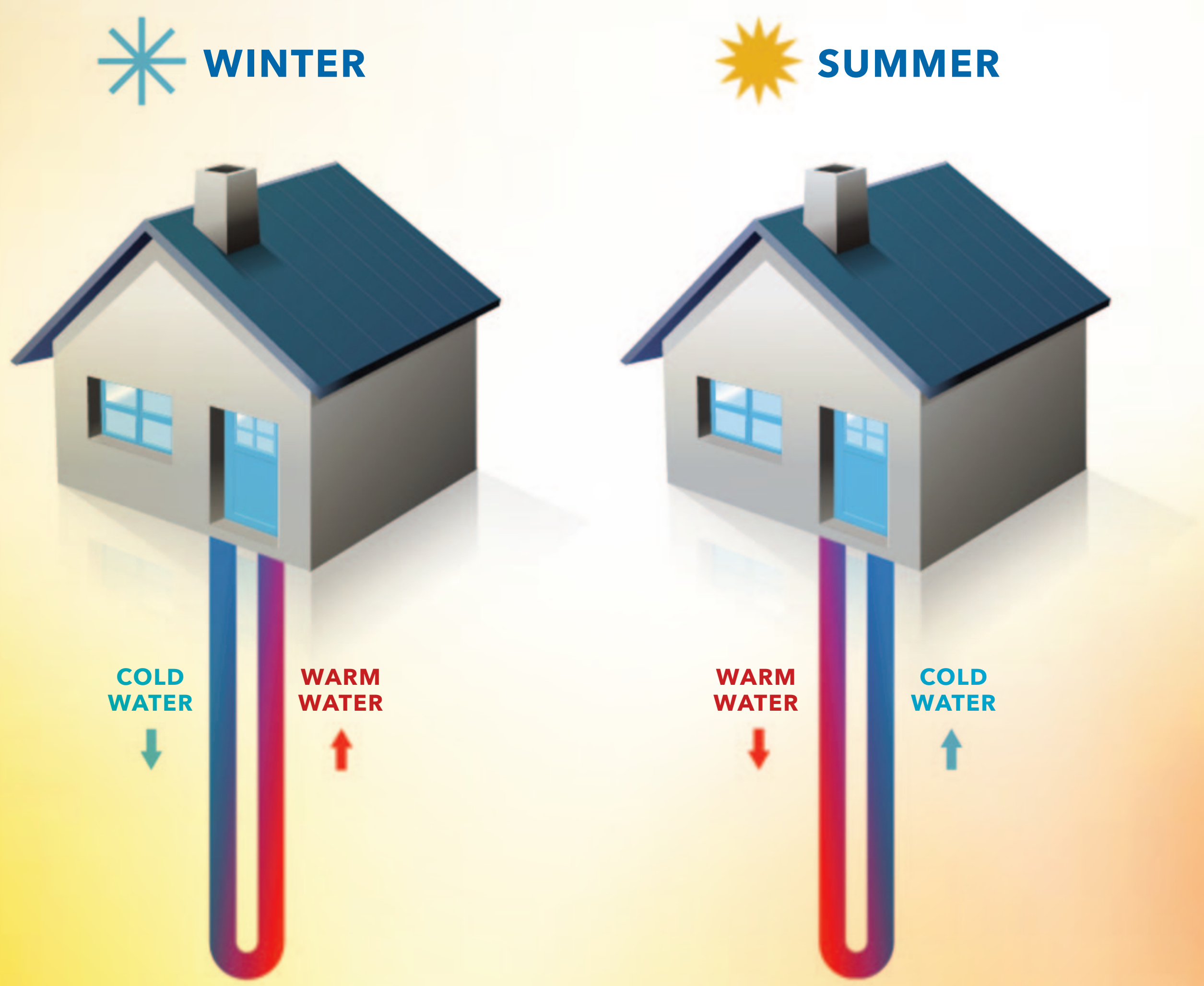
29 NOS, While ongoing, it is becoming clear that this transition is highly complex and taking more time than anticipated and promised in climate agreements. LINK

30 The International Trade Fair for Heating, Sanitary Engineering and Air-conditioning, visited 4 February 2020.

31 Installatie Totaal. LINK

32 Essent, 30 procent stijging energieverbruik tijdens-hittegolf. LINK

33 Duurzaam Verwarmd, Verkoop Aircos Stijgt Sneller dan ooit. LINK



Showering seems to relate more to the participants' relation to sweat, viewing it as dirt to be rinsed off, than to their desire to cool down. This matters for future energy demand.

Graphics with permission from Itho Daalderop

The practices

This section presents overviews of findings pertaining to the selected practices. These findings combine data from the different data sources introduced above: households, media, experts, and observations. Each section concludes with a list of stakeholders identified in shaping the future of summer comfort through the study. Before moving to the everyday practices, the section begins with a focus on the human body and hot weather.

Hot weather, comfort, and the body

Comfort is eventually a subjective bodily sensation. Within this study, comfort refers to a range of experiences that move from 'comfortable' to 'discomfort' to 'unacceptable' circumstances. In the household interviews, comfort is frequently spoken about in terms of temperature. This was stimulated by the set-up of the study, but is also a common tendency in society. Moreover, as recognized by the participants, bodily comfort depends on more than just temperature. Actual temperatures were not systematically reported over time nor measured in this study, so the numbers below should be taken with some caution. Having said that, the numbers do teach us something about the varied circumstances and preferences in participating households.

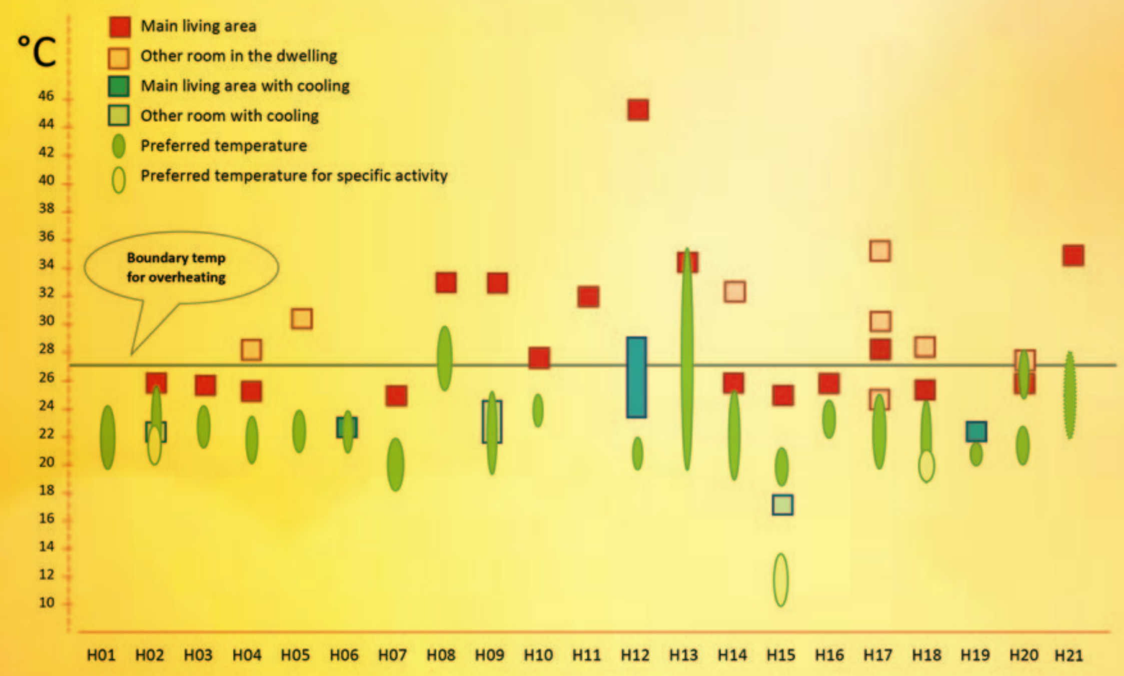


Figure 6: Self-reported data of actual and preferred temperatures in the participating households.

Actual temperatures

As can be seen in Figure 6, six households reported reaching indoor temperatures above 30°C in their main living spaces*. In H20, H14, and H17, the living room reached 29°C. For H20 and H14, this only happened after a period of absence, i.e. without active shading and ventilation. Roughly calculated, the warmest dwellings would exceed the 450 GTO bar within 45 hours. Conservatively, assuming these temperatures occur between 11:00 and 19:00, this would take six days during a heatwave.
Two-thirds of the households in the sample could generally keep their living spaces below 27°C. Two of these households did this with the help of mechanical cooling: an air-to-water heat pump, floor cooling and a split unit air conditioner. Both these households set their system to 23°C. For households without active cooling, bedrooms and attics would easily get warmer than 27°C during the day. For example, in H5 the attic office got to 31°C.

** The apartment of H12 is the warmest in the sample. It consistently gets warmer inside than outside. According to H12, the thermostat reached the 45°C mark in the summer of 2019. After the interview, this participant provided several movie clips that showed indoor and outdoor temperatures. With the mobile air conditioner and professional evaporative cooler turned on, the indoor temperature rose to 25°C with an outdoor temperature of 20°C. In another instance, despite closed curtains and open windows, the indoor temperature rose to 29.5°C with 22°C outside.*

Preferred temperatures

Maximum comfortable temperatures mentioned in the workbooks and interviews ranged between 21°C and 30°C. As known from earlier studies, one person's comfort is another's discomfort. For some, 21°C is considered too cool for summer; 23°C was reported as a minimum temperature by H10 and H8 likes to keep his home at temperatures between 25°C and 29°C year-round.

Preferred and acceptable temperatures also vary per activity, space, and circumstance. In the sample, acceptable temperatures for sleeping tend to be the lowest, followed by working and then relaxing, cooking, and eating. For example, H2a found 20°C very high for sleeping, preferred 22-23°C for working and used a mobile air conditioner to reach this temperature in his home office, but was fine with 25/26°C in the living room. H15 could not sleep above 15°C, while 25°C was fine during the day. H3 preferred a maximum of 20°C for sleeping and below 25°C for working. For H19a, 23°C was unacceptably high for sleeping and 25/26°C became too hot for working after a few days. H5 and H7 also considered 25°C the maximum home office temperature, while for H9b, 26°C was still fine. Within these activities, interpersonal differences were again high. For example, H20a could not work above 24°C, while his partner was fine at 27/28°C. Maximum acceptable temperatures for sleeping ranged from 15°C for H15a to 30°C for H8.

The body's capability to adjust to temperatures suggests that cultural and embodied differences in dealing with heat are relevant. The results seem to confirm this. The one person in the study who grew up in a warm climate had a widely different threshold for comfortable indoor temperatures (26-30°C) than the rest of the participants.

Temperature changes

An important aspect of summer comfort that came up frequently were temperature changes. These were discussed in a positive sense, as in the pleasant feeling of a relatively cool livingroom entered from a hot garden, but also in a negative sense, as in a feeling of shock in either direction. This particularly occurred in relation to air-conditioned spaces because artificial cooling increases temperature differences between the cooled space and other spaces. For example, H19 made sure to keep the temperature difference between the outside and their air-conditioned home within 10°C. This was advised by the installer and online for health reasons[34]. Still, she talked about the shock of going outside, which kept her and her husband from leaving the house. As H19a said:

> ***"When you are outside you really think, oh my god what is this? I'm going back inside." (H19a)***
>
> *"Als je buiten bent dan denk je echt van jemig man, wat is dit? Ik ga weer naar binnen." (H19a)*

When going somewhere during the heatwave, this household would take their air-conditioned car more or less as a rule. In relation to this shock effect, H18b reflected that she would not like air conditioning because her daily routines took her inside and outside frequently. H5, who did not have air conditioning, preferred a difference of maximum 4°C.

34 The Dutch trade organisation for cooling technology (NVKL) advises a temperature difference of 5-8°C in their Webinar 'Alles over airconditioning'. LINK

Time is also an issue here, as this quote from H15a illustrates:

> ***"If you slowly grow into it then it is ok, but if it is a sudden change then it [27°C] is very, very warm." H15a***
>
> *"Ja als je d'r langzaam in groeit dan valt het wel mee, maar als het een plotselinge overgang is dan is het [27°C] wel heel erg warm." H15a*

Along these lines, H18a talked about the difference of experience of their home climate between she and her husband, contrasting his feeling of shock when coming home from his air-conditioned office and car, with her gradual adjustment to the temperature by being inside it all day.

The physiology experts confirmed the effect of getting used to higher temperatures, but view this over a longer time span than a day or sudden change. The effect of acceptable temperatures increasing by 1°C per day in times of hot weather has been identified in physiological studies[35] and was mentioned by the sleep expert. Participants did not seem to be aware of this effect.

Bodily experiences of heat

Bodily discomfort from heat was expressed in various ways in the interviews. Sweat (or its aftermath) appeared frequently in the interview in terms of references to 'stickiness', which needs rinsing off in the shower, as well as a wetness (a drained shirt) that requires laundering. Several participants experienced it as an effective mechanism to cool down, especially in combination with a breeze, and could even occur too quickly.

The relation between physical activity and heat came up in many interviews. Strategies for dealing with very hot days were to take it easy, go with the flow or just sit still. But this strategy also resulted in a feeling of being trapped and getting bored (see also 'Free time'). The feeling of being trapped was not only experienced in the house, but also in the body. Participants expressed frustration with their body not being able to stand heat well and annoyance with their loss of energy and stamina on hot days. Other emotions discussed were irritation (and more arguing), e.g. from a house getting messier and dirtier with no stamina to clean and tidy up or from not being able to sleep or do work.

One participant countered these effects by focusing on accepting the heat (his living spaces were over 30°C) and listening to their body, which was effective for them This person saw others around him being much more bothered by the heat.

35 ISSO, Bepalings-methode Thermisch Comfort. LINK

Negative feelings were contrasted with positive associations that interviewees had with sunny weather; the long evenings, pleasant smells, and warmth. Associations with holidays, freedom, and taking it easy also came up as positive, but caused some friction when work had to be done.

As explained by the physiology experts, the body has two main ways of dealing with heat: one wet and one dry. The wet method involves cooling down through evaporation of sweat on the skin. The dry method is through heat exchange with the environment through the skin. The latter is strengthened by widening blood vessels and increasing heart rate. The wet method is more effective. It works less in higher levels of humidity and better with higher air flow. The dry method only works when surrounding temperatures are below skin temperature (approximately 35°C). Adaptation to heat over time mainly works through increased sweat production.

Personal care and clothing

Personal care and clothing were included as practices in the study because they form direct ways to modify the body's microclimate. Showering is used to warm the body in times of colder weather (Kuijer 2014). Is it also used to cool the body down? Clothing offers ways of modifying the direct insulation level of the body. Is it used as such?

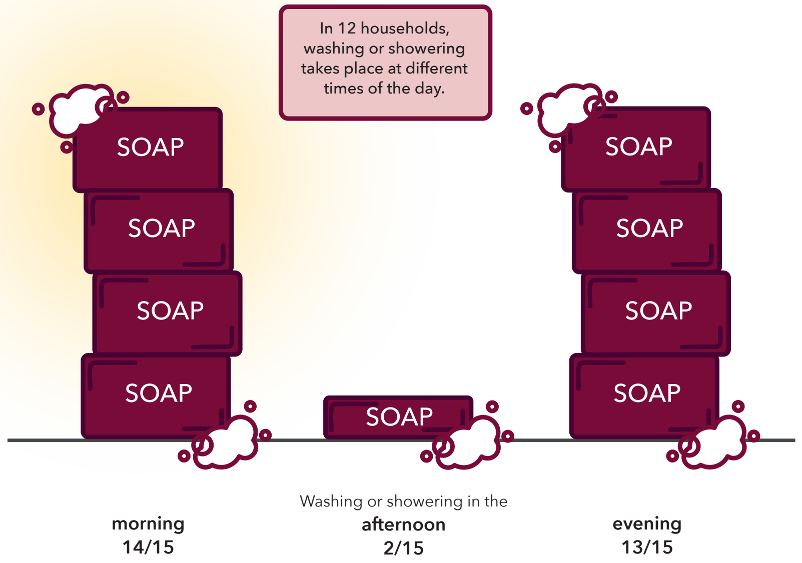


Figure 7: timing of showering in the participating households taken from the workbooks.

Rinsing off sweat and getting wet

The data points to an increased frequency in showering in hot weather. Two thirds of participants indicated that they shower more often in hot weather. This is mainly to rinse off sweat before going to bed, after getting up in the morning or at various other points during the day. Several participants use shower facilities at work after commuting by bicycle. One participant, living in an extremely hot apartment, indicated that they showered two to three times a day during the heatwave.

Participants who indicated that they did not shower more often in hot weather have a variety of reasons. For some, it was because it is not in their routine. For others it was because they felt showering makes them sweat more. Three households—one with a temporary pool in the garden—mentioned that they do not shower more because it is not worth the additional energy and water, while one household (H21) even takes shorter and cooler showers to prevent more heat getting into the house. Several participants mentioned they change clothes to refresh themselves after sweating instead of taking a shower.

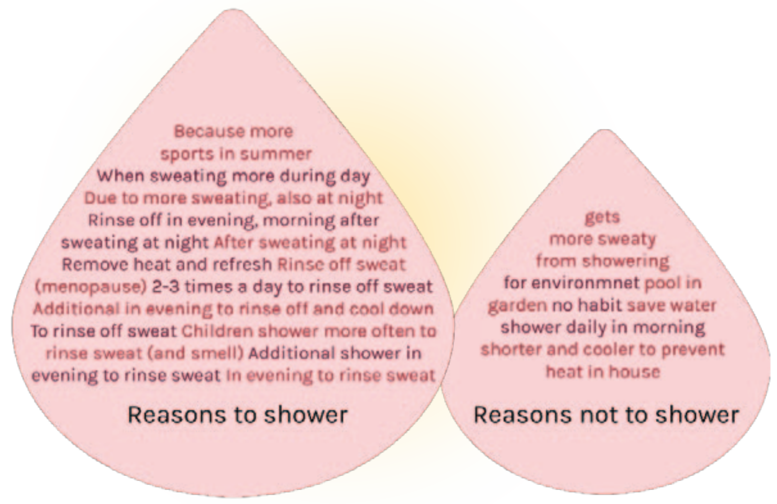


Figure 8: Reasons to shower more, or not to shower more in hot weather.

Showering is generally not used to cool down. Some participants took cold or cool showers, but this is done year-round for health reasons. Only H6 mentioned showering as a way to cool the body. Others reflected that the cooling effect of a shower, if experienced at all, lasts only a very short time. However, other forms of getting wet, such as garden pools, lidos, footbaths and public pools are used to cool down, as illustrated in the following quote. More about outdoor swimming can be found in 'Free time'.

> ***"Well yes, during the day we jump in about twelve times or so, really immersing our entire body up to the head. Because we have now really experienced that if you do that, you feel okay for at least an hour. While if you don't do it, you can become really shaky." (H4)***
>
> *"En ja, dan gedurende de dag springen we er echt twaalf keer in ofzo, en dan ook echt kopje onder. Want we hebben nu echt ervaren, als je dat doet, dan voel je je echt een uur lang wel oké. Terwijl als je het niet doet dan kun je echt helemaal gammel worden." (H4)*

While immersing the body in water is used to cool down, none of the participants used bathtubs for this purpose. Bathtubs are mentioned, but taking a bath is for children and wintertime. In relation to footbaths, the retired couple stated that they would not readily put their feet in a basin of water to keep cool because they associate this with retirement homes.

Overall, the bathroom is not a room that seems receptive to artificial cooling. Bathrooms are not deliberately ventilated to remain cool, but rather accepted as spaces that can warm up considerably in a heatwave. This is not seen as a problem as 'it is only the bathroom' (H3). However, the study indicates that demand for water and energy could increase with rising summer temperatures. This increased frequency of showering seems to relate more to the participants' relation to sweat, viewing it as dirt to be rinsed off, than to their desire to cool down. This matters for future energy demand. For the home with the air-to-water heat pump, heating shower water generates the biggest energy demand in summer. Moreover, any form of water heating and hot water storage is bound to generate some heat in the house. In H16, the transportation of warm water from the solar boiler to the tank noticeably generates heat in the living room.

Clothing

Modifications to clothing during a heatwave were limited among the households interviewed. In hot weather, participants preferred airy clothing made of light and natural materials. They tended to avoid synthetic materials because they are less airy, bad for the environment, and tend to easily give off a foul smell more when they come in contact with sweat. The fashion expert consulted in the study referred to wool as a material that is suitable for temperature regulation and has an added advantage of not easily smelling foul when in contact with sweat. Several brands offer woollen clothing and promote it as cool (e.g. Woolx 'Keep Cool, Wear Wool', Cool-Lite by Icebreaker, or Ashmei 'Be Cool In Wool'). However, wool has gained a reputation to be warm. It is therefore not readily considered as a cool material, as reflected in the study. Mostly, the strategy was to wear as little clothing as possible. During my field visit to social housing blocks, I noticed that several people coming to the door were wearing little clothing (underwear or towels) when indoors. H21 mentioned their 'very short trousers' (underwear) as their standard outfit at home, which would heat up to 36°C.

However, wearing less is not always an option. Professional dress codes are a recurring theme, particularly the (implicit) rule to not wear shorts. The COVID-19 pandemic has temporarily loosened these codes, but they still influence summer comfort. For example, H2, due to the formal nature of his profession, sometimes needed to wear a full suit for work regardless of the weather, while H18a and H19b always wore long trousers and a blouse to work.

Professional dress codes play a role in the need for air-conditioning in (home) offices. They might also play a role in a preference to take the (air-conditioned) car to work in hot weather (see also 'Working'). Some interviewees have found ways to deal with sweating on their way to work. H18c for example, a high school student, slowed down on the last kilometer of his 30-minute cycle ride to school to let his sweat dry in the breeze. Others showered at work.

The Japanese Cool Biz campaign is a successful example of how professional dress codes can be changed to match higher temperatures. In the campaign, office temperatures of 27°C were promoted alongside short sleeved, necktie-less professional dressing styles (Kuijer and De Jong 2012).

In terms of future anticipations, a few participants mentioned artificially cooled clothing, but nobody has tried them so far. Actively cooling garments are available in the market, primarily working on the basis of evaporation and textile coatings such as minerals and phase changing materials[36], but they are mainly directed at professional settings at present. An exception is Uniqlo's Airism[37] technology. Some participants reflected on warmer climates where people sometimes wear clothing that covers the entire body. This type of clothing is seen to protect a person from the sun, but is not clearly understood or copied. One participant mentioned that dark fabrics block heat from the sun better than light ones. This is confirmed in previous research (Hes et al. 2014, Kaspers et al. 2020). Most participants, however, avoided going out into the direct sunlight. An exception is (race) cycling. For this activity, thin airy clothing seems preferred to easily get rid of heat and sweat produced in the activity.

Stakeholders: *urban planners, municipalities, clothing designers, water provisioning, employers, office building managers, worker's unions, heat pump, boiler and hot water industries*

Laundering and cleaning

Laundering and cleaning were included in the study for three main reasons. Laundering and cleaning are relatively intense bodily activities, the appliances of washing and cleaning (washing machine, dryer, iron, vacuum cleaner) generate heat and there was a question referring to whether there would be more or less laundry in times of hot weather.

36
Swicofil, consult innovations litrax functionality. LINK
Swicofil, protection and safety cooling. LINK
Fibre2fashion, pcm in textiles. LINK

37
UNIQLO AIRism Experiment. LINK

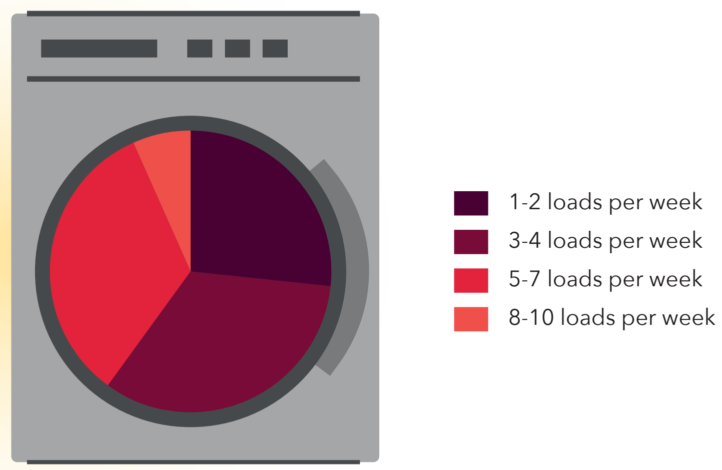


Figure 9: number of washes per week in the participating households (from workbooks).

Laundering

Laundering is performed throughout the house, but more often in attics (or generally the upstairs) and in gardens. Overall, participants indicated a slight increase in the frequency of laundering during hot weather. Summer clothing is generally smaller and lighter than winter clothing, but because it is changed more frequently due to sweating and more towels are used for more frequent showering*, the total amount appears to increase.

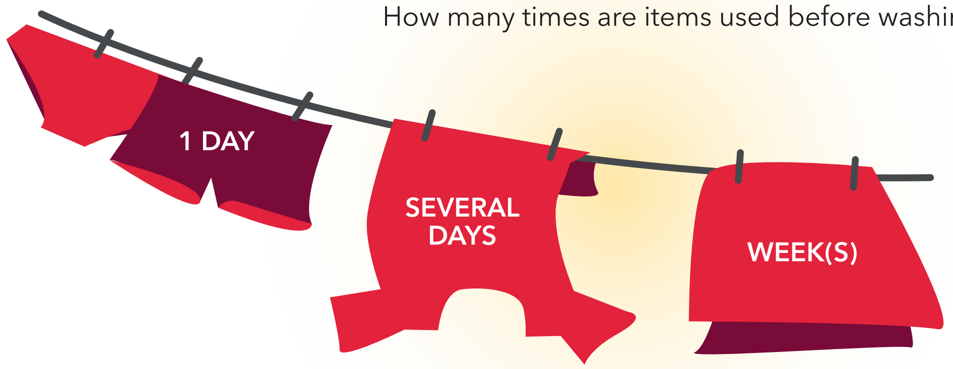


Figure 10: Frequency of washing for different categories of laundry.

** Six out of the 15 households that filled out the workbook washed their towels after each use. Other households used them several days to a week. Bedding was washed once a week or less. One household mentioned more frequent washing of bedding due to more sweating at night.*

While there is more laundry to be done, some households mentioned issues with getting it done during hot weather. One household living in an apartment mentioned fleeing the house due to the heat during the day, resulting in not being able to do laundry. During the evening, it was not possible due to the noise that disturbed the neighbours. This resulted in a piling up of laundry during the heatwave. Generally speaking, some participants mentioned not having the energy to do the laundry, having to ascend to the tropically hot attic for it. Overall, laundering mostly continued as normal during times of hot weather. It even had advantages because line drying happens more quickly. Doing laundry is hot business, but there is space to take it easy or to do the laundry at cooler times of the day such as early morning or late evening. Ironing, mentioned by five households, is a laundry related activity that seems more receptive to cooling. H19a, for example, switched on the air conditioning upstairs for about 30 minutes to an hour before she went there to do the ironing. H15 postponed ironing to after the heatwave. One-third of the participating households had solar panels. Some would take these into account in the timing of their laundry, while others would not.

The heat produced by washing machines and dryers (seven households had one) and the humidity caused by drying indoors was not experienced as an issue by most participants. In seven households, the washing machine sat in one of the living spaces, but mostly in bathrooms where heat and humidity were relatively accepted. In the other fourteen households, laundry equipment was placed in utility rooms and cupboards where heat and humidity could mostly be contained.

Cleaning and tidying

Other physical housework can become an issue during heatwaves. Spatial shifting is difficult, so strategies here involved temporal shifting to early morning or evening, or postponing it to after the heatwave. Cleaning can clash with other activities that are shifted to the morning such as professional work, exercise, laundering, relaxing, etc. Tidying can result in stress from a house that keeps on getting dirtier (e.g. H10). Several of the participating households had a cleaner. Participants had not thought about working circumstances for this group during a heatwave.

Stakeholders: *architects and housing developers, bath fixtures industries, health professionals, clothing and fabric designers, domestic appliance industries*

Cooking and eating

Cooking and eating, including shopping, food storage, and disposal were included in this study because cooking generates heat, consuming food and drinks can change body temperatures, and food storage may cause problems in hot weather. Below, cooking and eating are discussed in terms of when, how, and where they are performed, followed by food storage and waste disposal.

When

The households in the sample tended to eat during the same times, with breakfast between 7:00 and 8:00, lunch between 12:00 and 13:00, and dinner between 18:00 and 19:30. Exceptions to this were the retired couple, who had breakfast at around 9:00am, and a young couple who tended to have dinner around 20:00/20:30 year-round. H5 regularly ate a warm lunch and a simple meal at 17:00 because one of them works in the evening. In some cases, eating times changed during hot weather. Several households (H7, H11, H19) had a habit of cooking for two days, which reduces the time they spent in the kitchen during hot weather.

Another rhythm that changes in some households is their shopping frequency. Since perishables expire quicker in hot weather, shopping frequencies increased in some households. For H20, the size of their refrigerator was a major reason to shop twice a week instead of once (all year round). Shops in the vicinity make this easier. H15 changed the timing of their grocery shopping to earlier in the morning to avoid being out and active at the hottest part of the day. Shops are recognized by some as cooler spaces, but the trip back and forth negates the cooling effect.

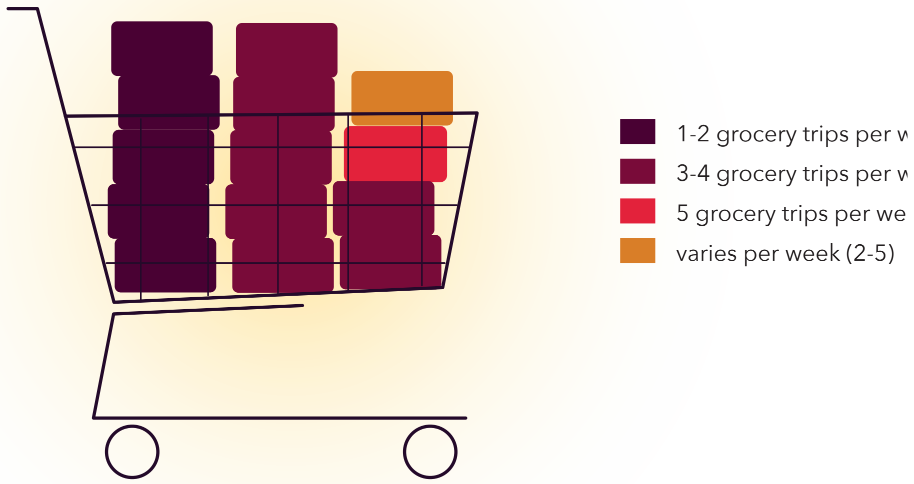


Figure 11: shopping frequencies from workbooks data.

What & how – heat from appliances

What is cooked and eaten changes significantly compared to when, not so much because food can make the body hot, but because of changing appetites. Loss of appetite in hot weather was mentioned frequently, including by H19, which has air-conditioned living spaces. In hot weather, the households tended to eat more salads and other light, uncooked foods, and drink more (water). H3 ate less meat in hot weather for easier digestion and better sleep. H8 left their cooked meal out for 10 minutes before eating it. H1, who actively engages in sports, reflected on how eating less may affect her energy levels on the longer term. She anticipated changing her eating rhythm to more, smaller meals as a possible strategy to keep her energy up in longer heatwaves in the future. Before having air conditioning, H19 used to eat salads, ready-made meals or take-away. Now they cooked 'as normal', using the oven and stove, noticing that this is much cheaper and healthier.

Although this is not the main aim, eating more salads automatically decreases the heat produced by cooking. Most participants, particularly those living in newer, highly insulated houses, were aware of the effects of cooking on indoor temperatures, with the oven as the largest contributor. However, it was still used in hot weather, primarily for baking. Electric/induction stoves are known to produce less heat than gas stoves, but two thirds of participating households (still) had the latter. Dishwashers generate heat too (H5 mentions running it at 55°C on the advice of a mechanic). Several households with solar panels were aware of the advantages (or moral obligation) to run dishwashers during the day, but most ran them at night. H19 managed to change this by setting alarms on her phone. Another effect of cooking on the indoor climate mentioned by H16 and H7 is that having the hood on can pull in extra heat through the natural ventilation system. Despite these effects, most households prepared their own meals at home most of the time (Figure 12).

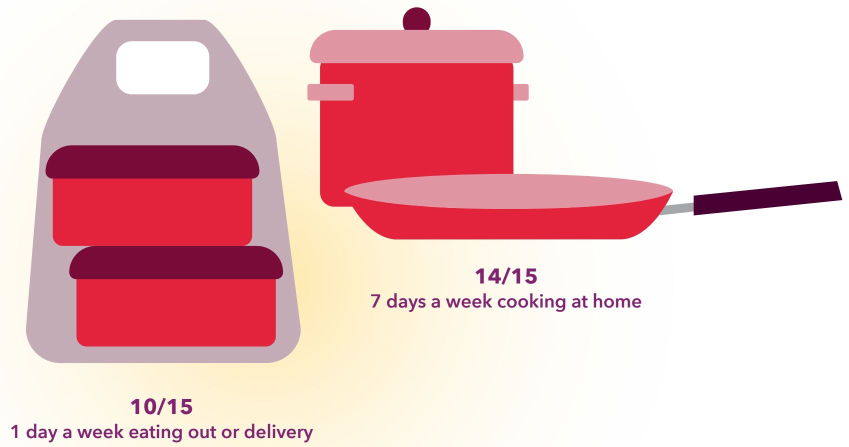


Figure 12: types of meal preparation reported in the workbooks.

Where

Most participating households cooked and ate at home most of the time, and for most, this did not change during times of hot weather. Meals were enjoyed mostly at the dinner table, together with all members of the household, either in the dining kitchen or living room. H8 and H12 did not have a separate dining table; they tended to eat on the couch in front of the TV.

Figure 13: access to private outdoor space in participating households.

** Sixteen of the 21 participating households had a garden. Three dwellings had balconies as their only outdoor space, but none of these were used for eating, likely because they were directly exposed to the sun. Two households did not have any outdoor space access as part of their dwelling.*

The garden* is also a popular place to eat, but only up to a certain point. Eating outside gives a feeling of being on holiday and can provide a nice breeze. But when temperatures rise, participants with a habit of eating in the garden reverted to dining indoors as it was the cooler space to be in. This did not come up in all interviews, but when eating outside, patio doors are kept closed on purpose to retain the 'cool bubble' in the house. Several households mentioned not eating outside because of bugs (H1, H3, H18). Two households explicitly referred to food going bad more quickly when taken outside (H18, H19), leading to more food waste.

Despite realising that cooking generates heat in the house, none of the households would cook outside on a regular basis. Only H19 mentioned they sometimes used the barbecue grill, and H9 would take their portable barbecue to the park. H2 talked about his neighbours having an outdoor kitchen. H7 placed the bread machine in the utility room to remove the heat it generates from his living space.

The type of meal can make it easier or more difficult to eat outside. H5 mentioned preferring to prepare salads because they are easier to take outside and H10 related how they regularly take their salads for a dinner time picnic at the riverside nearby. H18 had lunch with her child in the woods sometimes. One household would flee the house and eat in the park or at a friend's place or with family.

Going to restaurants was not popular among this group. This is likely influenced by the COVID-19 situation, but many participants were not in the habit of eating out anyway. H10 went out for dinner once during the heatwave. For the first time, they deliberately picked a place with air conditioning.

Overall, there does not appear to be a strong need for cooling for practices of cooking and eating. The practice of cooking generates heat, which is in part mitigated by cooking less, but rather minimally. There is potential here to cook outdoors at later times of the day or to order food that is prepared elsewhere.

Cool storage and waste

An important area of change in cooking and eating in hot weather was found in food storage. During times of hot weather, more food was stored in the refrigerator, especially perishables like fruit and vegetables that are normally stored in a cupboard or fruit bowl. Fruit flies were an often-mentioned indication that this is necessary, but eating cooled fruits is also experienced as pleasant in hot weather. Some participants cooled bottled tap water in the refrigerator and H18 stored additional cooling elements they use for shopping and picnics. Although none of the participants in the study did this, the often-mentioned tip of placing frozen water bottles in front of a ventilator[38] also requires additional cold storage in hot weather.

Limitations in cold storage sometimes led to higher shopping frequencies, but in many households, it led to (anticipated) desires for more cold storage capacity[39]. Several households had or mentioned wanting an extra refrigerator or freezer. They would be placed in the kitchen (H14), a utility room (H15, H19), cellar (H17) or outdoor shed (H18, H20, H10). For the latter, several participants noted that not all refrigerators or freezers can handle outdoor temperatures below zero[40]. In addition, H3 remarked that refrigerators have a maximum temperature at which they work. During hot weather, they decrease the temperature setting of their refrigerator to keep their stored items sufficiently cooled. Despite cold storage challenges however, attitudes towards buying an extra fridge ranged from 'hesitant' to 'negative' in most participants. If there was space to keep it at all, it was regarded as another electrical appliance that was only necessary for a limited time during the year. Also, cold storage devices generate heat.

Some houses had naturally-cooled food storage spaces, which came in very handy in hot weather. H7 had a 'larder' (a slightly recessed ground floor cupboard without floor insulation specifically made for naturally cool storage) and H17 had a sizeable cellar.

38
NOS, warme nachten tips ter voorkoming van slaap en concentratie-problemen. LINK
Noordhollands Dagblad, mens en dier in de hitte-golf. LINK

39
Essent. Increases in energy demand for fridges and freezers is already noticeable in energy demand patterns during a heatwave. LINK

40
Coolblue, a major electronic appliances wholesaler in the Netherlands offers an overview of temperature ranges for fridges and freezers. These range from 10°C to 43°C, the simplest version having a range from 16°C to 32°C. LINK

Perishable food waste is not kept cool. Foul smells of organic waste were mentioned by several interviewees. This led H2, a household that did not segregate organic waste, to empty their general waste bin more often. Most of the households had a sizeable garden in which they could keep their organic waste bins out of the sun and away from their activities. Two households cleaned the bin after it was emptied to further reduce the foul smells. But not all households had the benefit of such a space. A tenant living on the third floor of an apartment block experienced foul organic waste and related smells as irritations during hot weather. To manage them, she would walk down several times a day to empty the waste in the bin downstairs to prevent smells and unhealthy situations with organic material.

Stakeholders: *architects, housing developers, cooling appliance producers and designers, supermarkets (delivery services), urban planners, waste services, hospitality sector*

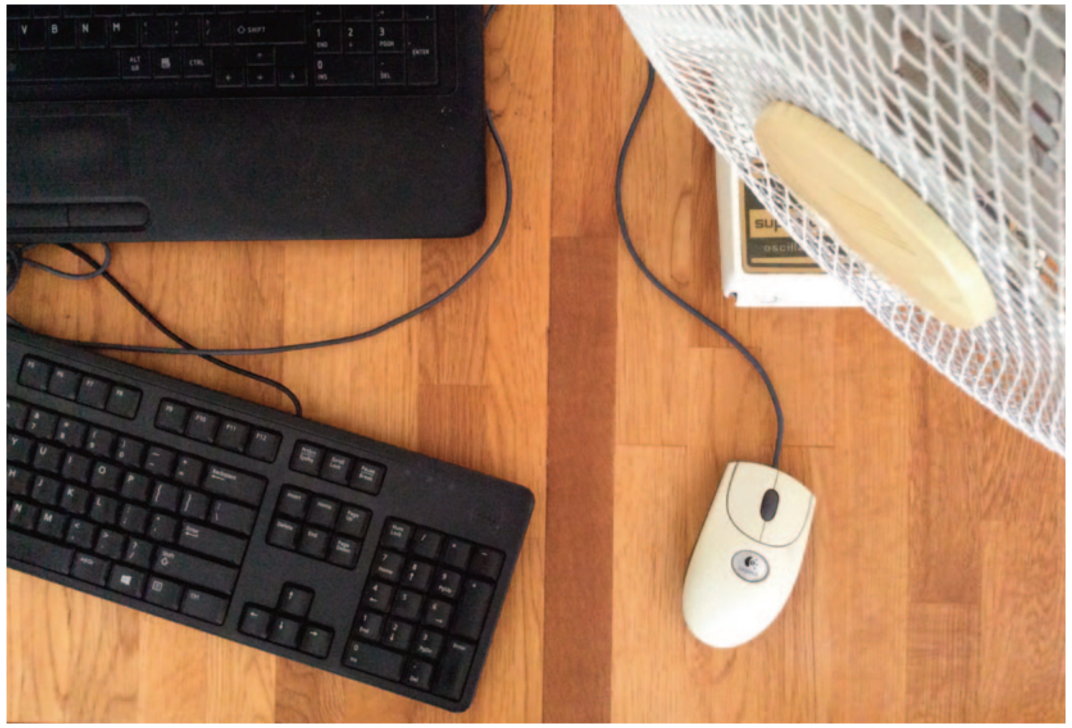
Working from home

Working in the home was included in the study because it was expected to be temperature-sensitive. Like laundering and cooking, it involves appliances that generate heat.

The main problems encountered while working from home during hot weather were loss of concentration and motivation, difficulty finding private spaces to work, and difficulty balancing ventilation with privacy. A reduction in freedom of what to wear because of work obligations and dress codes is also mentioned as a work-related form of discomfort in hot weather.

Computer-based working involves a lot of sitting still. In hot weather this is beneficial. Sweating was mentioned as a bodily response to hot weather during working, but it was mostly the clouding of consciousness (mental fog) and loss of concentration and thinking power that were identified as issues of working in high temperatures. Sunny, warm weather is associated with summer holidays, relaxing, and taking it easy. Especially when at home, participants reported that it was more difficult to get into a work mood in such circumstances.

To remain comfortable while working at home during a heatwave, participants adopted and speculated various strategies. The sections below offer an overview of the workspaces in homes and go deeper into these strategies and their challenges.



Domestic workspaces

Eleven out of 21 dwellings had designated office spaces. One (H3) had three rooms designated as workspaces, two homes (H2, H5) had two office spaces, the remaining eight households had one. Of the 15 designated office spaces, eight were on the first floor, five were on the second (top) floor, and two were on the ground floor (or level with the other living spaces in the case of apartments).

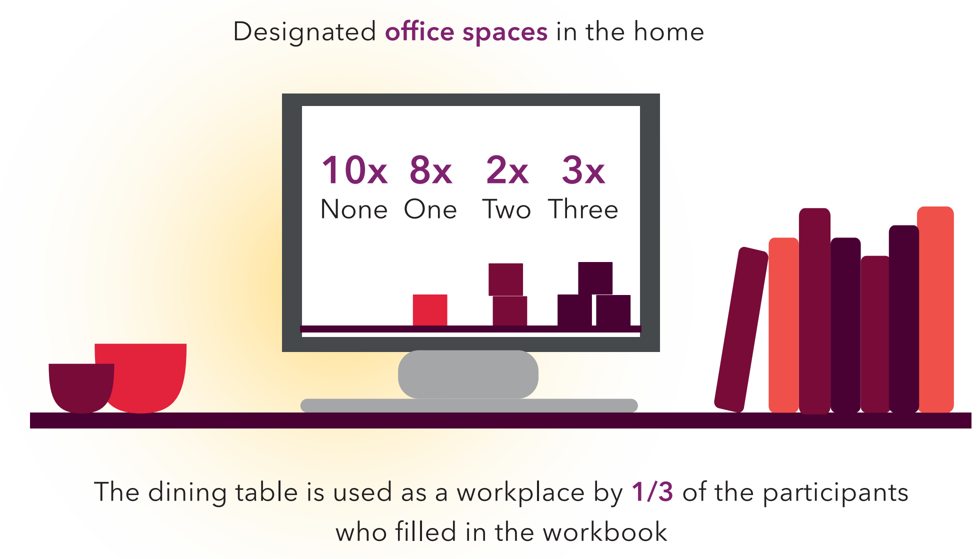


Figure 14: number of designated office space in the participating households.

During the COVID-19 pandemic, a total of 42 (out of 60) residents needed workspaces in the dwelling. 'Typically' this was 26, of which nine were high school children and six were students. All these 15 'youngsters' had workspaces in their own bedrooms, while only one of the adults had a workspace in their own bedroom. According to several participants, bedrooms were discussed as unsuitable for home working because of too little space and an inappropriate work atmosphere.

However, the architect consulted in the study indicated that demand for workspaces in (master) bedrooms is growing. His reflection is that designated space for working is relatively expensive. In some cases, adults would have workspaces in their children's bedrooms, but only when the children were in elementary school. In 13 households, the main living space was also or primarily used as a working space. For six households, a designated working area was made in the living area. For the other seven, this working space (mostly the dining table) was temporary and had to be cleared daily.

Spatial and temporal strategies

Part of the strategies for dealing with heat can be grouped under spaces. Several participants reverted or said they would revert to their work office space when their home office became too hot to work in. Outside of COVID-19, this is a relatively easy strategy, but office work is shifting to domestic spaces[41]. In addition, there is a group of people who do not have an external workspace to revert to because they are, for example, self-employed/freelance, unemployed or retired.

When working outside of the home, transportation and temperature differences emerge as issues. Not all, but most work offices had air-conditioning. Moreover, as discussed above, professional engagements tend to increase the insulation level of appropriate dress (suits, long trousers, socks and shoes). When coming home from work in times of hot weather, people tended to change out of their work clothes into something more relaxed and airier (e.g. H21), although not everyone (H16). None of the participants routinely showered after coming home from work.

Besides going to the office when possible, another spatial adjustment was to move to the living room, which was, in most dwellings, a few degrees cooler than other rooms. In one-person households, this worked well. However, a number of examples in the study illustrated how this was more difficult in multi-person households where privacy becomes an issue. For instance, H2 closed his office door when his family was home (making the room even warmer) and H5 did not like working downstairs because his partner may walk in.

Other often applied or anticipated strategies were temporal. Participants were mostly aware that early morning is the coolest time of day. Their strategy was to start work earlier in the day in order to end earlier or to take a break (sometimes referred to as 'siesta') at the hottest time of the day. One participant who worked part-time, would sometimes spread their work more over the work week so they had fewer hours to work each day. This strategy has its challenges though, particularly regarding concerted rhythms of work. Due to collaborations and meetings, workers are expected to be available during regular work hours. One participant was hesitant to change work hours during a heatwave because they were afraid that (international) colleagues would expect them to be available in those early or late hours all year round. Another risk was that, when starting earlier, they would not stop earlier, so work hours would be extended, leading to risks of fatigue and stress.

Not all participants worked during the August 2020 heatwave because they took summer holidays. However, this fortunate timing may not always be the case. As illustrated in Figure 15 heatwaves have historically occurred between mid-June and the end of August. With climate change, the likeliness of heatwaves occurring outside of the school holidays increases. Together with the prognosis of increased home working, the extent of the conflict between home working and hot weather can be expected to grow.

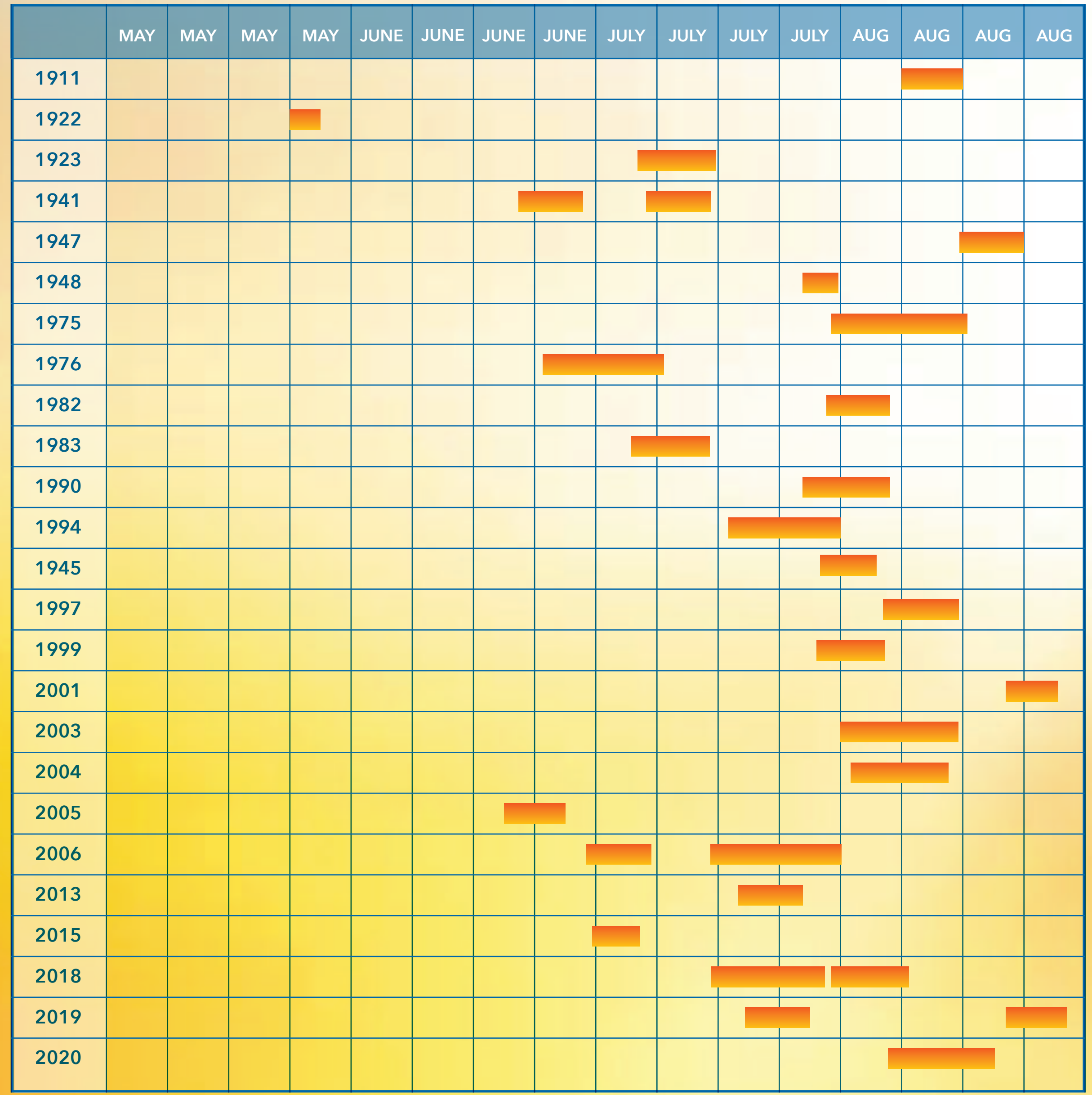


Figure 15: Based on weather data retrieved from https://www.knmi.nl/nederland-nu/klimatologie/lijsten/hittegolven (November 2020).

Working from home and ventilation, shading and cooling

Ventilation, shading and cooling are discussed in more detail at the end of this chapter. Specific to working from home is that managing ventilation and shading becomes somewhat easier. During daytime work hours, windows and shading should generally be closed to keep heat out, but if either are forgotten, this can be mended when someone is home during the day. Moreover, participants were hesitant to have sunscreens up when they were away, in case it rained. When working from home, ventilation can more easily be adjusted in changing circumstances, such as a relatively cool morning or unexpected rainfall.

There are also frictions between working from home and shading and ventilation. In the study, shading clashed with a preference for natural light (and views) when working at home. Work areas in bedrooms have a shading-versus-light conflict; while black-out curtains are good for sleeping, they do not work well as daytime shading. While sleeping and working do not go well together in terms of shading, they could combine well for cooling, being that they are the most 'cooling'-demanding practices in the home.

Working in the main living area makes it difficult to cool with a mobile air conditioner because of limited capacity (e.g. H9). H12 had no choice. He worked from home in an overheated apartment and used a mobile air conditioner and a professional evaporative cooler to bring the space to an acceptable temperature. The energy use of these appliances was not as high as he had expected, but his mobile evaporative cooler generated a lot of humidity, which interfered with sensitive computer equipment and generated a lot of noise (his friend referred to the room as an airport).

Combining working, ventilation, and cooling can become a real struggle. One home office in the sample was cooled using a mobile air conditioner set to 23°C. The improvised construction to guide the hose out of the window made it difficult to ventilate the room during the cooler times of day. The noise of the air conditioner interfered with meetings to an extent that it was switched off. Since the door was also closed for privacy, several meetings in a row would lead to an unpleasant room climate. When the air conditioner was on, this participant acknowledged that the door should also be closed to keep 'the cool' in the office, but doing so felt stuffy, so the door would be opened regularly.

One office was cooled using split unit air conditioners in two bedrooms across the landing. This worked well in terms of comfort, but the units cooled a much larger space than 'necessary'. One office space was part of a new, well insulated home, cooled with an air-to-water heat pump. The entire house was kept at around 23°C and so the office door could stay open. It was noticeable in this home that computer equipment and the human body generated heat and would increase the temperature in the room when the door was closed.

Work and representation in the study

The type of work most interviewees performed involved desk-based work behind a computer. The high percentage of these so-called 'white collar' workers reflects the relatively high education level of the sample. All adults were employed except the three retired persons, and all except three individuals (energy plant worker, craftsperson, sports instructor) had primarily computer-based work. So-called 'blue-collar' workers tend to have jobs that cannot be performed inside the home, such as construction. One participant in the study had such a job. Another participant worked in a (medical) service job that could not be performed at home either.

To gain some form of a rough overview, four types of 'workers' with varying time spent at home are distinguished for purposes of speculation[42]:

1. White collar and (high-school) students: can spend up to full-time working at home, primarily weekdays from 9:00-17:00; a significant part of the group works part-time. In this group, working from home is growing.
2. Blue collar or service jobs: spend relatively little time at home, more irregular work hours.
3. Adult not in employment (unemployment, with disabilities, housework, volunteer work): spends relatively much time at home
4. Retired, mostly over 65: spends relatively much time at home

While this section has discussed issues mainly from the first category, the section 'Free time' will go deeper into daytime summer comfort issues related to groups 3 and 4. Group 2 is expected to have fewer issues with overheating because they are mostly away from home during the day.

***Stakeholders:** employers, universities and high-schools, fashion designers, architects, urban planners, interior design, HVAC and shading industries*

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42 The Dutch population counts approximately 53% employed adults (half of which works part-time), 12% non-employed adults and 18% retirees. LINK

Free time

Free time was included as a theme in the study to capture activities in the home that were not (house) work. Free time offers opportunities to relieve the body of heat stress. On the other hand, some leisure activities involve bodily action or appliances (such as the television) and could generate heat.

Spending free time

All participants had free time, mostly in the evening and on weekends. For the pensioners, it was always free time. For the young parents, there is hardly any. A variety of activities were performed in various spaces and at various moments during the day and week. All fifteen workbooks mentioned watching television as one of these activities. Watching television generates heat in the living room, but because these tend to be relatively large, this is not directly noticeable. Generally, and as occasionally confirmed in the interviews, watching television is done less during summer than in winter. Other frequent activities were reading, gardening, cooking, walking, cycling, engaging in sports, and games. The living room (for most households the coolest space), garden, and nearby outdoor spaces such as parks were the main locations for these activities.

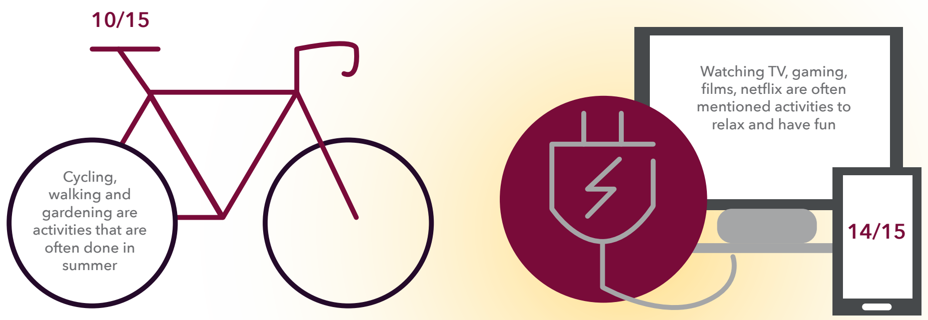

Figure 16: types of leisure activities reported in the workbooks.

Locked-in

Several participants related feelings of being locked inside and limited in their freedom during a heatwave. Some were not necessarily locked in because of the temperature, but because of summer smog affecting their asthma[43] When staying inside, the interviewees would take it slow and easy; do ‘nothing’, read, or watch TV. To some extent this was fine, but when these activities would take too long or it would get too ‘crowded’ in the living room, boredom and irritations could arise.

[43] Astma tijdens een hittegolf: zó ga je daar het beste mee om. LINK

For the retired couple, the feeling of being locked inside was prominent in their experience of the heatwave. Their normal lifestyle—full of free time—involved many outdoor activities such as gardening, cycling, and walking. During a heatwave, they could no longer perform these activities because of their self-reported low tolerance for heat and reverted to staying indoors, sitting out the heatwave mainly by reading. A different approach and relation to hot weather can be found in H14 – a single household with an active lifestyle. H14 viewed herself as relatively tolerant to heat. She found dealing with heat most difficult on days when she had nothing planned. She gots listless. During the August heatwave, she was working on a DIY project concerning woodwork, which made her sweat a great deal, but she was not bothered by the heat[44] due to the distraction of the project and the will to complete it.

Generally, summer (vacation) is associated with being outside, enjoying outdoor space, fresh air, and the warmth of the sun. But in a heatwave this ideal is disrupted, leading to friction. The story of the ‘bedroom pizza’ is telling here. During the heatwave, H9’s apartment was considered too hot to be in. They were out as much as possible and mostly dined elsewhere, with friends, family or in parks. One day, they had pizza in their bedroom, with the curtains closed, the door closed, and the mobile air conditioner on. After eating, they stayed there for the rest of the evening. The couple laughed about it, also because it was, in fact, so sad.

> *“Yes, so then it is the height of summer and there you are with your curtains closed, bedroom door closed and aircon on, having your dinner.” (H9b)*
>
> *“Ja, dus dan is het hartje zomer en dan heb je de gordijnen dicht, je slaapkamerdeur dicht en de airco aan en dan zit je daar te eten.” (H9b)*

Artificial cooling does not mend the issue of not being able to enjoy the summer ‘properly’. It does seem to mend the issue of feeling locked inside. The households with air conditioning throughout the house also stayed mostly inside in hot weather, but did not feel locked-in. H19a stressed the contrast she and her partner experienced with life before and after air conditioning; mainly in the form of being able to go about life ‘as normal’ in their (spacious) air-conditioned home. This may have to do with different lifestyles—some people are more outdoors-oriented than others—, but also points to another dimension of being locked-in, namely in one’s own body. While air conditioning increases the effect of being locked into the dwelling, it allows for free movement within that space.

[44] A decreasing tolerance for heat with age is confirmed by the physiology experts. This is due to a decreasing capability to sweat.

Escaping the home

As mentioned above, there were participants who fled their homes as much as possible during the heatwave, but they were an exception. Other households varied relaxing at home with going out during leisure time. This included outdoor space around the home, although balconies were not used during the heatwave by any of the interviewees.

Especially in the morning and evening, or when well-shaded, participants experienced the garden as a pleasant place to be in; not in the least because of the breeze that could sometimes be enjoyed there. However, sitting in the garden in the evening was not always pleasant due to growing numbers of mosquitos.

Another form of escape was to family or friends. Parents' houses frequently came up as a place for escape. Parents tended to have larger homes and larger gardens than the interviewees (with apartments or city homes), making a good refuge from the heat. For day trips and brief refreshment, parks, woods, swimming pools, lakes, and rivers were visited by some of the interviewees. These trips were good for spending some time in cooler environments, but were not always effective for cooling down. This was because the trip back home could nullify the effect. A 'solution' for this issue was found by some participants in the air-conditioned car (H19, H17), which was even used by H17 as a cool refuge in and of itself. Swimming in public pools or lidos is a popular activity in hot weather. Issues with swimming in water were crowding (especially during the COVID-19 pandemic) and pollution (blue-green algae).

Based on the research conducted in Australia, participants were asked specifically about going to public, cooled facilities to escape the heat. Although they reflected on supermarkets being cool (or cold), this option was not on anyone's radar. In part, this has to do with the COVID-19 situation, but more generally, it is not common in the Netherlands to, for example go, to the cinema in the summer. It seems related to the 'urge' to be outdoors in nice weather. H17 for example, felt it was a bit sad to walk within a cooled shopping mall on a hot day. He would much prefer to be in an outdoor shaded space with a breeze such as the woods.

Stakeholders: *municipalities/urban planners, architects, public and commercial buildings, craft and hobby industries, mobility providers*

Sleeping

Sleeping was included in the study because it is a heat-sensitive practice, and because the typically lower temperatures make evenings important for 'summer night ventilation'; opening the windows to let the cooler night air in.

Sleeping and heat

Heat sensitivity during sleep was confirmed in the study (see also 'Temperatures'). Many participants indicated having trouble sleeping in hot weather. For example, H15a bought an air conditioner specifically for sleeping because she gets very uncomfortable at night temperatures above 12-15°C. For H17, sleeping was a priority for potential artificial cooling in the future.

Several participants had little trouble falling asleep even in temperatures that others would find unbearable (e.g. 25°C plus). The parents of the infant related that they were tired enough to fall asleep easily despite their hot bedroom. H21 were deep sleepers who had no trouble falling asleep despite their apartment being above 30°C. H13 was consciously working with meditation and mindfulness to accept and adjust to the heat, e.g. by slowing down and taking cold showers. Two (H14, H1) participants related that doing sports in the evening helped them fall asleep more easily. Young children were mostly fine despite generally going to bed earlier, and thus in higher temperatures than adults.

Trouble with sleeping in a heatwave is not all about being too warm. Most households used some form of summer night ventilation, which can interfere with sleep. H14 for example, related how keeping the windows open at night made her sleep less deeply because she was on the alert for possible intruders. Once, a cat came in through an open window at night. She also woke up earlier because, when the windows were open, she could not close the curtains and the early sunlight woke her up. In addition, towards the morning, it could get chilly with all the windows open, again waking her up. Both H11 and H12 preferred to keep the bedroom windows closed during the night because of noise and pollution from a busy city street under their windows. H12 had ventilators on with the windows closed. H11 alternated between two 'bads' because having the windows closed made it practically unbearable in the bedroom, while having them open allowed noise and pollution from the street to come in. Several other participants mentioned being bothered by mosquitos or sounds from the outside when the windows were open at night. Despite insect sheets, mosquitos still made their way into the bedrooms. When the air conditioner or ventilator was on, mosquitos stayed away.

Several participants were hesitant to use a ventilator or air conditioner, mainly because they found them to be too noisy. H12 on the contrary said the sound of his three ventilators helped him sleep — they drown out the noises from the busy city road in front of his house. In H6 and H2, teenage children in the attic bedrooms used ventilators to help them sleep, and H1 and H4 anticipated using one when it gets warmer. The five households that use artificial cooling for sleeping consciously set it to a low noise level or only used it to cool down the bedroom before sleeping.

The two homes with split unit air conditioners in the bedroom left it on all night, with the thermostat set to 18°C and 23°C respectively. The household that set it to 18°C preferred even lower temperatures, but could sleep well on this setting, speculating that this was because the air conditioner lowered the humidity in the room[45]. They kept the bedroom door closed, but a small window was open to let fresh air—oxygen—in during the night. In H19, windows and doors were kept closed when the bedroom air conditioner was on. During the night, air conditioners in the rest of the house were switched off. When outdoor temperatures sank below 23°C, she sometimes opened the windows, but the air conditioner remained more comfortable at lower outdoor temperatures, again probably because it lowered the humidity levels.

The dwelling with balanced ventilation and radiant floor cooling with an air-to-water heat pump throughout the house had outside air blown into the bedroom at night through the WTW (with bypass)[46]. Still, the couple had the bedroom window open. This was because one of them preferred this, but also because when the door and window were closed, the CO2 level rose, which triggered the ventilation system to go up a notch and become too noisy.

Artificial cooling in bedrooms can help people sleep in hot weather. Temperatures and humidity are lowered to comfortable levels, and the sealed microclimate keeps out noises, most insects, and pollution. It does clash with summer night ventilation and the habit of young parents to keep bedroom doors open (e.g. H4).

'Just a sheet'

During hot nights, several participants related sleeping under 'just sheets'. One participant (H21) even experimented with putting these sheets in the freezer[47], but this did not work very well; they felt damp and warmed up again quickly. However, while being cooler than a duvet, sleeping under just sheets seems to be viewed as an emergency measure — an improvisation that is not generally desirable. For example, H6 related how, in their previous home, the bedroom could get up to 28°C. They would then sleep under 'just a sheet' and use a ventilator. Now, with their home kept mostly under 23°C/24°C, they slept under a duvet and did not use a ventilator. Similarly, H19 talked about spending a holiday in a hotel without air conditioning and having to sleep under 'just a sheet' as highly uncomfortable, and H12 needed something to cover himself to sleep well.

"Because sometimes it happens that in the middle of the night everything [ventilators] is off. You know, the timers have switched off, and I wake up and think, what is going on!?! Wow, so hot. And then I go and check [the thermostat] and it says 26, 27 degrees at night, you know. Five in the morning or something. Then I take the duvet out of the cover and keep the cover only. I do need to lie under something, otherwise I cannot sleep well." (H12)

45 Physiology experts confirmed that this can be the case, because a lower humidity feels cooler as it makes losing heat through sweating easier.

46 WTW ('WarmteTerugWinning' in Dutch) is mechanical ventilation with heat recovery. The bypass switches heat recovery off to enable summer night ventilation. LINK

"Want ik heb soms, dat het midden in de nacht, en dan is alles uit. Weet je wel, die timers zijn uitgegaan, word ik wakker, en dan denk ik wat is er aan de hand!?! Oh zo heet. En dan ga ik hier even kijken, dan staat er gewoon 26, 27 graden, in de nacht, weet je wel. Vijf uur 's nachts ofzo, en dan nog. Dan haal ik de deken uit het dekbed, dan hou ik alleen maar een dekbed. Ik moet wel ergens onder liggen ofzo. Anders kan ik niet lekker slapen." (H12)

The comfort of a duvet seems important for sleeping. Possibly this has to do with the feeling of cosiness and the feeling of security it brings. It also has a practical side – H1 and H14 related starting under a sheet, but having to get up to get a duvet during the night because it got chilly. This is also nicely illustrated by the story of H4 that their 6-year old daughter, who sleeps in the hottest bedroom of the house, went to sleep under a sheet and was later covered with a blanket when her parents went to bed.

Spaces and rhythms

With bedrooms often being warmer than other spaces in the dwelling, several households experimented with or anticipated sleeping elsewhere. Two children in H10 would habitually sleep in the living room during hot spells. In another household, two teenage children would sleep in the sizeable basement. H17 has a large provision cellar (2.2x4m) and had considered sleeping there, but never did. Several households considered sleeping in the garden, in a tent or on the trampoline, on the balcony or at a campsite.

H14 went deeper into the idea of sleeping downstairs, speculating that it was more difficult to ventilate during the night than the upstairs because of a higher risk of intruders, and a stronger hesitation to have curtains open at street-level. Sleeping in the garden has obvious safety issues as well, but was regarded to be more positive. H14 and H11 had hammocks, but did not use them for sleeping. H14 explained that, for her, this was due to the posture.

Six out of 21 participants considered or tried taking a nap during the day to get through the warmest time of day or to catch up on missed sleep. Two participants (H13 and H14) considered naps an attractive option. They viewed it as part of changing their rhythm, starting earlier and working later while taking a rest during the warmest hours of the day[48]. Southern Europe was referred to, explicitly or with reference to the Siesta practice. For others, daytime naps were more of a consequence of feeling too tired, from sleeping poorly at night or generally feeling tired. However, changing rhythm, as also discussed in 'Working from home' can be complicated in combination with work and other external rhythms to adhere to.

Participants adjusted their bedtimes in hot weather. For example, H2 and H3 went to bed later in the evening, waiting for the temperature to go down and activity inside and around the house to calm down, while H6 went to bed earlier because he felt more tired. Getting up earlier in hot weather was done by several households for various reasons.

47 This was also one of the tips found in a news article on sleep in hot weather from the scoop. LINK

48 NOS, Warme nachten: tips ter voorkoming van slaap en concentratie-problemen. Recommended by experts. LINK

H21 would get up extra early, (5:30/6:00) to open doors and windows and let cool air into their overheated apartment. Further on in the heatwave, they would keep everything open at night and set the alarm to close it at 5:00. Only their bedroom doors and windows would be closed to keep the cats in. H15b would get up briefly at around 5:00-6:00 to go to the toilet and then open the patio doors and close the insect door before going back to bed. H15a got up around 8:00 and closed the doors around 9:00/10:00 when the sun reached them. The area is safe enough to have the doors open all night.

Stakeholders: *beds and bedding, architects, windows, ventilation systems, cooling systems, ventilators, health professionals, employers*

Shading, ventilating and cooling

Shading, ventilation, and cooling were included as practices because they have a direct relationship with domestic indoor climates. Moreover, all three are relatively novel, emerging practices in the Netherlands. These practices are dispersed in the sense that their performance tends to become integrated or closely intertwined into other practices such as working, sleeping, and laundering. They have come up frequently in the discussion of other practices above. This section collects and complements these accounts.

The importance of shading and ventilation for low-energy summer comfort clearly emerged from the research visit to Australia and was confirmed in expert interviews and related research. Calculations by W/E consultants showed that active ventilation and shading can make a significant difference to GTO of 500 – 1000 hours (W/E 9604, 2019).

All interviewees performed shading and ventilation activities to manage their indoor climate. All kinds of objects are enrolled in these activities. Crucial to this are windows and doors, curtains, screens, trees, parasols, blinds, shades, shutters, fans and ventilation systems. Six households currently had some form of artificial cooling. With the other households, the idea of artificial cooling was discussed in a speculative manner that anticipated more, longer, and warmer heatwaves.

Shading

The daily path of the sun is predictable and during the timescale of a heatwave, changes little. During the August 2020 heatwave, sunrise shifted from 6:00 – 6:30 and sunset from approximately 21:30 – 21:00[49]. The number of hours of sunshine varies strongly per day due to clouds. According to the KNMI[50], the maximum number of hours of sun during the heatwave was 14 hours on 7 August, and the minimum on 17 august, with a little over 3 hours. In the future, the number of hours of sunshine is predicted to increase (KNMI 2015).

49 KNMI, tijden van zonopkomst en -ondergang. LINK

50 KNMI, maand- en seizoensoverzichten. LINK

Outdoor shading

Interviewees were all aware of the orientation of their home in relation to the sun's daily and seasonal journey. All interviewees made use of indoor shading in the form of closing curtains. They also mostly realised that outdoor shading is more effective because it keeps the sun's warmth out of the dwelling. Yet only two dwellings had full outdoor shading on all sun-facing living area windows. Ten had partial outdoor shading and nine had no designated outdoor shading. Seven out of the nine were tenants; one was part of an owner's association and one had an overhang that mostly prevented direct sun from entering the living room and a broken sunscreen. None of the social housing dwellings in the sample had outdoor shading.

Figure 17: levels of outdoor shading in the participating households.

Among the tenants, roughly two groups can be distinguished. One group had not seriously pursued outdoor shading, because so far, they did not find it necessary, or were not aware of its importance for managing the indoor temperature in summer. Two believed that their landlord would allow them to buy and install their own outdoor shading, but they had not found it necessary so far. One experienced that the insulation upgrade from two years ago was the cause of overheating in his apartment. He closed his curtains to block the sun, but did not mention outdoor shading as an option. Three households had negotiated with their housing provider about outdoor shading but had not managed to come to a solution.

This had several reasons. One was the practical challenge of installing the shading. Five of the households without outdoor shading were apartments situated above the ground floor level. The difficulty and cost of installing outdoor shading for the living areas of such dwellings is higher than for ground floor apartments and houses. Hiring a lifting ramp adds a disproportionate amount of cost and effort to individual installation of outdoor shading. Added to this is the difficulty that the disposable income of tenants in the rent-controlled sector tends to be relatively low. This makes it more difficult to finance such an investment – even for a selection of windows on an individual or collective basis. Adding to the barrier of investing in outdoor shading for tenants was the temporal character of housing. Several of the tenants interviewed did not consider their housing as their permanent dwelling (partly due to overheating) and were more or less actively looking for other housing.

The significant investment costs for outdoor shading are also a factor for other households. For example, one household made the choice between air conditioning and outdoor shading and opted for air conditioning because of costs, comfort, and aesthetics. H10 did not feel like investing in formal shading for their east-facing windows because they only experienced this as a problem for a short time during the day and during a few days a year. For two households, disagreements or regulations within the Owners Association got in the way of installing outdoor shading.

For most dwellings, outdoor greenery provided some-to-significant amounts of shading in and around the house. Exceptions were a house in a new suburban neighbourhood where trees were still immature and high-rise apartments. Of the dwellings that had outdoor shading, most had several types. Frequency of occurrence of types of shading are offered in Figure 18. Within these, parasols placed in front of sun-facing windows and other improvised forms of outdoor shading such as bed sheets and garbage bags over windows are interesting because they are unstable. Even tarpolines, although sold as designated forms of outdoor shading, were viewed as improvised solutions (H7, H14, H10). For H7, although his tarp worked well and was flexible, he talked about it as 'making do' (behelpen). With a 'make do' solution, people are likely to be on the lookout for a 'proper' one. What this might be is currently open and illustrates the emergent character of the practice.

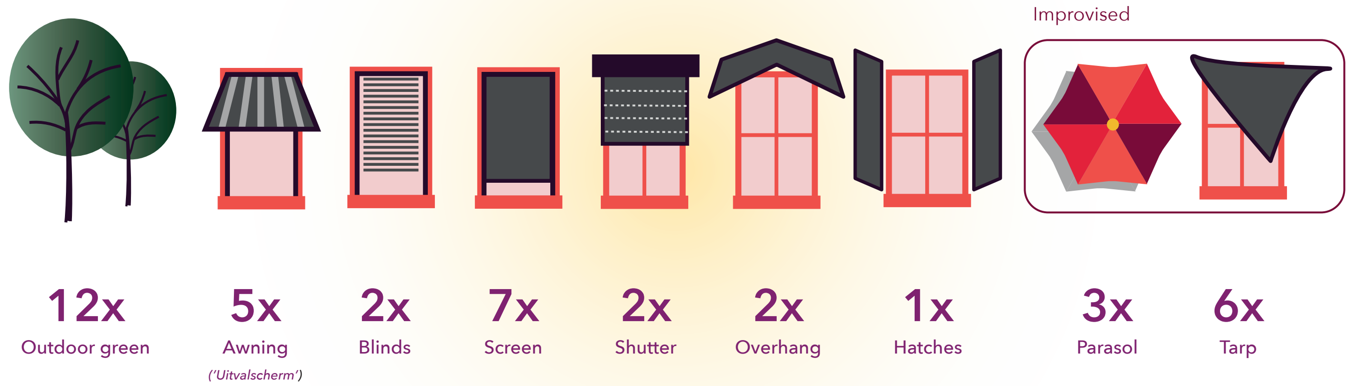

Figure 18: Types of outdoor shading in the 12 dwellings with some form of outdoor shading.

Operating shading

Due to the changing strength and position of the sun, shading is dynamic. Just a few of the dozens of shading devices in the sample operate automatically. In H5, the owners were pleased with the automatic function on one of their sunscreens, which has both sun and wind detection. In H6, the home automation system modified outdoor shading based on sunshine and indoor temperature. Other participants were familiar with automated shading, but H2 mentioned how he found the up-and-down-effect irritating. H5 confirmed that on certain days it could become irritating, which is why they switched to a manual setting for most of the year.

Most outdoor shading is operated manually. This does not always sync well with the sun's path. In H2, the screens on the south-facing attic bedroom windows tended to remain open because the teenage children forgot to close them. The other screens, on the master bedroom and living room windows, were operated by the parents with a remote control and were generally closed when the sun reached the façade. This type of routine is reflected in other households; preferably, shading was closed reactively. This seems related to the reduced light intake and view that is seen as a loss, particularly in living spaces: H1, H5, H6 and H7 related that they did not like shading because it made it dark inside. H2 felt locked inside when all the screens were down. H9, living in an overheated apartment, did not care about darkness and just wanted full shading (preferably shutters). They would put on some nice lamps to make it cosy. Forms of shading that offer a balance between light/views and blocking sun-warmth exist but were not known among this group of participants.

In non-living spaces, light and views were not an issue. Curtains in bedrooms were kept closed all the time in several cases. H14, who was away for work during the day, kept the curtains in the living room closed. However, outdoor shading is not usually kept closed when out or away from home because of fear of damage; they form considerable investments that are considered too vulnerable to be left to the elements.

Ventilating

Proper ventilation routines keep warm air out of the house during the day and let cooler air flow in during the night. That proper ventilating can make a few degrees difference in indoor temperature is confirmed in stories where interviewees had been away for a few days and their house had warmed up more than normal because they did not ventilate it at night.

H1 explained her ventilation routine in one sentence: during the day, 'everything is closed' and during the night, 'everything is open'. But ventilation is generally not that simple due to clashes between human and climate rhythms. Looking at data from De Bilt[51] on the August 2020 heatwave (Appendix A), the lowest temperatures occurred between 23:00 and 6:00. During eight out of the thirteen days of the heatwave, the temperature had reached and exceeded 25°C by 8:00 and reached temperatures above 20°C at 5:00 in the morning for five consecutive days. The hottest times of the day during the heatwave, for this station, occurred between noon and 16:00. From 6 to 13 August, De Bilt still recorded temperatures at above 25°C at 19:00. And on 8 and 11 August, it took until around midnight to go below this level.

This rhythm did not generally match the night rhythms of the households. Only a few households got up in time to close doors and windows at 6:00 when temperatures started to rise. This limited potential of 'morning time' cooling is confirmed in De Vries et al. (2020), where ventilating in the morning turned out to have a limited-to-no effect on lowering indoor temperatures. Another ventilation challenge, discussed in depth in 'Sleeping,' is that open windows make way for more than fresh air; 'intruders' such as rain, burglars, insects, and more unusual ones such mice (H16), cats (H14), and eggs (H7). In other cases, windows are opened too early. Several participants reported opening their patio doors and windows when getting home from work. For H8, this was as early as 16:00. The house may feel somewhat stuffy after being shut tight for the day, but opening it up at 16:00 is likely to only make it warmer. During field visits, many examples of wide-open windows were observed during the middle of the day.

Below: Variety of strategies and struggles in dealing with summer comfort. Both photographs were taken on the afternoon of 12 August at 30°C+.

Most households had some form of mechanical ventilation (exhausts in the kitchen, toilet, and bathroom). Such ventilation is recommended for building renovations that improve insulation[52]. Except for two, these were all simple ventilation systems that actively exhausted air from the bathroom, kitchen, and toilets, which naturally drew-in air through ventilation rosters on windows. These systems tend to be continuously on and are switched on in response to CO2 or humidity levels, for example during cooking and showering. As such, these systems contribute to drawing in air during the day when temperatures are highest. This effect was not actively managed by most participants and neither was the potential of such systems to strengthen night ventilation fully used. This may be related to the sound that they produce, which can disturb sleep.

Shading and ventilation can also get in each other's way. When curtains or screens are down, windows are sometimes obstructed from opening or opening fully (e.g. H9, H5, H14). This problem is prevented in newer buildings where windows tend to open to the inside.

Cooling

Six of the participating households used some form of active cooling. Two had split unit air conditioning: one in the bedroom, the other in the living room and two bedrooms. Three households used mobile air conditioners and one had underfloor cooling throughout the house from an air-to-water heat pump.

A topic specific to cooling that is not part of other practices is maintenance. The two households with split unit air conditioners dealt with this differently. H15, with air conditioning only in their bedroom, did not acquire a service contract. They did not have their air conditioning serviced yet since they had it installed two years ago. The installer had not insisted on the contract and they did not think it was necessary considering the maximum 30 days per year it runs. They thought maintenance would involve cleaning filters, but had not looked into this yet. H19 did acquire a service contract, mainly because the thought of the system breaking down seemed like a nightmare scenario to them. For the mobile air conditioners, two of which were bought secondhand, owners noticed their performance decreasing over time, but were unsure what maintenance to include other than occasionally emptying the water reservoir. Maintenance was not discussed in relation to the heat pump system.

58 The NVKL recommends a 5-8°C difference: NVKL webinar 2020. LINK

What did come up in the interviews was humidity. Towards the end of the August 2020 heatwave, the humidity in H6 had increased to 70%. Other than air conditioning, floor-based systems did not remove water from the air. With indoor temperatures being relatively low compared to outdoor temperatures, humidity can be expected to rise in such dwellings.

As discussed, air conditioners interfere with ventilation routines. This is particularly true for mobile air conditioners. Since they require some kind of sealed fixture to lead their hose out of a window or door, opening these for ventilation is hampered even when the system is not in use. Partly due to these inhibitors, shading and ventilation efforts seem to decrease when air conditioning is installed. H2, H5 and H7, H16 expressed their (negative) surprise about the behaviour of neighbours who had air conditioning and clearly did not follow basic 'rules' of shading and ventilating; i.e. having windows and curtains wide open during the day. This was also observed in the field (refer to photos above). As opposed to air conditioning, shading and ventilation require active and non-routine actions from residents.

Daytime air conditioning matches well with solar power generation. As reflected in the interview with H19 and H14, solar panels[53] are seen as a justification for the added energy use of air conditioning.

For households that currently do not have active cooling, the question whether they would consider getting it in the future was discussed. About one third of households that currently had underfloor heating all considered converting this system to underfloor cooling. Converting radiators for cooling did not come up in any of the interviews, even though the floor heating infrastructure in these households were only present in the living room.

When asked where they would install air conditioning, the participants realised that this decision was not easy. The topics of sleep and home working came up repeatedly, leading to bedrooms and attic offices as candidates. H10 was an exception in considering the coolest rooms of the house as the most logical place for air conditioning, reasoning that there it would cost the least energy to cool them down to a workable temperature. Several participants began to consider the advantages of mobile air conditioning to move along with them to provide cooling throughout the house. However, they realised that such a device would probably be quite heavy to carry up and down the staircase, which made some anticipate that they would be getting several.

59 A currently well-known form of top-up heating of this kind are wood-burning stoves, but air-conditioners are quicker

60 Dutch water companies notice a strong increase in water use during hot spells. LINK

A recurring topic in the discussion of air conditioning was the aversion towards air-based climate control. The feeling of air conditioned spaces, which was familiar from holidays, offices, and cars, is considered unpleasant, and devices have a reputation of being energy-intensive and noisy. These unpleasant effects of air conditioning are specified as the temperature difference with the outside, the feeling of draft, the unevenness of temperature, and dry air that causes a sore throat and a runny nose.

4

CONCLUSIONS

The study confirms the expectation that artificial cooling in Dutch dwellings is likely to increase in the future. This is reflected in growing sales figures of artificial cooling systems, but also in actual and experienced overheating in dwellings and frictions with emerging practices of shading and ventilation. The latter, along with embodied acclimatisation, have strong potential to contribute to summer comfort in a low-energy manner. However, their establishment is hampered by existing material arrangements, embedded routines, and historically shaped values, as well as competition between practices. The sections below elaborate on these points.

Actual and experienced overheating

Overheating is already an issue in Dutch households. From the perspective of the Nearly Energy Neutral Buildings[54] (NENB) standards, several dwellings in the study—all city apartments—exceed the 450-hour Weighted Temperature Encroachment norm for overheating, which starts counting at indoor temperatures above 27°C. Stories of residents confirm that these dwellings become practically unliveable during a heat wave. Moreover, as illustrated in Figure 6, most households in the study considered their dwellings to be overheated below this requirement[55]. With climate change, these overheating issues are expected to grow. So what strategies do households currently apply and aspire to deal with these issues?

54 An implementation of the EU Energy Performance of Buildings Directive (BENG in Dutch) that was instigated in January 2021.

55 It has to be noted that a study of 11 Dutch households found estimated temperature tolerances to lie a few degrees below the actual temperature tolerance (De Vries et al, 2020).

Acclimatising

Apart from conditions in the dwellings, it seems that those who were able to enjoy or accept the heat and modify their daily schedules around it were most capable of getting through the heatwave without too much discomfort. However, the freedom to adjust one's daily schedule is not accessible for everyone, especially when heatwaves occur more often outside of summer holidays in the future. Moreover, freedom to adjust one's schedule is not a guarantee for getting through the heatwave well, as illustrated by the retired couple.

As known from physiological research, not all bodies are equally capable of dealing with heat and these capabilities decrease with age (Foster et al., 1976, Kenney and Chiu, 2001). However, the study shows that common knowledge on bodily responses to heat show a gap with state-of-the-art research, particularly regarding the role of sweat in dealing with heat (it is mostly seen as something negative) and the capability of bodies to adjust to higher temperatures over time. Improved equipment, skills and dispositions to deal with heat well—to acclimatize—could reduce feelings of being locked into one's home and body and contribute to well-being in a low-energy manner.

Cultural frictions with shading, ventilation and, cooling

Emerging practices often compete with existing ones. As Shove et al. (2012) explain, when practices change, new links must be made and old ones broken.

A seemingly embedded friction that arose from the interviews is the relationship that 'the Dutch' have with warm weather. Warm and sunny weather is associated with being outdoors and enjoying the light and warmth of the sun. In the spring, when days get longer and warmer, people open doors and windows to let fresh air in, extending their living spaces onto balconies and gardens. Fluctuating temperatures mean that Dutch summers can have relatively cool spells that precede heatwaves. When temperatures go up, the sun is initially welcomed into the home. But during a heatwave, this behaviour leads to overheating, which is then difficult to correct.

Proper, disciplined outdoor shading and summer night ventilation routines could reduce the extent to which indoor spaces heat up (Alders 2016, W/E 2018, 2020), but adopting these routines requires more than new equipment and behaviours. Viewing the sun as an 'enemy' instead of a 'friend' for part of the year requires a cultural shift. The Dutch friendship with the sun is deeply embedded in customs ('rokjesdag', sunbathing, 'terrasjes'), the built environment (ample, sun facing windows) and related professional practices such as architecture. For most of the year, the sun is and will remain a friend, helping to light and warm dwellings, and keep people healthy and cheerful. Learning to occasionally 'cool' this friendship may be difficult to achieve and implicitly seems to hamper the potential of shading and ventilation practices to develop.

Artificial cooling is more explicitly approached with reservation. Participants without cooling are familiar with air conditioning, but find it too energy-consuming, noisy, expensive, and uncomfortable. However, even highly committed, knowledgeable residents in modern homes, equipped with the latest shading and ventilation technologies, had trouble maintaining a comfortable indoor climate without the use of additional artificial cooling. Many anticipated getting some form of artificial cooling in the future. Those who already had cooling (except for mobile air conditioners) were content with their systems. Although there is friction to integrate artificial cooling into Dutch households, it seems more easily overcome than those related to shading and ventilating. Added to this lower barrier to uptake is the risk that artificial cooling creates a further threat for shading and ventilation practices to reach their potential. They compete.

Shading, ventilation, and cooling compete

Shading and artificial cooling can complement each other in dwellings, but they compete in the market. Both air conditioning and outdoor shading require considerable investment. If households have an opportunity to only invest in one, then cooling has the better position in terms of low-effort comfort. This competition is also visible in the NENB building requirements, where adding a form of active cooling lowers incentives for further measures against overheating such as shading.

Cooling and summer night ventilation compete directly in the dwelling. While the cooling system is on, windows and doors need to be closed to retain the microclimate. This is even stronger for mobile air conditioners because securing the hose in the window can further hamper the opening of windows when the device is not in use.

In general, artificial cooling, when properly dimensioned, can secure comfortable temperatures in the dwelling regardless of other measures such as shading or ventilation. Shading and ventilation require the active involvement of residents. With artificial cooling in place, the incentive to invest money, time, and effort in them is reduced. Mobile air conditioners have a particularly problematic position in this respect because of their relatively low threshold and energy-efficiency. While they can be life-savers on the scale of individual users, in the broader picture these appliances form undesirable symptoms of overheating in Dutch dwellings that contribute to the problem.

Entry points for artificial cooling

The lure of artificial cooling is strong. The study shows that this lure varies for different practices, rooms, dwelling types, and types of residents. Sleeping and working are practices that seem to be most receptive to air conditioning. Working occurs in different spaces in the home, but bedrooms form an appealing entry point. They can be cooled relatively efficiently and can be used for two activities that require cooling most. The study did not find many bedroom/offices, but the architect consulted mentioned that they get frequent requests for workspaces in bedrooms because it is an efficient use of space.

When installed in living rooms first, work might move to the living room—although in multi-person households this is hampered by privacy issues. Sleeping then remains an issue, as people do not seem eager to sleep downstairs during heatwaves as a rule. This may stimulate installing multiple units in both the living room and bedrooms. Air conditioning can also spread between homes. Neighbours, friends, or family are more likely to get it installed after experiencing the cool escape during a heatwave.

Mobile air conditioners seem like an obvious solution to cover multiple activities, but on closer observation, they come with a range of challenges. Besides the issue of their relatively low efficiency, their capacity tends to be too small for most living rooms. When used in other rooms, they hamper ventilation practices and their noise levels interfere with sleeping and working. Although mobile, they cannot be easily moved up or down the stairs. As argued above, they can play a role in a growing habituation of and appetite for artificial cooling at the cost of ventilation and shading.

The type of households that seem most receptive to air conditioning are higher income households that spend more time at home, for example, when habitually working from home or when in retirement.

Pathways for artificial cooling

So far artificial cooling is discussed as one practice, but in fact the study shows that different forms of artificial cooling are currently developing in parallel. Main pathways are water-based and air-based cooling. Water-based cooling, mainly in underfloor or other settings powered by heat pumps or district cooling are slow systems that cool the building mass along with the air; a process that can be sped up with convectors. Such systems are likely to run continuously during hot spells. An advantage of these systems is that for water-to-water heat pumps, cooling can be provided on low-energy demand, or energy-positive manners when heat is stored for heating in winter. This is not the case for air-to-water heat pump systems.

Air-based systems, powered by air conditioners (and evaporative coolers[56]), work more quickly and are more likely to be used based on occupancy and direct demand[57]. These systems do not cool the building mass, so spaces also heat up again quickly when they are off. Within the air-based systems, mobile versions allow for even more directed, person-oriented, albeit fleeting forms of cooling.

56 Evaporative coolers are relatively energy efficient forms of cooling, but they require water. This water use is a reason for evaporative cooling to go mostly out of use in Australia, where water is a scarce resource. According to this site they use around 25L of water per hour.

57 Kuijer and De Jong (2012) describe this difference between slow and fast systems for heating in the Netherlands and Japan.

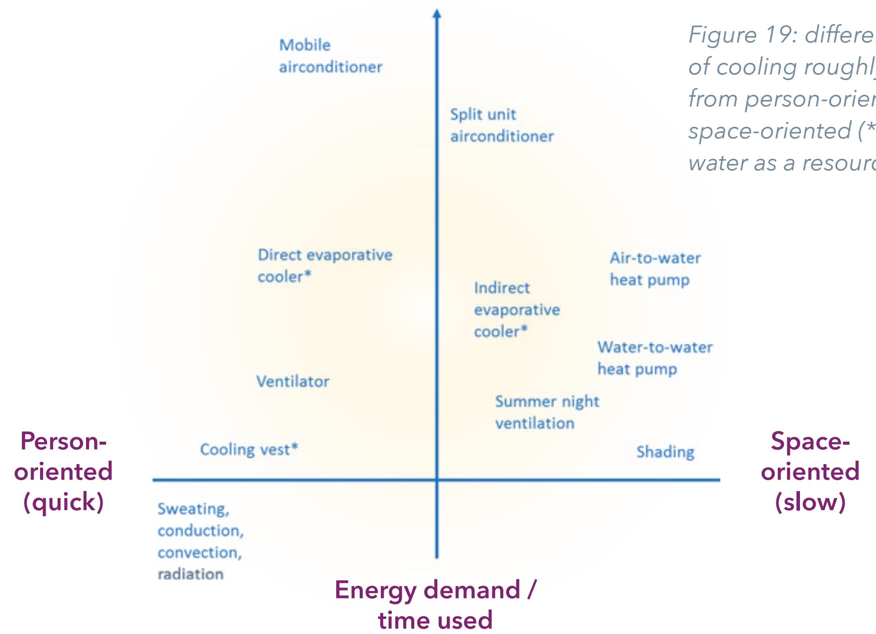

*Figure 19: different types of cooling roughly mapped from person-oriented to space-oriented (*use up water as a resource to work)*

Levels of energy demand for artificial cooling do not only depend on the type of systems and when it is used, but also to what temperatures it is set. When artificial cooling is used depends in part on the temperature setting that becomes normal. With heating, for example, this is for the bulk of systems between 18 and 22°C. The temperatures to which people set their systems needs more research. Looking at temperature preferences and building norms, this is likely to settle somewhere between 21°C and 26°C, with temperatures towards the lower range for sleeping and working, and higher for other activities such as eating and relaxing. For water-based systems, this is likely to be one fixed temperature (23°C in the case in the study). For air-based systems, these temperatures may vary, for example, set lower at night because sleeping has a lower heat tolerance than other activities. The recommendation to keep the setting within a 10°C[58] difference from the outdoor temperature mentioned by one of the participants may prevent extremely low daytime settings of 18°C, but becomes trickier when outdoor temperatures rise above 30°C. An additional downside of air-based systems, particularly in cities, is their contribution to heat islands (Ohashi et al. 2007).

Cooling <> heating

Except for evaporative coolers, most artificial cooling systems can also heat. Their proliferation can therefore be expected to have a relation to heating practices. The gas-fired, high-temperature central heating system dominant in the Netherlands lies somewhere between the water-based and air-based systems distinguished above in terms of flexibility and use pattern; these thermostat-operated heating systems tend to be on continuously during colder times of the year, but are generally turned down a few degrees when occupants are away or asleep (). Water-based, low-temperature systems occur in well-insulated homes and work best within a narrow temperature range (i.e. 1°C). This heating practice is likely to translate to cooling practices for these systems.

Air-based systems are quicker and support more on-demand use patterns. These may even translate to winter. On-demand forms of heating have, in earlier studies, been calculated to be about five times less energy-intensive than common Dutch central heating (Nakagami et al. 2008, Kuijer 2014).

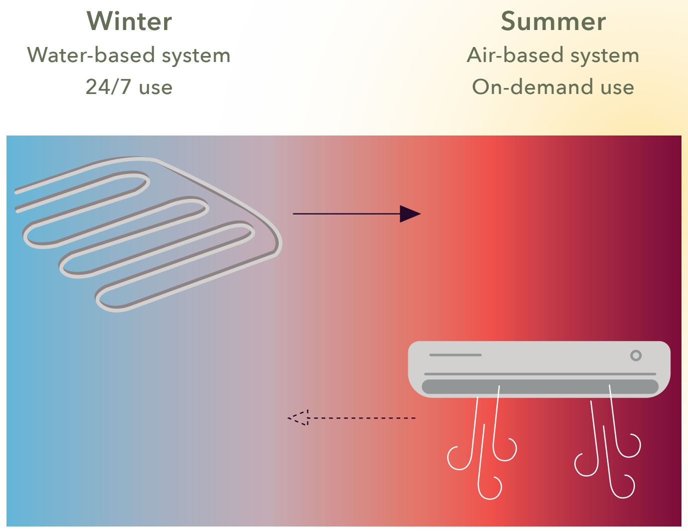

Figure 20: Overlapping effects between heating and cooling practices.

However, if air-based systems are used in addition to—and not as a replacement of—central heating systems, then the resulting increase in energy demand could grow further. As shown in H19, air-based systems are easy to use as a quick form of 'top-up heating'[59] on cooler days outside of winter-time. Further research is needed to investigate how these patterns may develop.

Additional effects of warming on everyday life

The use of artificial cooling in the home seems to lead to a dependence on artificially cooled spaces that extends beyond the dwelling. The examples in the study indicate a trend towards spending more time indoors, and the car becoming preferred over other means of transportation. Beside increases in CO_2 emissions and energy costs that accompany the increased use of most forms of artificial cooling, these trends indicate undesirable health effects resulting from lower activity levels and lower natural vitamin D intake.

Once artificial cooling is installed, other trickle-down effects may occur. For example, leaving the air conditioner on when leaving the house for the sake of pets, as in Australia (Strengers et al. 2019). Other areas in which increases in energy demand could arise are in increased capacity for cold food storage, showering and laundering. Fruits and vegetables that are normally kept in dry storage are moved to refrigerators, where they compete for space with more cooled drinks. This leads to an increased demand for (larger) fridges and freezers—appliances which, in turn, directly contribute to overheating in dwellings. The study also indicated that shower frequencies increase during hot spells[60]. The main reason for more showers within the sample was not to cool down, but to rinse off sweat. This requires water as well as energy to heat it. Finally, natural fluctuations in daily temperature patterns mean that morning time, as the coolest time of day, becomes populated with many activities: sports, work, cleaning, etc. Besides leading to friction between themselves, this does not have direct consequences for energy demand. An exception here is laundering. Hanging out laundry is physically intense. Doing it in the morning requires the washing machine to run during the night, which is out of sync with solar energy production.

Different consequences for different types of households and dwellings

Figure 21 presents a rough overview of different possible scenarios for different types of households and dwellings. While the figure mostly speaks for itself, the 'low comfort' end of the spectrum deserves some additional attention. While it is difficult to draw a clear line, 'low comfort' is a clear understatement for some of the dwellings in the study. These examples represent a larger group of households for which homes become unliveable for part of the year due to overheating.

Smaller, well-insulated dwellings, with higher window-to-content ratios, high sun exposure (e.g. in high-rise), little shading and ventilation opportunities, located in cities (heat islands) heat up the most. Such dwellings are more likely to be occupied by lower-income households and are more often rented than owned. This might also mean that the potentially higher amount of time spent at home by the residents due to lower levels of employment could add to the overheating issues.

Overheating is slowly starting to be acknowledged as an issue[61] and the owners of these buildings are beginning to contemplate on how to intervene. The study indicates that the costs of installing and maintaining outdoor shading on non-ground floor windows plays a role in hampering households and housing providers to act. Moreover, demand for shading and cooling seems low among social housing tenants. This could have all kinds of causes such as other more pressing issues on the tenants' minds, a fear of unmanageable rises in rent, and unfamiliarity with the effects of shading and ventilation on overheating. Despite various efforts to involve them, low-incomes households were only present indirectly in the study through stories of higher income tenants and observations during fieldwork. More research is needed into the specific issues, wishes and strategies of this group.

[62] 20-25% of newly built dwellings is equipped with such systems.

HIGH COMFORT

	LOW ENERGY	HIGH ENERGY
HIGH COMFORT	New or renovated houses with active inhabitants. Mostly in rural or suburban areas. Cooling with water-to-water heat pumps[62], solar panels, full outdoor shading and WTW ventilation. Residents in moderately insulated, shaded and ventilated homes that are away from home a lot. Do not eat at home much, so little food storage required. Various types of houses with creative, accepting inhabitants with flexible lifestyles	Artificial cooling used throughout the dwelling throughout the day, no outdoor shading, simple ventilation. More driving in an air conditioned car. More showering to keep fresh (& more laundering). Mainly cooking at home, so ample cool storage. Sizeable pool in the garden. Young urban people in social or private rental apartments, no outdoor shading, and simple ventilation systems. Are away from home a lot, use ventilators, mobile air conditioning and air purification unit(s) continuously, buy additional refrigerators, high showering frequency, high car use.
LOW COMFORT	City apartments with (multiple) residents on low income, vulnerable to heat due to age or health conditions, spend much time at home. Outdated central heating or district heating systems without cooling options, poor ventilation and shading equipment and skills, and small cold food storage capacity. Little access to green space and swimming water.	City apartments without outdoor shading. Multiple (second hand) mobile air conditioners used continuously in combination with open curtains and windows. Food storage in old, large fridges, and freezers. Little space and few places to go outside the home to cool down.

LOW COMFORT

Figure 21 rough scenarios for different types of households and dwellings with low and high comfort and energy demand levels

Opportunities and next steps

Briefly looking ahead to the next phase of the project, several opportunities were identified that might direct Dutch domestic practices of summer comfort onto more inclusive, healthy, and less energy-intensive pathways. Three related practices emerge so far as foci for interactive technology design: acclimatising, shading, and ventilating.

Acclimatising

A range of opportunities present themselves around acclimatisation, i.e., modifying bodily relations with hot weather. There seems to be a gap between state-of-the-art physiological research on how bodies deal with heat and everyday knowledge among the interviewees. In particular, the benefits of sweating, in combination with drinking enough water as a highly effective way to deal with heat is not fully acknowledged. Moreover, none of the participants talked about bodily adjustment to heat over time, while research shows that this effect can be as strong as 1°C per day[63].

Also close to the body are the temperature-regulating and self-cleaning qualities of woollen clothing, and technologies for active cooling through clothing and other person-oriented forms of cooling such as small ventilators or cooling blankets. A relaxation of professional dress codes such as in the Japanese Cool Biz campaign[64] could improve comfort and reduce demand for cooling in homes, offices, and on the road. These body-oriented paths show potential to contribute to summer comfort with the added advantage that they don't restrict freedom of movement to indoor spaces[65].

Shading and ventilating

Outdoor shading during the day and ventilation during the night can reduce or prevent overheating. The study shows that barriers exist for these practices to develop to their full potential in Dutch households. Automation can play a role here, when shading responds automatically to levels of solar gain, rain and wind, and ventilation to temperature and humidity differences inside and outside the dwelling. However, the role of residents cannot be ignored here. Not only their autonomy in deciding whether to have these systems at all, but also in the ways they are used.

In the study, a wide array of circumstances occurred in which people might disable automated shading, such as feeling locked-in, wanting more light, annoyance with repeated movement, wanting to open windows, etc. For ventilation systems, it became clear that their automated responses to CO2 or humidity levels can conflict with summer comfort by drawing in hot outside air during the day, while summer night ventilation, in the majority of homes, requires residents to open and close windows while they are sleeping.

When artificial cooling is added to the picture, which according to this and other studies can be increasingly expected, matters are complicated further. Cooling might reduce residents' acceptance of the experienced downsides of shading (including the costs), and lowers incentives and opportunities to utilise cooler night air.

Developing shading and ventilating into practices that work in the Dutch context, and making shading, ventilating and artificial cooling practices collaborate instead of compete harbour opportunities for interactive technology design. Moreover, facilitating practices of acclimatising as part of these systems shows further potential to contribute to low-energy summer comfort.

But first

Before exploring specific directions however, the next step in the project focuses on expanding the range of possible futures of summer comfort to be considered. This will be done through a series of design projects with interaction design students and workshops with experts. These projects and workshops will explore and extend the boundaries of summer comfort on selected dimensions:

Fully space-oriented	< >	fully person-oriented
Fully private	< >	fully public
Fully manual	< >	fully automated

5

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6

APPENDICIES

Appendix A:
temperatures August 2020 heatwave

	5-aug	6-aug	7-aug	8-aug	9-aug	10-aug	11-aug	12-aug	13-aug	14-aug	15-aug	16-aug	17-aug	18-aug
1	14,3	13,5	15,9	16,3	22,5	21,8	23,5	22,7	20,5	20,4	20,3	18,7	15,9	15,3
2	16,2	12,9	15,7	15,8	21,6	20,4	21,9	21,6	19,3	19,6	20,1	19	16,8	14,7
3	15,9	12,5	15,8	15,4	23,6	19,1	22,5	23	19,4	19,6	19,8	18,8	16,4	13,9
4	15,6	12,1	14,7	14,9	23,3	19	21,8	21,9	20,5	19,2	19,9	19,2	16,5	13,5
5	14,7	13,2	15,9	15,8	22,8	20,4	21,9	22,1	20,5	18,8	20	18,7	16,4	14,5
6	16,2	17,6	21,3	20,6	22,8	22,1	22,9	22,5	22,3	20,2	20,3	20,1	16,9	17,2
7	18,4	20,4	24	25,7	24	24,8	24,5	23,7	24	22,3	20,8	21,5	17,8	18,5
8	20	23	26,5	28,9	24,9	26,6	26,7	25,5	25,6	24,6	22,3	24,2	18,8	19,8
9	21,9	24,6	28,3	31,4	25,8	28,3	28,6	27,8	26,1	25,8	23,4	26,1	20,4	20,7
10	23,4	26,1	30,5	32,7	28,7	29,8	30,2	29	28,2	26,6	24,2	27,3	21,2	21,9
11	24	27,7	31,8	33,4	29,9	30,7	32,2	30	29	27,6	24,6	28,4	23,3	20,9
12	25,1	28,4	32,2	33,9	31,1	32,1	33	31	29,6	27,8	26,6	29,5	23,9	20
13	26,5	29	32,8	33,7	31,8	32,2	33,4	31,3	30,7	28,1	26,1	29,9	24,6	22,4
14	27,2	29,7	33	33,7	32,1	32	33,6	31,6	30,9	27,8	27,1	29,4	22,1	23,5
15	27,5	30,1	33	32,6	32,3	31,5	33,6	31,5	30,7	27,5	28,2	28,1	24,9	22,9
16	28	30,2	33	31,9	31,9	31,6	31,2	30,9	29,2	26,2	27,2	28,1	21,3	23,2
17	27,9	29,9	32,1	31,3	30,7	31	26,8	30,8	28,4	24	23,4	27,2	19,2	22,5
18	27	27,8	31,3	30	29,8	30,3	28,2	29,5	26,7	23,3	23,6	18,2	19	22
19	22,8	25,9	28,1	28,6	28,2	28,3	27,2	28	25,2	22,3	23,3	18,9	17,1	20
20	18,4	23,7	22,6	26,9	26,5	24,4	26,1	24,5	23,6	21,5	21,2	18,2	16,2	16,3
21	18,4	20,7	20,1	26,4	25,6	22,2	24,7	25,2	23,9	21,7	20,5	17,6	15,6	14,9
22	15,6	20,6	18,5	25,7	24,4	22,4	24	24,2	23,1	21,2	19,7	17,6	15,8	14,2
23	14,6	19,2	18,2	24,8	22,6	21,8	25,5	22,5	22,4	21	19	17,7	16,7	13,7
24	15,5	17,1	17,1	24,3	22,9	24	24,2	20,4	21,6	21,1	18,6	16,5	15,9	13,6
Average	21	22	25	26	27	26	27	26	25	23	23	22	19	18
												RAIN		

Figure 22: temperatures measured at De Bilt weather station (obtained from KNMI …)

Appendix B:
Recruitment materials and booklet

Workbook provided to participants in household study. A PDF of the full workbook is available on request.[a screenshot could be added here of the table of contents of the workbook (p7)]

Materials used for digital recruitment and enrollment of participants in the study. In addition, physical flyers, letters and door to door recruitment methods were used.

Appendix C: Summary of findings per practice

PRACTICE	CURRENT SITUATION	PROGNOSIS NEXT 10-30 YEARS	RISKS AND OPPORTUNITIES
The body and temperatures	High diversity, sleeping and working most heat sensitive, moderate to high discomfort in heatwaves (expressed in sweat, boredom, low-energy and irritation), but also positive associations with nice weather, importance of temperature differences, comfort zone largely below BENG norm, city apartments above BENG norm	Development of a different relation with the sun that is more complex and nuanced, from 'all good' towards practices of selective shielding.	Bodily adaptation to heat over time isn't on the radar of households.
Personal care and clothing	Increased frequencies of showering during heatwave, light, airy clothing style but limited by professional dress codes, bathrooms low cooling demand	Relaxation of professional dress codes in warm weather, catalysed by corona experiences of home working, development of everyday fashion around water-cooled clothing. Possible frictions between showering frequencies and future water-use restrictions (and boiler capacity).	Relaxation of professional dress codes might be hampered if temperature settings in cooled offices remain low.
Laundering	Slight increase in laundering frequencies during hot weather (towels), low effect of heat from appliances due to locations.	Shifting use of washing machine and dryers to daytime for solar power.	Cooler morning time might induce the use of washing machine during the night. Self-cleaning property of wool.
Cooking and eating	Heat generated by appliances directly into living spaces, ovens and stoves used less; fridges and freezers more.	In longer heatwaves, cooking appliances are used more again for variety. Food cooling capacity increases.	More cooking and more cooling appliances generate more heat. Cooking outdoors or eating out/take-away.
Working from home	High heat sensitivity for working, clashes with external time demands and professional dress codes. Privacy issues in multi-person households. High diversity in work locations in the home.	More clashes between home working and heat due to climate change and more home working among white-collar workers. Possibly bedroom/office combi's as entry point for outdoor shading and/or (mobile) aircon in homes.	Home working receptive to cooling. Employers not keen to finance air-conditioners.
Free time	heatwaves limit type and location of leisure activities, feeling of being locked inside, or response to escape the home to shaded, water-rich places	Development of new summer hobbies indoors, increased car use. More indoor exercise?	Negative health effects of reduced exercise and vit D intake. Cooled public places such as libraries, cinemas and museums as places of refuge.
Sleeping	Trouble sleeping from heat but also due to clashes with summer night ventilation, need for blanket cover.	Growth in use of (mobile) aircon for sleeping along with reduced practice of summer night ventilation	Development of bed-focused cooling devices
Shading	Growing, but city apartments lack outdoor shading while they need it most. Outdoor shading clashes with home working and entertainment need for light and views	Continued spreading of outdoor shading, but market competition with air-conditioning, the latter wins in terms of comfort-for-money.	Outdoor shading is currently not seen as an energy saving technology. Competes directly with air-conditioning.
Ventilation	Summer night ventilation by opening windows widely performed. Simple ventilation systems can contribute to drawing in warm air during the day and aren't used to complement summer night ventilation.	Ventilation skills may improve over time, but summer night ventilation reduces with the spreading of (air-based) mechanical cooling. WTW ventilation with bypass could grow together with floor cooling, but not in existing dwellings due to elaborate space requirement.	Risk of unhealthy air with use of mobile aircon in closed spaces
Cooling	Air-based aircon systems have a reputation among non-users to be unpleasant. Households with floor heating consider floor cooling.	Mobile aircon, split unit aircon and floor cooling are expected to increase in parallel. Their use patterns could be quite different. Air-based aircon may develop in parallel with on-demand cooling and heating patterns. Floor cooling and heating are more likely to be on continuously.	Growth in use of cooling may hamper development of shading and ventilation practices, making the energy demand of cooling unnecessarily high