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Thermal Comfort at Home

Mapping Design Approaches to Democratic Everyday Solutions

Master's thesis in *Industrial Design Engineering*

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Abstract

Thermal comfort at home sits at the intersection of household energy use and everyday well-being. Buildings account for around a fifth of recent global energy demand growth, most of it driven by households, while access to safe indoor temperatures remains unevenly distributed across regions and income groups. Solutions available only to a limited share of the population are therefore unlikely to reduce emissions at the scale the climate problem requires. This thesis adopts IKEA's Democratic Design as a lens for exploring how thermal comfort at home can be made both sustainable and accessible, grounded in how comfort is actually sought and lived day to day.

The project began with a literature scan and an exploratory survey, which together produced a framework of the factors shaping thermal comfort experience and identified the aspects most actionable through design. In a later stage, the project drew insights from user interviews and digital ethnography that produced a set of desirability attributes that translate Democratic Design into thermal comfort terms. These attributes reflect people's desires and expectations for thermal comfort solutions and together with identified insight themes, led to four refined concepts and functional prototypes: a bamboo block mat, an air-insulated blind, a no-drill awning, and a thermal rhythm broadcast service. An analysis of our creative process results converged into a Design Approach matrix that offers structure for future design interventions for thermal comfort at home.

Keywords: thermal comfort, Democratic Design, home environment, exploratory method, factor framework, prototyping, design approach, everyday practice.

Contents

1	Introduction	1
1.1	Background	1
1.2	Purpose	3
2	Method	5
2.1	Stage 1: Defining Thermal Comfort	5
2.2	Stage 2: Current Solution and Frictions	13
2.3	Stage 3: Develop Future Solutions	16
3	Results	29
3.1	Thermal Comfort Factors	29
3.2	Current Everyday Thermal Experience	36
3.3	Synthesis of insights for Design	49
3.4	Desirable Attributes	52
3.5	Ten Initial Concepts	54
3.6	Refined Concepts and Prototypes	65
3.7	Develop Future Solutions Strategy	75
4	Discussion	79
4.1	Contributions	79
4.2	Approach	81
4.3	Further work	82
5	Conclusion	85
A	Exploratory Survey Questionnaire	I
B	Insight Cards from Stage 1 Synthesis	V
C	Survey Data Analysis	XIII
D	Interview Materials	XIX
E	Interview Quantitative Data	XXVII
F	Evaluation of conventional solutions	XXXV
G	Evaluation Form and Outcome	XXXVII

1

Introduction

1.1 Background

Global energy demand continues to rise, and the buildings sector is one of its central contributors. Between 2019 and 2024, buildings accounted for 20% of global energy demand growth, with households responsible for 70% of this increase (International Energy Agency, 2025). Much of what households consume goes into thermal regulation: space and water heating make up the largest share of residential energy use in advanced economies, while in emerging and developing economies demand for space cooling is rising with population, income, and summer temperatures (International Energy Agency, 2025). This drive to stay comfortable feeds a self-reinforcing loop, as the energy spent on heating and cooling raises greenhouse gas emissions that intensify the climate pressures driving demand still higher (Sánchez-García & Bienvenido-Huertas, 2023). Climate instability is now sharpening that loop, with more frequent heat extremes and shifting seasonal patterns pushing households toward still greater heating and cooling needs (Intergovernmental Panel on Climate Change, 2023).

The pursuit of thermal comfort is not only an energy matter but also a question of everyday well-being. Indoor comfort can be characterized in four main categories: thermal comfort, visual comfort, acoustic comfort, and air quality. A questionnaire survey conducted by Frontczak et al. (2012) in Danish households found that occupants rated thermal comfort as more important than visual comfort, acoustic comfort, or air quality. Thermal comfort therefore sits at the centre of any effort to align everyday well-being with sustainability: it is the most valued dimension of indoor comfort and, as a leading driver of residential energy demand, the one where improvements carry the most weight for both.

However, thermal comfort at home is not produced by building systems and indoor temperatures alone. Thermal comfort can be defined from several perspectives: from the building management perspective, it rests on regulatory and generalised standards aimed at satisfying the majority of occupants, assessed as a function of four physical variables: air temperature, mean radiant temperature, relative air velocity, and air humidity; and two variables related to people: activity level and clothing. From an individual perspective, it depends on whether a person would wish to feel neither warmer or cooler when asked about their specific thermal state and preference inside a given space (Frontczak & Wargocki, 2011). Renström (2019), citing

Goulden et al. (2014), argues that energy plays a background role in most people’s lives, serving primarily as a medium for fueling daily activities. Everyday life both shapes energy systems and is shaped by them through the artifacts and infrastructures that provide comfort and convenience (Renström, 2019). Comfort, in this view, is something actively performed and negotiated through what people do at home, through clothing layers, window adjustments, the timing of daily routines, and the spaces occupied at different hours (Shove et al., 2014). Household practices around thermal comfort are therefore an important foundation for understanding how comfort is achieved at home (Ekdahl, 2025).

These practices, however, are unevenly resourced. Efforts towards efficiency and sustainable energy transformation are unevenly distributed across the world, and inequalities exist in how different regions allocate energy use (Igorevich et al., 2025). Economic development is a key factor in determining energy consumption trends, with higher GDP levels linked to lower emissions and higher use of renewable sources, while in developing economies climate initiatives are often displaced by more immediate economic priorities (Igorevich et al., 2025).

This unevenness extends to thermal comfort itself. A growing literature on fuel poverty, cooling poverty, and thermal justice has documented that access to safe indoor temperatures depends not only on energy availability, but on housing quality, occupational conditions, and adaptive capacity (Mazzone et al., 2024; Walker & Day, 2012). In high-income countries, large shares of households remain unable to maintain healthy indoor temperatures during winter, with the burden concentrated among renters and lower-income groups (Zhang & Zhou, 2026). In rapidly warming regions, the inability to afford or access cooling places informal workers and residents of dense low-income neighborhoods at the sharpest edge of heat exposure (Mazzone et al., 2024). Solutions available only to a limited share of the population are therefore unlikely to generate meaningful reductions in greenhouse gas emissions or fossil fuel use at the scale the climate problem requires.

Sustainability and accessibility are therefore not separable goals. This perspective aligns with IKEA’s vision of creating “a better everyday life for the many people” (Inter IKEA Systems B.V., 2020). IKEA’s Democratic Design articulates this vision through five parallel principles: form, function, quality, sustainability, and low price, which are intended to be balanced throughout the product development process, with sustainability treated as a basic requirement rather than an added value (Inter IKEA Systems B.V., 2020). This thesis adopts Democratic Design as a working frame for exploring how thermal comfort solutions can be made sustainable and accessible to the many, grounded in how thermal comfort is actually sought and lived at home.

1.2 Purpose

1.2.1 Aim

This project is driven by the conviction that thermal comfort at home should be both sustainable and democratic, using less energy while bringing comfort to more people. Rather than starting from existing solutions and asking how they can be improved, the project takes a more exploratory path, stepping back to ask what shapes people's experience of thermal comfort in everyday home practices. It aims to explore how design can respond to people's expectations of creating thermal comfort, through affordable and energy-efficient solutions aligned with IKEA's Democratic Design philosophy.

1.2.2 Research Questions

RQ 1: What are the common factors that shape people's experience of thermal comfort at home?

RQ 2: How do people manage thermal comfort at home today, and what are their expectations of it?

RQ 3: How can we create solutions for thermal comfort at home that align with IKEA's Democratic Design principles?

1.2.3 Demarcations

Thermal comfort at home is intertwined with many aspects, ranging from climate and building systems to economic and infrastructural conditions. Among these, the project concentrates on what happens in everyday life and on aspects approachable through personal choice, particularly consumer-level solutions. Building-level interventions such as HVAC systems, insulation upgrades, and energy infrastructure therefore lie outside its scope.

To investigate this everyday dimension, the research is exploratory and qualitative in nature, drawing on surveys, interviews, and digital ethnography rather than on physical measurement of indoor environmental parameters or engineering solutions.

As part of this qualitative approach, the project includes participants and respondents from different cultural and national contexts. However, the intention is to bring a rounded perspective and broaden the source of inspiration, rather than to conduct a systematic global or comparative study.

Finally, design outcomes are developed at the concept level and validated through user feedback. Full engineering specification, production costing, and market analysis are beyond the scope of this thesis.

2

Method

According to Martin and Hanington (2012), when designers are working in unfamiliar territory, the recommended method to build an empathic knowledge base is through user and product studies in an exploratory research exercise. This project followed that logic. Thermal comfort at home is a wide topic, while existing solutions tend to fall into a fixed set of conventional categories. To avoid being framed by those categories from the start, the project was intentionally kept open in its early phase and structured to move from a broad exploration of the opportunity space toward a focused solution across three stages(Figure 1).

Stage 1 mapped the factors that shape thermal comfort at home, and identified the aspects within that map most open to design influence. These focus aspects set the scope for Stage 2, which went deeper into people’s daily routines without yet committing to a solution path, and produced a set of *desirable attributes*, a list of choice-driving criteria against which conventional solutions were evaluated. In Stage 3, these criteria and the earlier research insights guided a brainstorm with the IKEA team that opened the solution space. From there, we further developed the ideas, evaluating them against a refined version of desirable attributes, and working toward solutions that improve thermal comfort for the many through the refinement of 4 design concept.

2.1 Stage 1: Defining Thermal Comfort

The purpose of the first stage was to build a grounded understanding of the current state of research around thermal comfort, and of what thermal comfort means and how it is experienced specifically in everyday life at home. This understanding was then used to build a factor framework that would guide the research focus and design opportunity of the later stages.

The stage began with a literature scan, capturing the theoretical grounding of thermal comfort as a research topic (Section 2.1.1), combined with an exploratory survey to develop an early understanding of people’s thermal experience in the home context(Section 2.1.2) . By synthesizing insights from both activities, the stage produced its main output: a thermal comfort framework covering the aspects relevant to home thermal comfort(Section 2.1.3) .

2. Method

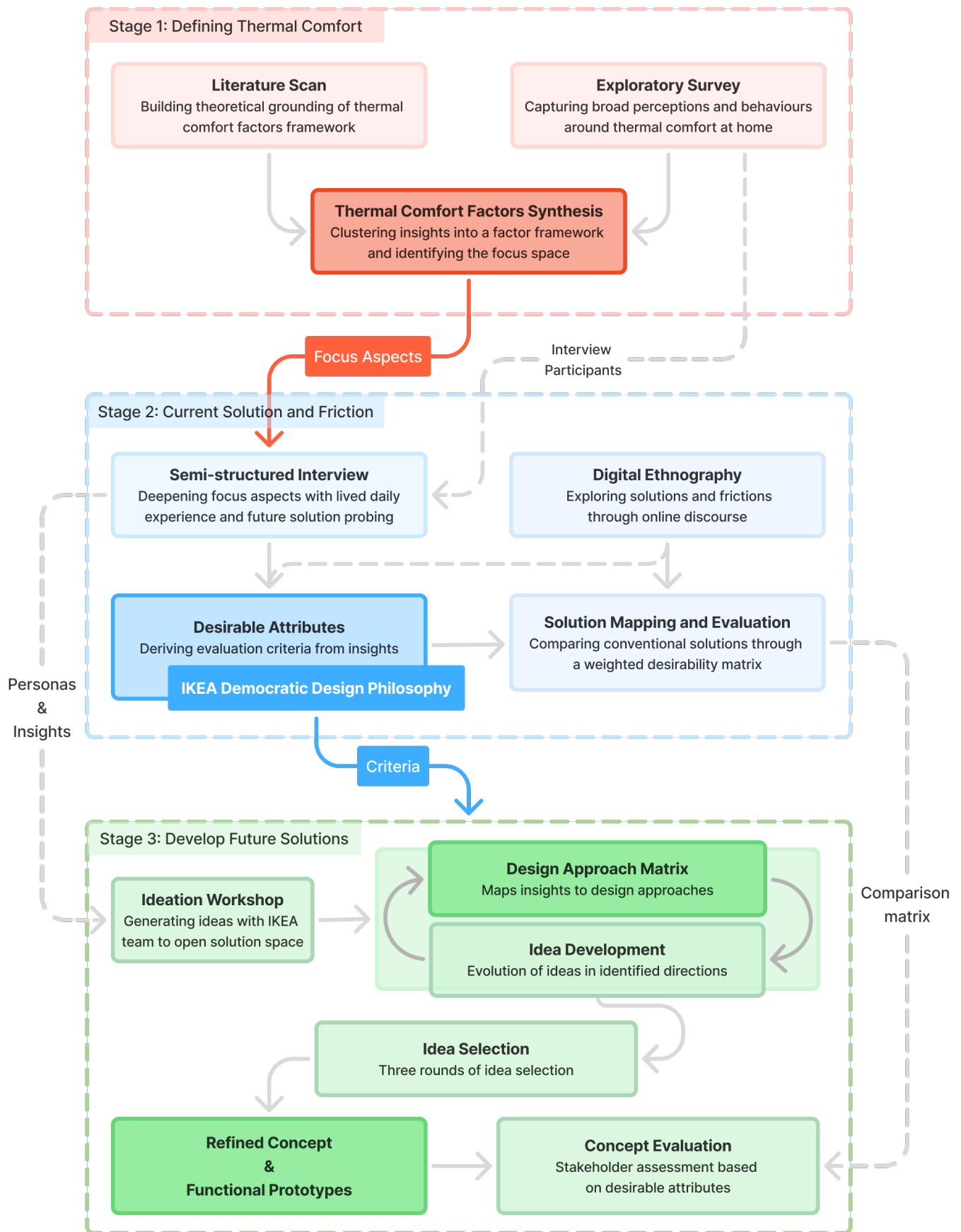


Figure 1: Method overview

2.1.1 Literature Scan

In this project, the literature scan aimed to develop a theoretical understanding of the factors that shape thermal comfort at home, and to situate the project within the broader field of residential comfort research. Rather than a systematic review, the scan was conducted as an exploratory and iterative process, since thermal comfort sits at the intersection of environmental engineering, occupant behaviour, and available living conditions. New sources were added throughout Stage 1 as themes developed.

Sources were identified through Scopus, Chalmers Library, Consensus, and Google Scholar, complemented by literature recommended by supervisors and domain experts. Searches were conducted in English, using combinations of keywords grouped around the following themes:

- Thermal comfort: thermal comfort models, adaptive thermal comfort, personal comfort, summer comfort, indoor comfort.
- Indoor environmental quality: indoor environmental quality, indoor air quality, residential comfort, local conditioning.
- Occupant behaviour and everyday practice: occupant behaviour, occupant perception, habits, household energy use, comfort behaviours, vulnerable groups.
- Psychological dimensions: controllability, schema, cognitive representations, adaptive model.

Each source was documented in its own structured table, compiled together into a shared reference document. Each table contained an index number (e.g. L1, L2, L3), the full citation, keywords, relevant quotations, and extracted insights (Figure 2). The index number was used to trace each insight back to its source during the affinity diagram in Section 2.1.3.

The literature scan also served another function for informing the exploratory survey design. Existing questionnaire-based studies on residential comfort (Frontczak et al., 2012) provided direct structure and wording reference for question formulation. Beyond that, some key aspects that were showed influenced thermal comfort at home, such as the role of perceived control over the indoor environment and the influence of daily activities on comfort needs. These aspects were integrated into the survey structure.

2. Method

TITLE			APA referenc	
L1-Staying Cool in the Face of Heat: Exploring Sustainable Everyday Climate Adaptation through Practice-Oriented Design			Ekdahl, K. (2025). <i>Staying Cool in the Face of Heat: Exploring sustainable everyday Climate adaptation through Practice-Oriented Design</i> [MA thesis, Chalmers University of Technology]. http://hdl.handle.net/20.500.12380/309853	
AUTHORS	KEY WORDS	METHOD	NOTES	CITATION
KAROLINA EKDAHL	Household climate adaptation Urban apartments apartment living Sweden Everyday Practice Student & <u>Yound</u> Adults Overheating	Practice-oriented design what practice now, and what practice future Workshop, Expert Interview, Research-through-Design (RtD)	The Project Writer work with "Household energy resilience in crisis and sustainable transition" https://www.ri.se/en/energy-and-electrification/project/household-energy-resilience-in-crisis-and-sustainable-transition	(Ekdahl, 2025)
ABSTRACT				
This thesis investigates how urban apartment dwellers in Sweden adapt to increasing heat and heatwaves in everyday life. It frames climate adaptation not as a purely technical or infrastructural issue, but as a reconfiguration of everyday practices that affect energy use, comfort, and quality of life.a				
QUATATION				
With further global warming, it is expected that the adverse effects of climate change will intensify, while also becoming increasingly complex and difficult to manage (Lee et al., 2023). the household perspective on climate adaptation is still rather unexplored At the same time, the transition to increased electrification and diversification of the energy system may also introduce risks and vulnerabilities for the access to electricity. Meanwhile, society is becoming increasingly dependent on electricity, contributing to more severe consequences of disruptions (MSB, 2021b), Coping is about using available skills and resources to handle adverse conditions (UNISDR, 2009), Numerous studies have shown that the older population, usually defined as above 65 years old, are one of the most vulnerable groups. This is largely due to pre-existing diseases, but also due to reduced ability to regulate the body temperature. However, the temperatures that people are exposed to indoors can become significantly higher than the meteorological conditions outdoors (SMHI, 2011).				
INSIGHT				
1. Heat already affects everyday life, not just future risk Even among younger, non-vulnerable groups, overheating already affects sleep, daily energy levels, and overall wellbeing 2. Conflicts between summer values in sweden and heat-adaptation advice Heat-adaptation advice such as closing blinds or windows often conflicts with desires for light, views, and openness. Solutions must preserve light, openness, and experiential qualities (Friction) 3. Apartments strongly constrain adaptation capacity Apartment dwellers lack control over: Orientation, Shading, Ventilation systems 4. Heat adaptation should be supported as part of everyday rhythms and practices The paper does not argue for new appliances. Instead, it proposes supporting people's decisions through: Feedback, Timing, Awareness, Rhythms. treating heat adaptation as a reconfiguration of everyday practices rather than a technology problem 5. The key opportunity lies in making heat understandable and actionable Design can support users by clarifying how actions affect indoor temperature and by offering timely, situation-specific guidance. Climate adaptation = everyday practice change Treating heat adaptation as a reconfiguration of everyday practices rather than a technology problem (Daily routines and micro-decisions) A critical friction "Summer value conflict" Closing blinds = thermal benefit but experiential loss				

Figure 2: Literature reference table example.

2.1.2 Exploratory Survey

An exploratory survey was conducted to build a broad understanding of how people experience and manage thermal comfort at home. The questionnaire format was chosen to capture self-reported perceptions and activities across a range of domestic contexts (Martin & Hanington, 2012). At this stage, the survey was not intended to produce statistically representative conclusions, but to surface recurring tendencies, everyday vocabulary, and areas of concern that could inform the synthesis of thermal comfort factors in Section 2.1.3.

The survey consisted of 36 questions organised into three parts, as shown in Table 1. The full questionnaire is included in Appendix A, covering personal definitions of comfort, seasonal comfort levels, recurring problems, adaptive behaviours, use of devices and solutions, improvement needs, and demographic background. The questionnaire combined closed-ended and open-ended questions. Closed-ended questions, including single-choice, multiple-choice and rating-scale items, enabled the identification of broad patterns across respondents. Open-ended questions allowed participants to describe their thermal comfort experiences and expected improvements in their own words, adding contextual depth to the quantitative patterns.

The final survey was distributed online via Google Forms in three language versions: English, Chinese, and Spanish. Respondents were recruited through online communities and social media, and via university networks, professional networks, and personal contacts. A total of 125 valid responses were collected. The sample was geographically concentrated in Sweden (56.0%), followed by China (16.8%), Mexico (14.4%), the United States (5.6%), and other countries (7.2%). The majority of respondents were aged 26–35 (51.7%), with a roughly balanced gender distribution (52.0% female, 44.8% male).

After data collection, closed-ended responses were analysed with descriptive statistics to identify distributions and recurring tendencies. The two open-ended questions were analysed through affinity diagramming, grouping individual responses into thematic clusters. Exploratory cross-analysis was also conducted to examine relationships between selected variables, such as seasonal comfort, perceived control, housing type, ownership status, gender, and mood impact, to probe whether contextual or demographic factors related to comfort experience. These analyses served as inputs for the later synthesis of thermal comfort factors described in Section 2.1.3. The full survey analysis is presented in Appendix C.

2.1.3 Thermal Comfort Factors Synthesis

The synthesis stage brought the literature scan (Section 2.1.1) and exploratory survey (Section 2.1.2) together into a single framework that could guide the rest of the project. By this point, both activities had produced a large amount of material, including theoretical concepts, statistical tendencies, and user quotes. The challenge had shifted from collecting information to making sense of it.

Table 1: Overview of the exploratory survey structure

Section	Theme	Purpose	Questions	Types
1. Comfort Self-evaluation	Personal thermal comfort definition	Capture how respondents understand and describe thermal comfort in their own words	Q1	Open-ended
	Perceived comfort level	Quantify comfort frequency across seasons and emotional impact of discomfort	Q2–Q6	Single choice, Likert 1–5
	Comfort conditions & problems	Identify preferred temperature, problematic weather conditions, and everyday situations where discomfort occurs	Q7–Q10	Multiple choice
2. Activities around thermal comfort	Perceived control & barriers	Assess respondents’ sense of controllability over home temperature and what prevents improvement	Q11–Q13	Likert 1–5, Multiple choice
	Adaptive approach	Map behavioural responses to thermal discomfort, covering both too-hot and too-cold conditions	Q14–Q16	Single choice, Multiple choice
	Devices & solutions	Identify common devices used for cooling and heating at home, assess perceived sustainability of current solutions	Q17–Q19	Multiple choice (with images), Likert scale
	Improvement needs	Capture reflective unmet needs after completing the full experience mapping	Q20	Open-ended
3. Context information	Demographics & housing	Collect background variables for cross-analysis	Q21–Q25	Short answer, Single choice
	Household	Ownership status and who the respondent lives with, providing context on shared control over thermal comfort	Q26–Q28	Single choice, Multiple choice
	Personal profile	Collect age, sex, time spent at home	Q29–Q32	Single choice
4. Further Participation	Interview recruitment	Recruit willing respondents for follow-up interviews	Q33	Single choice

Affinity diagramming was used as the synthesis method. It externalises research material onto individual cards and clusters them by shared meaning, allowing themes to surface from the data itself rather than being fitted into a predefined structure (Martin & Hanington, 2012). This suited the project, where the inputs spanned different formats and origins and the aim was to stay close to how thermal comfort is actually experienced and being influenced at home.

2.1.3.1 Input material

Around 110 cards were prepared for the exercise, each representing one insight extracted during earlier work (Figure 3). Cards were coded by source so that every grouping decision could be traced back to its origin:

- **L-#**: insights from the literature scan (Section 2.1.1).
- **S-#**: findings from the exploratory survey (Section 2.1.2), including both closed-ended distribution insights and open-ended response themes.
- **D-#**: insights from the digital ethnography conducted as part of Stage 2 (Section 2.2.2).

Home temperature control contributes more to thermal comfort during winter than summer.	Apartment dwellers lack control over: Orientation, Shading, Ventilation systems	Windows & Sunlight plays an important role in MRT comfort In modern buildings, especially with large glazed facades, mrt is often dominated by window temperatures
S-C4	L-1	D-28
The majority of people report feeling slightly colder or much colder than the people around them. 63.49% female and 36.51% male.	Healthcare Definition of Comfort 2 context of comfort Physical (bodily feelings) Psychospiritual (inner self) Social (family/cultural relationships) Environmental (light, noise, temperature, sensations)	When shared with others, comfort can feel like a scarcity. comfort feeling like a finite resource—when someone gets more, someone else gets less.
S-C5	L-22	D-26

Figure 3: Example of Insight Cards.

D cards from the digital ethnography were included as additional input where they helped clarify themes already emerging from the L and S cards.

2.1.3.2 Process

The synthesis was carried out as a physical exercise. All cards were printed and laid out on a table without any predefined categories, and clustered in two rounds (Figure 4).



Figure 4: Sorting photo.

Round 1: Bottom-up clustering by underlying meaning.

Cards were grouped according to the mechanism or underlying idea each one described, rather than the wording on the card. For example, *"habits persist because energy use is not directly visible"* and *"getting comfortable takes effort, and people give up on it"* use very different language, but both point to a barrier in changing thermal habits, and were placed together. Each cluster was then named after the shared mechanism running through its cards, not after any individual quote or keyword. This round produced ten themes: Sensation, Behaviour, Frustration, Personal Factors, Activities, Emotion, Environmental Factors, Cognition, Knowledge, and Solutions. Within each theme, sub-patterns were also identified. For example, the Frustration theme split internally into three barriers respondents most wanted to address: control, cost, and insulation.

Round 2: Reorganisation by role in the comfort process.

The ten themes from Round 1 were not at the same conceptual level. Some covered broad categories such as Environmental Factors and Personal Factors, while others described narrower aspects such as Sensation, Cognition, or Knowledge that in fact sat within those broader categories. A flat category would not show how they actually relate to one another, second round was therefore carried out. Organising themes around the central question of how thermal comfort is experienced at home, and the role each theme plays in that process: the constant attributes people bring into any thermal situation, the physical conditions of the home at a given moment, the situations that shape how comfort can be managed in daily life, and the outward expressions that arise from these and trigger adjustment.

2.1.3.3 Output

The synthesis produced a framework of thermal comfort factors that serves two purposes in this thesis. First, it acts as the conceptual conclusion of Stage 1, mapping

out the factors that shape thermal comfort at home. Second, within the framework, the aspects most open to design influence were identified and used to focus the subsequent interview and design stage. The framework itself is presented and described in Section 3.1.

2.2 Stage 2: Current Solution and Frictions

In this section, we describe how we proceeded to deepen our understanding of current practices around thermal comfort management. We conducted interviews, gathered information about solutions online, and used this information to compile and evaluate a list of current solutions.

2.2.1 Semi-structured Interviews

To recruit volunteers for our interviews, we added a question at the end of our exploratory survey to ask participants to share their contact details if they were interested in participating further in the study. We sent 33 invitations and received 13 sign-ups for interviews between 11th and 17th March. We held 11 individual interview sessions and one with a couple that shared a home. The duration of the sessions was approximately 45 minutes, and they were split into 3 main parts.

The first section consisted in a *directed storytelling* technique (Martin & Hanington, 2012), which is a method used to understand people and document their experience based on their narrative around a determined topic or activity. Interviewees were asked to describe their daily activities and their thermal comfort experience and strategies while going about their day. The conversation was focused on a "really hot" and a "really cold" day. We represented their descriptions in a Experience map (See Figure 5)

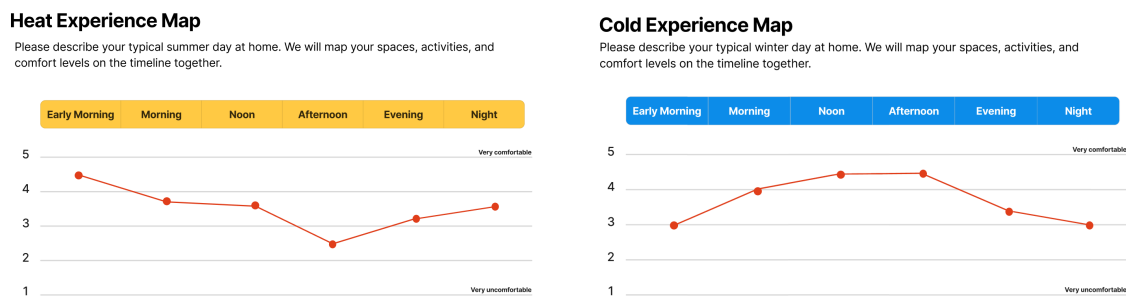


Figure 5: Example of Experience maps for hot (left) and cold (right) weather.

The second section of the interview was centered around activities and clothing. Based on the answers from question 1 of our exploratory survey, we learned that many people define thermal comfort by the clothes they need to wear in order to not feel too cold or too warm. First we asked them to list the top 3 activities they do on a regular basis where thermal comfort is most important for them. Then, we designed

an graphic tool meant to reflect the way people wish to dress while performing such activities both in warm and cold weather (Figure 6).

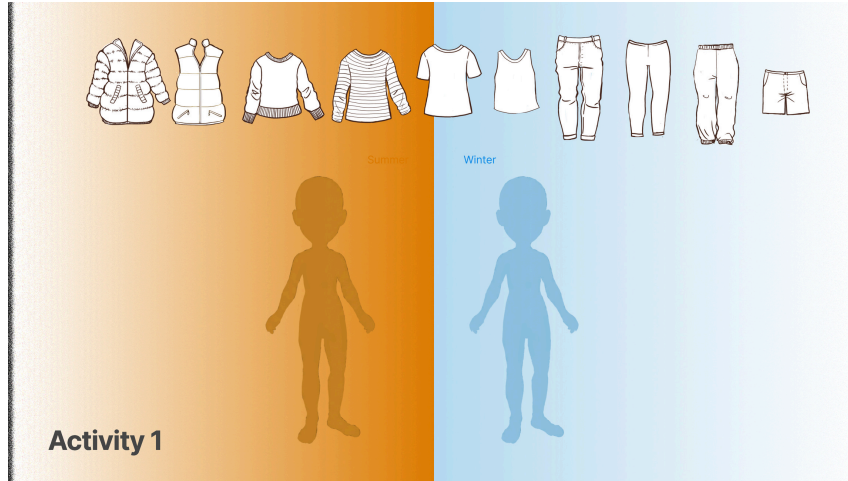


Figure 6: Activities & clothing exercise example

In the last section of the interview, participants were shown images of existing non-conventional solutions designed to improve thermal comfort. The products were categorized into “Personal Devices,” “Furniture-Integrated,” “Micro-climate Environments,” “Wall/Floor Systems,” “Heating/Cooling Blankets,” and “Window Add-ons.” Participants were asked to share their opinions on these product categories, including whether they had used similar solutions in the past or could imagine using them in the future. Desirability was documented using three response categories: yes, maybe, and no. Appendix D shows a full set of the interview materials.

2.2.2 Digital Ethnography

To understand the current online discourse around home heating and cooling, not just from a technical or academic perspective but from the point of view of real people navigating these decisions in their daily lives, we conducted a digital ethnography study. Digital ethnography is an established research method to study how people live, think and make decisions through and within digital spaces (Hine, 2015; Pink et al., 2016). This approach allowed us to access the public conversation happening around heating and cooling: the questions people are asking, the frustrations they are expressing, and the solutions they are exploring and sharing from different parts of the world.

Online public platforms such as YouTube, Reddit, Instagram, and Gapminder’s Dollar Street were consulted using keywords including “Cooling devices,” “Heating devices,” “Home passive cooling,” “Home temperature,” “Sustainable home temperature,” “Home energy use,” and other similar combinations. Additionally, selected IKEA internal insight sources were reviewed. As with our Literature Scan (Section 2.1.1), the gathered material was documented by creating a structured table for each source and compiling these into an indexed document. Each table included

fields to track the source's origin, screenshots, relevant quotes, and extracted insights (Figure 7).

Source		Screenshots
Title or caption	3. What temperature do you keep you house in the winter?	
Search prompt	reddit home temperature	
Type of content	Forum posts	
Language	english	
Publication date		
Access date	13-02-2026	
Creator	-	
URL	https://www.reddit.com/r/AskEurope/comments/12217la/what_temperature_do_you_keep_your_house_in_the/	

QUOTATION

They're quite old now and get cold easily but just throw on extra layers instead of turning on the heat.

France is no different. People just bundle up during the day, and then light the woodstove for an hour or two in the evening

That's changing. A lot of houses in the country in Denmark are using heat pumps. In the cities it's still more common to have distributed heating, though.

23-24 my house is basically a greenhouse. Whole building receives heating from city system so even if we turn off all radiators pipes in walls and floor are heating us up and flats around add additional warmth. On sunny day with closed windows we can easily hit 26 even with snow outside.

I have it at 24 degrees and I am still cold most of the time. Everytime this topic comes up, people forget that it is different for everyone. Literally everyone has their own perfect temperature. Some higher, some lower. But people do not accept it.

INSIGHT

Comfort temperature cannot be treated as a fixed value. Individual preferences, clothing habits, and adaptation significantly influence acceptable indoor conditions.

Occupants evaluate comfort based on the entire thermal environment, not air temperature alone.

In multi-family housing, thermal comfort often depends on collective building behavior rather than individual heating actions. Heating practices appear influenced by regional norms and building traditions, not solely climate.

Figure 7: Example of a digital ethnography reference table.

This approach provides a complementary layer to more formal research methods: it grounds the project in how thermal comfort is actually understood, discussed, and acted upon by ordinary people around the world, not just how it is defined in academic or industry literature. This is particularly relevant given that people increasingly turn to the internet to research and inform purchasing decisions before

buying (Aw et al., 2021; Babić Rosario et al., 2020). This means that the online discourse does not just reflect perceptions, it actively shapes them. By including sources ranging from experts (although sometimes self appointed) in YouTube channels and Reddit forum threads to cross-cultural visual databases like Dollar Street, opinions from a wide range of geographies, income levels, and housing contexts were captured.

2.2.3 Solution mapping and Evaluation

Building on the findings from the exploratory survey (see Section 2.1.2), the interviews (see Section 2.2.1), and the digital ethnography study (see Section 2.2.2), we developed a weighted matrix (Martin & Hanington, 2012; Ulrich & Eppinger, 2012) to evaluate common thermal comfort management solutions. This type of matrix is traditionally used in design processes to evaluate concepts in development stage, however, it was considered as the ideal tool to make a comparative evaluation of the current solutions in the market for this project.

A set of desirability factors was identified based on users' considerations when selecting thermal comfort solutions. These factors were subsequently used as weighted evaluation criteria to assess and rank the identified solutions. Criteria weights were determined by systematically comparing them against each other. During this process, we evaluated whether a criterion was more important, equally important, or less important than the compared criterion. The comparison scores were then aggregated to establish the final weight assigned to each criterion.

The solutions were evaluated using a qualitative scoring scale ranging from 1 to 5, where 1 represented the least desirable value and 5 represented the most desirable value for a given criterion. For example, within the criterion "Performance," a score of 1 indicated a barely effective solution, whereas a score of 5 indicated a highly effective solution. The overall evaluation was qualitative in nature and based on the collective insights obtained through the previous research activities conducted by the authors.

2.3 Stage 3: Develop Future Solutions

Stage 3 translated the research insights and desirable attributes developed in the previous stages into future solution concepts. The process began with an ideation workshop with the IKEA team to open the solution space, followed by internal idea development, direction identification, concept selection, refinement, prototyping, and evaluation. Throughout this stage, the desirable attributes from Stage 2 were used as criteria to guide decisions and assess how well the concepts responded to the identified thermal comfort frictions.

2.3.1 Ideation Workshop

Stage 2 gave a layered picture of how people experience thermal comfort at home and what they want from a solution. To move from this understanding into concrete design opportunities, a three-hour workshop was organised at the IKEA office. The intent was twofold: to draw on the input of an IKEA team practised in IKEA's creative approach, opening a wider opportunity space, and to secure stakeholder engagement early in the design phase (Martin & Hanington, 2012).

In total, eight participants joined the session, their disciplines ranged from innovation, engineering, product development, and design, and were split into three teams.

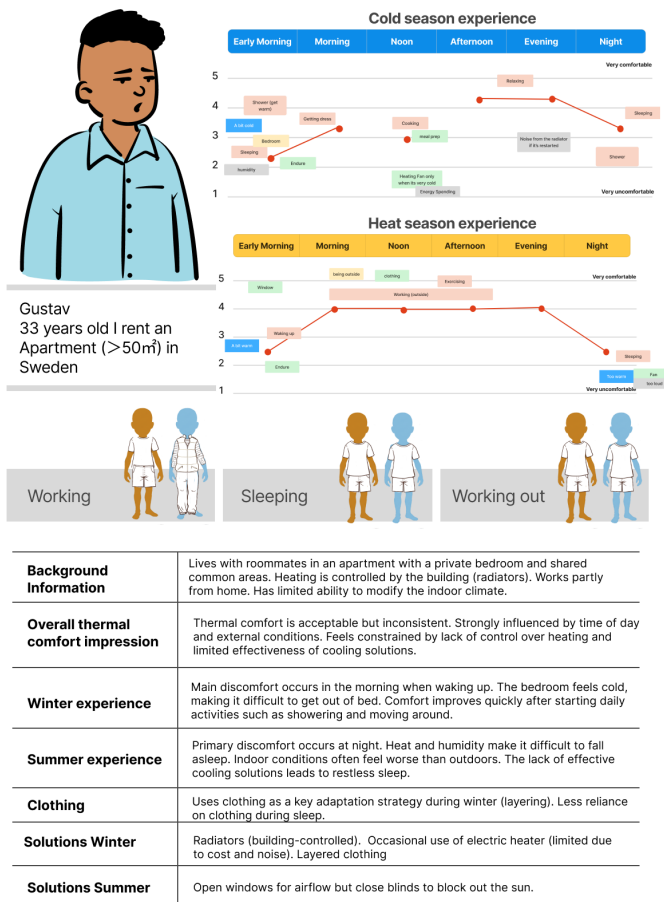
The session opened with a thirty-minute presentation of the Stage 1 and 2 findings. It introduced the factors framework as a shared grounding for what shapes thermal comfort at home, and then drew out a few points that framed the design problem: *people want comfort that feels calm, stable, and effortless; discomfort is often moment-based rather than constant; lack of control is one of the strongest barriers*. The desirability attributes from Stage 2 and the evaluations of conventional solutions were also presented.

Each team was also assigned one persona built from the interviews (Figure 8), covering background, an experience map across both seasons, current solutions in use, and the persona's goals, frustrations, and design opportunities. With the question *Where can IKEA help with improving people's thermal comfort experience?* on the screen, teams spent ten minutes brainstorming on blank paper based on their persona, followed by a short discussion to share how each team had framed the problem and where their ideas were heading.

The inspiration material was held back until this point, so the first round would not be pulled toward specific technologies too early. After the warm-up, a curated set of references was introduced across four categories: contemporary technologies and materials, ancestral and cultural responses, a habit-behavior model as a lens for how a product enters and stays in daily use, and four design approaches from personal devices to wall, floor, and window add-ons.

The second round ran for forty minutes. Teams worked on the template shown in Figure 9, adapted from workshop facilitation materials developed by *INDUSTRY of Us* and IKEA. The session closed with thirty minutes of pitching and cross-team discussion in a "yes, and..." mode rather than critique, so that fragments from one team could get picked up by another. By the end, twenty-six ideas had been generated, which were later used as input for clustering and identifying initial design directions.

2. Method



Gustav

33 years old I rent an Apartment (>50m²) in Sweden

Goals

- Achieve better sleep quality year-round
- Reduce morning discomfort in winter
- Find simple, affordable ways to improve comfort
- Gain more control over indoor climate

Frustrations

- Lack of control over heating system
- Fans do not solve humidity or overall heat
- Trade-offs between ventilation and noise/smells
- Comfort varies too much depending on time of day

Opportunity

- Affordable, plug-and-play climate solutions
- Devices that address both temperature and humidity
- Quiet, efficient solutions for nighttime use
- Personal comfort systems independent of building infrastructure



Figure 8: Example persona used in the workshop (Gustav).

Healthy Living | Opportunity Workshop Pack

Improving Thermal Comfort Sustainably

Idea Capture Template

Idea Name:_____

Describe the idea:

What makes this a good idea for the many people:

How does it create a healthier life for the many people:

Sketch it, or add an image(s)

Notes

INDUSTRYofUs

Figure 9: Workshop ideation template

2.3.2 Idea Development and Design Approach Mapping

In this stage, idea development and the mapping of design approaches ran in parallel, with each shaping the other as the phase progressed.

At the start, the ideas from the IKEA workshop served as the entry point for further ideation, and the framing was deliberately kept broad. The twenty-six ideas were clustered into a set of categories, which became the provisional directions for the subsequent idea development:

- Micro-space
- Windows
- Materials
- Smart/AI
- Service
- Wall & Floor
- Furniture

Idea development then happened mostly inside the design team, intertwined with work on these categories. Each new direction that surfaced from revisiting Stage 2 insights would feed back into another round of sketching, and ideas coming out of sketching would in turn suggest directions that had not yet been named, or pull attention toward the ones that looked more promising. Sketching sessions alternated between open exploration and themed rounds focused on a single direction, for example all ideas situated at the window, all ideas built around a personal device, or all ideas anchored to a specific material. Returning to Stage 2 insights from time to time, the discomfort scenarios, the activities affected, and the points of friction in the solutions people already used, kept this scatter grounded.

By the end of this phase, nineteen further ideas had been generated on top of the twenty-six from the workshop, giving forty-five ideas in total to take into the first round of selection. The seven categories above stayed loose throughout and were provisional working directions rather than a fixed structure, although certain ones, such as sleeping activity and windows, came up repeatedly in the Stage 2 insights and took up more of the design effort as the work progressed. These categories were later regrouped into a condensed set of design intervention approaches which, together with the insight themes surfaced from the Stage 1 and 2 research, form the Design Approach Matrix presented in Section 3.7.

2.3.3 Idea Selection

After continuous idea generation, forty-five ideas entered a three-round selection process, with criteria becoming progressively stricter at each round (Figure 10).

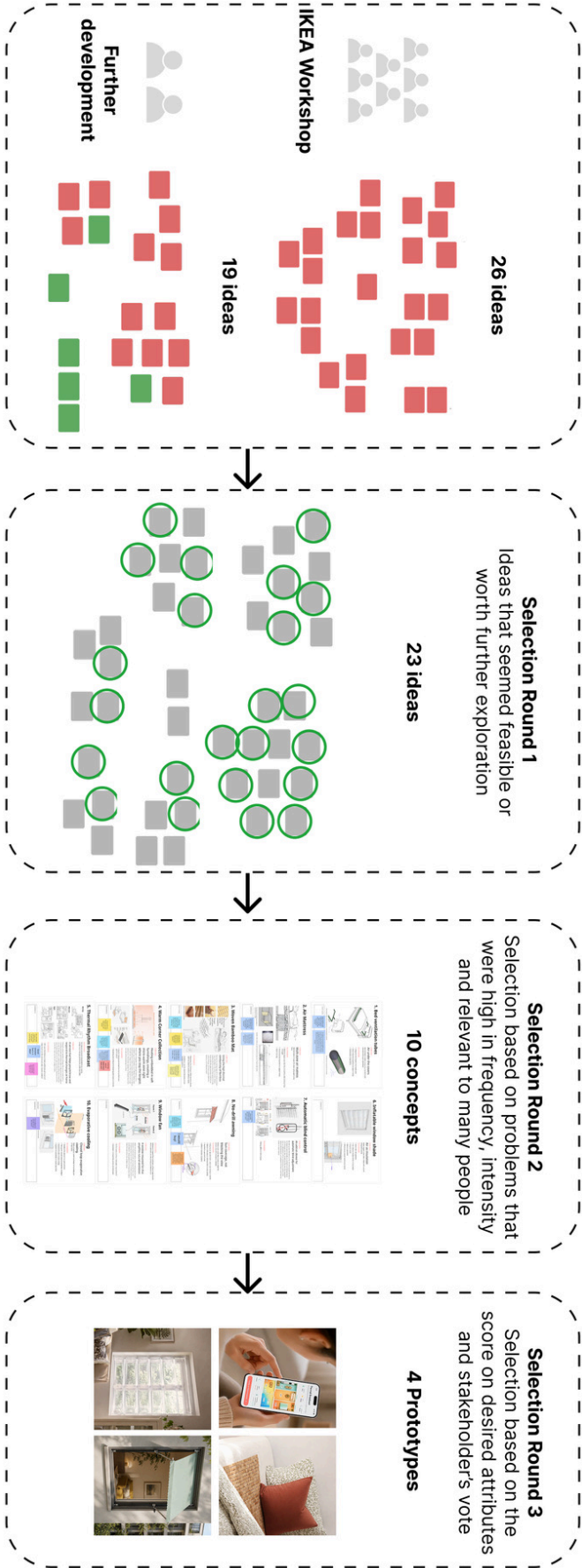


Figure 10: Three-round idea selection process.

Round 1. The first round was carried out within the design team. Ideas were kept if they seemed feasible or worth further exploration, while duplicates, clearly unworkable ideas, and weaker versions of stronger ones were removed. Forty-five ideas were narrowed down to twenty-three.

Round 2. The second round shifted the question from "does this idea work?" to "does this idea address a problem that actually matters, and matter to the many?". Before assessing the ideas themselves, the team revisited the Stage 2 research and mapped the recurring discomfort situations into a frequency table (Figure 11). For each situation we noted when it occurs, what people currently do about it, and where those current solutions fall short. Each was then rated on frequency, intensity, and relevance to the many. The twenty-three ideas were assessed against this map through discussion, with preference given to those tackling the situations that scored highest. Ten ideas were retained and developed into full concept cards.

Round 3. The third round opened the evaluation to a wider group and combined two parts: stakeholder voting and attribute scoring.

The ten concept cards were shared on a Miro board (Figure 12). Stakeholders included the workshop participants, the thesis supervisors, fellow students, and participants from the Stage 2 interviews. They were asked to go through the cards and vote for any they found valuable, with no limit on the number of votes, and to leave written comments on sticky notes.

Each idea was then scored on seven desirable attributes drawn from Stage 2: energy use, ease of installation, performance and effectivity, maintenance and attention, presence and integration, investment and cost, and flexibility of control. The rubric reflected the project's goal of sustainable and democratic design, for example, passive solutions scored highest on energy use, and solutions requiring no installation scored highest on ease of installation. The full rubric is shown in Table 2. The attribute scores were summed together with the vote counts, and four concepts were taken forward into refined design and functional prototyping. The scoring outcome and the reasoning behind the final selection are presented in Section 3.5.11.

Table 2: Scoring rubric for seven desirable attributes used in Selection Round 3.

Attribute	5	4	3	2	1
Energy use	Passive	Solar	<50 Wh	<100 Wh	>100 Wh
Ease of installation	No installation	–	Easy installation	–	Hard installation
Performance / Effectivity	Noticeable change	Improve daily activity	–	Slight / Complementary	–
Maintenance / Attention	Out of mind	–	Sparing	–	Frequent
Presence / Integration	Fully blended in	Hidden / concealed	Perceivable	–	Attention grabbing
Investment / Cost	Low	–	Mid	–	High
Flexibility & control	High	–	Mid	–	Low

Season	Situation	Current Solution	Friction	Frequency	Intensity	For the many?
Both	Sleep and work are very affected by thermal comfort for most people.	-blanket/duvet -personal heaters/ fan -AC	-its hard to fall asleep if temperature is high. -its hard to wake up when temperature is low -its hard to stand still if temperature is low. -Its hard to modulate at different times of the day	High	High	High
Summer	In summer, feels warm at home but don't have a efficient solution to choose, and AC is too high investment or expensive to use	Fan Window	If open the window for ventilation at night, it bring noise in morning influence sleeping If using the blinds in daytime, need frequently manually adjust No natural light if cover with blinds/ curtains If they have pets, they can't open window that much	High	High	Medium/ High
Winter	People have insufficient system solution, or don't have the control over that, even some lack of infrastructure, in winter always feel slightly cold, and among the time they don't have district heating, they feel more uncomfortable.	Cloth All kind of Heater Device for supplementary	-Stand alone heating devices is adding cost but people feel necessary to use, so they use it temporally -Some need to control frequently, some easier to control by app	High	Medium	Medium/ High
Both	People want more insulation on windows but don't want to block sunlight. Heat loss or gain through window material + air leaks.	-curtains -foam sealing stripes -air insulated windows	-curtains cover sunlights -air insulated windows are expensive and imposible to install for not owners. Rebuilding necessary.	High	High	Medium/ High
Both	Highly humidity at home, which feels freezing inside home, and in summer feels everything is so wet	endurance Dehumidifier(disecant beads, disecant dehumidifier, refrigerant dehumidifier)	High levels of endurance, hard to remove the humidity (specialized device)	High	High	Medium, Depend on climate region
summer	People live in the place with AC, feels comfortable, cooling in summer, but sometimes worry about cost of electricity	AC	- inefficient or old AC system - heat gain for poor insulation and leakage	Medium	Low	Medium
both	People don't think their building materials are insulating enough	-in-wall insulation -outdoor coatings -Rugs/carpet -Trees / shade	-No easy to install solutions for walls -Rebuilding necessary in many cases	medium	medium	medium
both	People have difference preference in certain activity, example in sleep they prefer colder, and wake up and shower need to be warmer, cooking need to be cooler Feel hot from cycling back home, or feel cold from just back from outside	-clothing	-Discomfort in short transition period, mostly they just endure the discomfort	Medium	Low	Medium/ High

Figure 11: Frequency table mapping recurring discomfort situations

2. Method

Thermal Comfort at Home

We've invited students at Chalmers, working in teams to help people to create thermal comfort at home in a sustainable and low-cost way.

We've developed 10 early concepts and would like your input to help us decide which ones to develop further.

How to vote?

Review the concept ideas. If needed, add comments using sticky notes.

In the last slide vote the ideas you find valuable and that you think could improve thermal comfort. There is no numbers limit.

Ideas around Furniture

1. Bed ventilation tubes

PROBLEM: Air under the covers. For people sleeping under a blanket or a quilt, it's hard to get fresh air.

SOLUTION: A tube that goes under the covers and connects to the room air. It can be used to draw in fresh air or to push out stale air.

2. Air Mattress

PROBLEM: Multi-zone air mattress. Most air mattresses are one size fits all. They are not comfortable for people with different body types.

SOLUTION: A multi-zone air mattress that can be adjusted to fit different body types. It can be used to create different levels of firmness and support.

3. Woven Bamboo Mat

PROBLEM: Using the high thermal conductivity of bamboo. Bamboo is a natural material that is very strong and durable. It can be used to create a mat that is cool to the touch and provides good support.

SOLUTION: A woven bamboo mat that can be used as a bed or a floor mat. It can be used to create a cool and comfortable sleeping surface.

4. Warm Corner Collection

PROBLEM: Heating embedded in soft furnishings, creating a micro-warm zone right where you stay the longest.

SOLUTION: A collection of warm corners that can be used to create a warm and comfortable sleeping environment. It can be used to create a warm and cozy atmosphere.

5. Thermal Rhythm Broadcast

PROBLEM: A device that helps people know and respond to thermal changes at home.

SOLUTION: A device that can broadcast thermal information to people. It can be used to create a warm and comfortable sleeping environment.

Ideas around Windows

6. Inflatable window shade

PROBLEM: Air as insulation. Inflating the window shade with air can create a layer of insulation that keeps the room warm and comfortable.

SOLUTION: An inflatable window shade that can be used to create a warm and comfortable sleeping environment. It can be used to create a warm and cozy atmosphere.

7. Automatic blind control

PROBLEM: An add-on device for automatic blind adjustment. It can be used to create a warm and comfortable sleeping environment.

SOLUTION: A device that can automatically adjust the blinds to create a warm and comfortable sleeping environment. It can be used to create a warm and cozy atmosphere.

8. No-drill awning

PROBLEM: Sun coverage, not blocking the view. A no-drill awning can be used to create a warm and comfortable sleeping environment.

SOLUTION: A no-drill awning that can be used to create a warm and comfortable sleeping environment. It can be used to create a warm and cozy atmosphere.

9. Window fan

PROBLEM: A window-mounted fan that provides natural ventilation. It can be used to create a warm and comfortable sleeping environment.

SOLUTION: A window-mounted fan that can be used to create a warm and comfortable sleeping environment. It can be used to create a warm and cozy atmosphere.

10. Evaporative cooling

PROBLEM: Closed loop evaporative cooling. It can be used to create a warm and comfortable sleeping environment.

SOLUTION: A closed loop evaporative cooling system that can be used to create a warm and comfortable sleeping environment. It can be used to create a warm and cozy atmosphere.

Vote!

Drag a dot to the ideas you like (use any color you like)

1. Bed ventilation tubes

2. Air Mattress

3. Woven Bamboo mat

4. Warm Corner Collection

5. Thermal Rhythm Broadcast

6. Inflatable window shade

7. Automatic blind control

8. No-drill awning

9. Window Fan

10. Evaporative cooling

There is something with the blinds and the window. Easy now, don't break the window! But it needs to be simple. Great job you made!

Thank you for sharing this, great examples and good luck.

2.3.4 Refined Concept & Functional Prototype

The four concepts taken forward in this phase, *Bamboo Block Mat*, *Air-Insulated Blind*, *No-Drill Awning*, and *Thermal Rhythm Broadcast*. Since each concept had a very different design problem to focus on, as well as different material and functional characteristics, the refinement of each began with a discussion of the specific questions the concept needed to deepen and validate. These questions were drawn from the evaluation comments collected during stakeholder voting, together with the team's own reading of where each concept remained under determined.

Table 3: Questions guiding the refinement of each concept.

Concept	Questions to deepen and validate
Bamboo Block Mat	• How can the block form be kept while still offering a relatively soft tactile experience? • How acceptable would this surface be to a user lying or sitting on it?
No-Drill Awning	• How can the awning be installed on a window without drilling? • How can it be detached safely during strong winds or removed in winter?
Air-Insulated Blind	• How does the inflated cover look on the window? • How can the inflated cover conform to the window frame? • Does the air layer actually contribute to insulation?
Thermal Rhythm Broadcast	• Where in everyday life does this service have meaningful application? • What form should the service take to interact with users? • Would users think this service is useful?

Once the focus of each concept had been clarified, the process moved into prototyping. The prototypes were not intended as final product solutions but as functional and exploratory artefacts, built to sufficient fidelity to communicate the concept and test its central interaction, material principle, or functional logic. Prototyping at this stage served two purposes: to develop the concepts further through the act of making, and to bring each to a level where its core function could be examined in the following evaluation phase.

Because the guiding questions differed across the four concepts, each prototype took a different form and was approached with a different method. The bamboo block mat was explored through hands-on tactile testing of physical samples. The air-insulated blind was tested for its visual effect and, informally, for its insulating effect by hand. The no-drill awning was approached through the installation and detachment mechanism. The thermal rhythm broadcast, having no physical artefact to build,

was approached through scenario analysis and an audiovisual representation of the service experience. The prototypes and what each produced are reported in Section 3.6.

2.3.5 Evaluation

The evaluation aimed to examine how the four prototype concepts performed against the desirability attributes identified earlier in the thesis, and to gather participants' qualitative reactions to each concept. The focus was on assessing the core concept, intended function, and user-perceived value of each solution, rather than judging the prototypes as final product designs.

Participants. Since the evaluation required participants to see, handle, and respond to the physical prototypes, recruitment was limited to participants available in Sweden. In total, 10 participants took part in the evaluation.

Evaluation Process. Each concept was introduced with a context image to support participants' understanding of the intended use situation. For example, the Bamboo Block Mat was presented together with an image of a warm summer night in a bedroom. Participants were then given a short explanation of the concept, its intended function, and key features, followed by the opportunity to handle the physical prototype.

After examining each prototype, participants rated the concept on a 1–5 Likert scale across seven desirability attributes: energy use, installation, performance, maintenance, presence, flexibility, and control. Initial cost was collected separately: rather than a 1–5 rating, participants were asked for a price range, from the point at which they would start considering the product to the point at which it would feel too expensive. On the evaluation form this attribute was labelled "investment" to make the question easier for participants to understand, and it appears as a price range in the results.

During the evaluation, short follow-up discussions were conducted to collect qualitative feedback. Participants were asked to explain the reasons behind their scores, for example by answering why they gave a particular rating. This helped reveal the reasoning behind the numerical results.

The four concepts were presented in a randomized order to reduce sequence effects. Each session lasted approximately 30–45 minutes.

Analysis. The quantitative results were analysed using average scores. For each concept, the mean score for each attribute was calculated across the 10 participants, and these were combined into an overall score.

Investment was analysed separately by calculating the average lower and upper price ranges given by participants, since it was collected as open numerical data rather

than 1–5 ratings. Qualitative comments were reviewed alongside the scores to explain the reasons behind participants' ratings.

3

Results

3.1 Thermal Comfort Factors

This section addresses a core question of the project: are there common factors that contribute to thermal comfort at home, and if so, what are they? Rather than treating sustainable thermal comfort solely as a matter of preventing energy demand from rising while maintaining quality of life, this stage breaks down how thermal comfort expectations are defined in everyday life and experienced in everyday home routines, looking for the opportunity space where design can contribute meaningfully to the lives of many.

The synthesis described in Section 2.1.3 produced a framework of four interconnected groups of factors that together shape the experience of thermal comfort at home: *Personal*, *Environmental*, *Contextual*, and *Expressions*. The complete framework is presented in Figure 13, and the following sections describe each group in turn, drawing on the literature scan (Section 2.1.1) and the exploratory survey (Section 2.1.2). The full set of insight cards underlying these descriptions is provided in Appendix B.

3.1.1 Personal factors

Personal factors describe the individual attributes a person carries into any thermal situation. These do not change moment to moment with the home environment, but they shape how every other factor is experienced. Five sub-factors were identified: biologic, economic, cognition, sensation, and knowledge.

Biologic. Conventional thermal comfort theory identifies a stable set of biological determinants: age, sex, body composition, health, and metabolic rate (Arowoiya et al., 2024; Ortiz et al., 2017). These attributes change slowly and are largely outside the reach of design, but they could partially explain why two people in the same room can disagree about whether it feels comfortable.

Economic. Cost shapes both what comfort people can actually achieve at home and what they consider acceptable as “comfortable enough”. In the survey, cost was the second most frequently named barrier to improving home comfort (35.1%), after limited control. At the same time, the literature points to a significant willingness-to-pay for indoor comfort, with thermal comfort accounting for roughly half of that value (Berto et al., 2023). The two findings together describe a tension: people

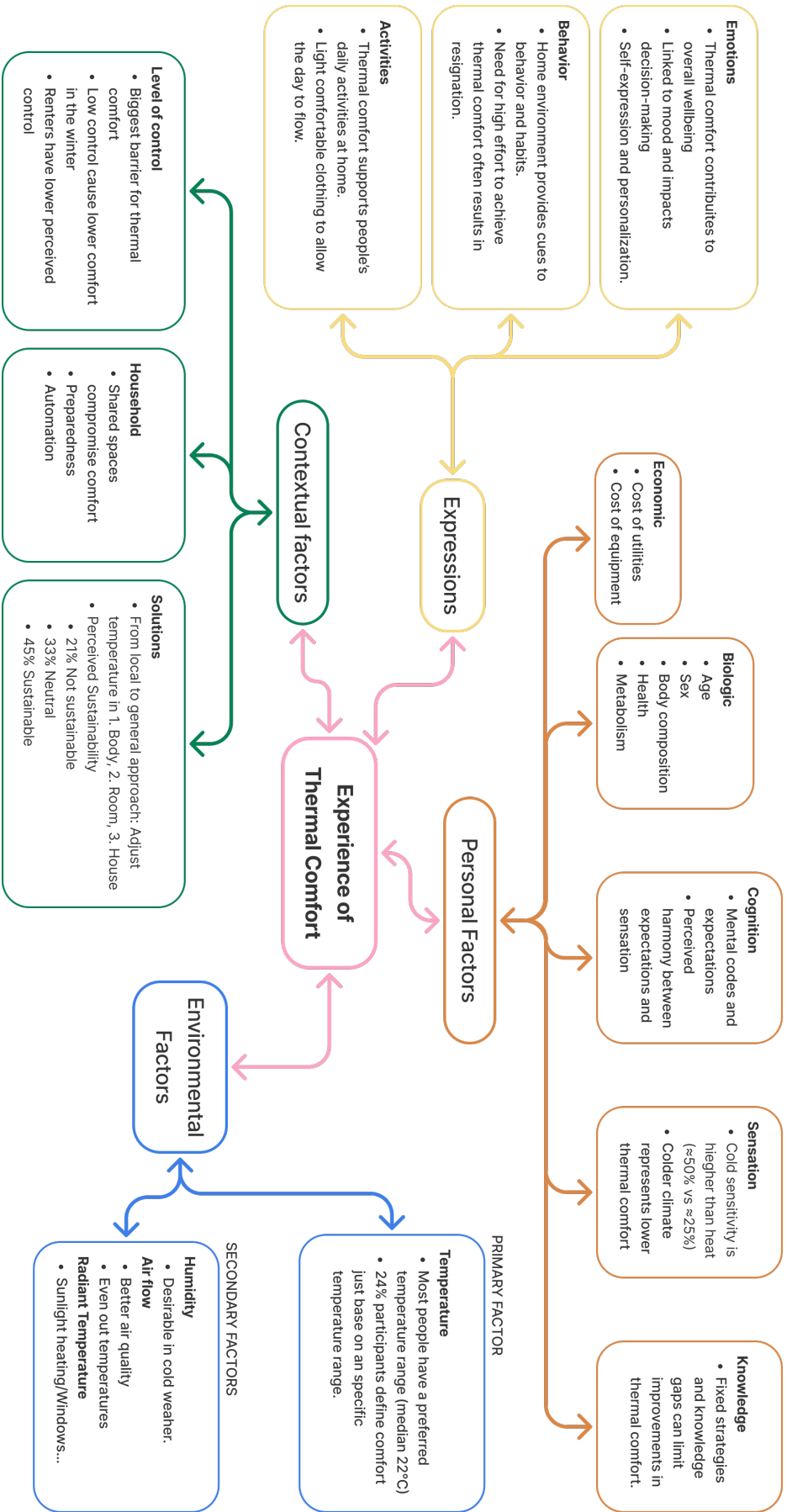


Figure 13: Thermal Comfort Factors Framework

experience cost as a real constraint in everyday decisions, yet are willing to pay substantially for thermal comfort when given the choice.

Cognition. Comfort has long been described as a holistic state, “a pleasant state of physiological, psychological and physical harmony between a human being and its environment” (Ortiz et al., 2017). The cognitive layer of this definition matters here: thermal comfort is not a direct readout of room temperature but is mediated by mental codes, schemas, and prior expectations (Omoya et al., 2026). People interpret what they feel through past experience and seasonal memory, and the sense of harmony between what they expect and what they sense is part of what comfort means in the first place. The survey reinforced one specific aspect of this. Respondents repeatedly described thermal comfort as something that should remain in the background, an “invisible” condition they do not have to actively think about. When people have to notice the temperature, comfort has already been lost.

Sensation. Sensation defines the individual spectrum of what feels comfortable. Survey Q1 showed that preferences vary widely, with some respondents preferring cooler conditions and others warmer ones. Across this variation, however, a common asymmetry emerges in the data: more than half of respondents (54.6%) reported feeling colder than the people around them, while only 24.4% reported feeling warmer. The same asymmetry was visible at the seasonal scale, with winter comfort rated lower (46.2% high) than summer comfort (52.9% high). Together these patterns suggest that cold sensations are both more common and harder to resolve than warm ones in domestic settings.

Knowledge. Knowledge of how heating, ventilation, and cooling systems work shapes whether people can act on discomfort or accept it as given. Studies of occupant behaviour have shown that misunderstanding of thermostatic radiator valves leads to overheating in households (Frontczak et al., 2012), with knowledge confidence varying considerably across countries. The survey extended this picture: 13.2% of respondents named “not knowing what to do” as a barrier to improving thermal comfort, echoing a related finding in the literature that more than half of occupants do not actively seek information about their indoor climate unless a problem becomes serious enough to act on (Frontczak et al., 2012). Without clear knowledge, people may continue using fixed, inherited strategies, limiting their ability to improve comfort over time.

3.1.2 Environmental factors

Environmental factors describe the physical conditions of the home at a given moment, the conditions that most directly cause comfort or discomfort to be felt. The framework distinguishes one *primary factor*, temperature, from three *secondary factors*, humidity, air flow, and radiant temperature. The distinction reflects how strongly each one drove comfort responses across the data: temperature consistently emerged as the dominant variable, while the others act as modulating conditions

that shape how a given temperature is experienced.

Temperature (primary). Temperature is the most frequently mentioned environmental factor across both the literature and the survey, and is treated in the literature as the central variable in conventional thermal comfort models alongside humidity, air velocity, and mean radiant temperature (Arowoia et al., 2024; Liu et al., 2023). The survey confirmed that temperature is also how people themselves define comfort: 24% of respondents identified staying within a specific temperature range as their definition of being comfortable. The exact range and tolerance, however, varied considerably between individuals, with the median preferred indoor temperature settling around 22°C. Temperature is therefore both the most consistently named factor and one whose acceptable values are personal rather than universal.

Humidity (secondary). Humidity influences how a given temperature feels, but its role is uneven across seasons. Survey responses indicated that higher humidity levels are seen as more desirable in cold weather, where dry indoor air during the heating season is associated with discomfort. In warm conditions, by contrast, humidity is more often described as a source of discomfort than a remedy. Humidity therefore acts as a seasonal modulator of thermal comfort rather than a constant factor.

Air flow (secondary). Air flow contributes to thermal comfort by helping even out temperatures across rooms and by supporting a sense of freshness in the home. In the survey, the perceived value of air movement was closely tied to ventilation: respondents valued the ability to open windows highly, both as a way to refresh the indoor air and to reduce uneven warming between spaces. The literature similarly identifies natural ventilation as a feature people actively want to preserve in their homes (Frontczak et al., 2012).

Radiant temperature (secondary). Radiant temperature shapes how warm or cool a space feels independently of the air temperature, and is largely driven by the surface temperatures of walls, floors, and furniture, as well as by sunlight and window glazing. In modern buildings with large glazed facades, radiant temperature is often dominated by the windows themselves, which can introduce significant warming in summer or cooling in winter regardless of how the heating system is set.

3.1.3 Contextual factors

Contextual factors describe the situations and constraints at home that shape what people are actually able to do about it. Unlike personal or environmental factors, these are not properties of the individual or the room itself, but of the wider conditions surrounding them: who shares the space, who controls the system, and what means are available for adjustment. Three sub-factors were identified: level of control, household, and solutions.

Level of control. Perceived control over the indoor environment has long been identified in the literature as a key aspect of thermal comfort. Feeling able to adjust heating, open a window, or manage privacy reduces stress and increases comfort, independently of the physical conditions in the room (Ortiz et al., 2017). Building on this, the survey was designed to test how strongly control would surface in everyday domestic experience, and the result was clear: limited control was the most frequently named barrier to improving thermal comfort (50.9%), ahead of cost and all other reasons. Controllability is also unevenly distributed. Cross-comparison of the survey data showed that renters report substantially lower perceived control than owners, and that the relevance of control is itself seasonal, mattering more for winter comfort than for summer comfort. Apartment dwellers similarly lack control over building-level conditions such as orientation, shading, and ventilation systems (Ekdahl, 2025), leaving many adjustments outside their reach regardless of preference.

Household. Comfort at home is rarely a solo experience. When a space is shared, comfort can begin to feel like a finite resource: when one person gets more, someone else gets less, and adjustments that suit one occupant may worsen conditions for another. Beyond this scarcity dynamic, household composition shapes who acts on the environment in the first place. Earlier studies have observed, for example, that window-opening behaviour is more frequent in families with someone at home during the day, and that it increases with family size (Frontczak et al., 2012). Comfort behaviours, in other words, are negotiated rather than chosen individually.

Solutions. If level of control sets the boundaries of what people are able to do, solutions are the means through which they actually act, making this arguably the most consequential contextual factor in shaping how adjustments are made. The survey revealed a clear preference in how adjustments are made: respondents first adjust their own body (54.6%), then a specific room (29.4%), and only last the whole home (12.6%). Clothing is the primary body-level adjustment, with 73.7% adding clothing in cold conditions and 54.1% modifying or removing clothing when too warm. Beyond the body, devices such as fans, radiators, and air conditioners are widely used, though both their availability and the social acceptability of using them vary. Air conditioning, for instance, is often experienced as a desirable solution but can crowd out lower-energy practices such as natural ventilation (Kuijer, 2022). When asked about the sustainability of their current solutions, 44.9% of respondents rated them as highly sustainable (4–5), 33.9% as neutral, and 21.2% as low (1–2), indicating that low ratings are a minority view but are not negligible. The pattern that emerges is one of layered, primarily local solutions, with the body as the first and most accessible point of intervention.

3.1.4 Expressions

Expressions describe the outward manifestations of comfort and discomfort that arise from the interaction of personal, environmental, and contextual factors. Unlike the previous three groups, which can be more thought of as inputs to the daily comfort process, expressions are how comfort or its absence becomes visible, both to the person experiencing it and to those around them. They also feed back into the system: a felt expression often triggers an adjustment to the environment or to behaviour, closing the loop between sensing and acting. Three sub-factors were categorized: emotions, behaviour, and activities.

Emotions. Thermal comfort and emotional state are tightly coupled. The literature describes comfort as part of a broader state of wellbeing, expressed through relief, ease, and a sense of harmony with one’s environment (Ortiz et al., 2017), and the survey reinforced this in concrete terms: respondents consistently associated thermal comfort with a calm and stable mood. The reverse was equally evident, with 63.0% reporting that feeling too warm at home had a high impact on their mood and 50.8% reporting the same for feeling too cold. Thermal discomfort, in other words, does not stay confined to the body but reliably spills over into emotional state. Beyond mood, comfort also carries an expressive dimension. Small everyday acts, such as opening a window, can be read as ways of caring for the home and connecting with the outside world (Frontczak et al., 2012), suggesting that comfort is not only felt but actively made. This emotional weight is also what motivates adjustment in the first place: feeling emotions enables decision-making and shapes the behaviours that follow (Ortiz et al., 2017), linking this sub-factor directly to the next.

Behaviour. The home environment provides cues that shape thermal behaviour, often automatically and outside conscious deliberation. Layouts, furniture, visual design, and the placement of controls all influence which adjustments people reach for and which they overlook (Ortiz et al., 2017). Because energy use is largely invisible in everyday life, the habits that form around heating and cooling are difficult to change once established (Ortiz et al., 2017). A second pattern, also drawn from the literature, is that comfort takes effort, and when that effort feels disproportionate to the result, people stop trying. Resignation, rather than active adaptation, becomes the default. The survey echoed this in its findings on barriers and on the limited use of devices for active temperature control: even when discomfort was present, many respondents relied on minor body-level adjustments rather than engaging with the systems available to them. Behaviour at home is therefore shaped less by what is technically possible than by what is habitual, low-effort, and cued by the surrounding environment.

Activities. Thermal comfort matters because it supports the activities of daily life: sleep, relaxation, working from home, eating, hosting, and the small transitions between them. The survey made this link explicit, with respondents describing thermal comfort as something that supports daily activities at home and contributes to feeling “just right” across these moments. The activities most vulnerable to thermal

discomfort are also visible in the data: discomfort is most commonly reported when waking up or getting out of bed (46.5%), followed by sitting still (35.1%), showering or after shower (28.1%), sleeping (23.7%), and doing housework (18.4%). Clothing, in addition to functioning as a body-level solution, also carries symbolic weight in this group: 32% of respondents associated comfort with the freedom to wear lighter clothing at home, suggesting that what people wear is read as a sign of how comfortable they actually feel. Activities, in this sense, are both the reason comfort is sought and the surface on which its presence or absence is most directly observed.

3.1.5 Focus Aspects for Design

Looking into the resulting framework from Stage 1, the selected routes to take research effort towards were *Contextual factors* and *Expressions*. The reasoning for this selection rests on one criteria: an aspect should be open to design influence.

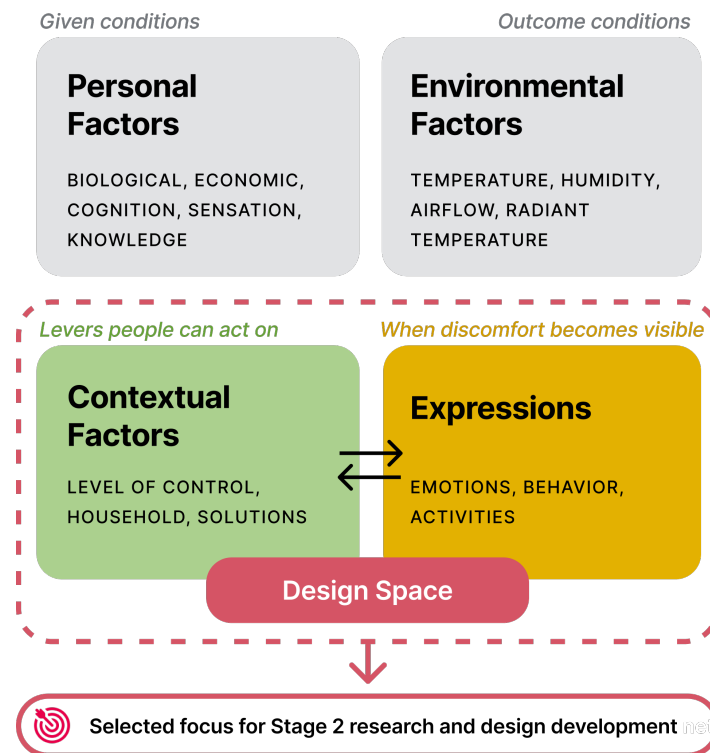


Figure 14: Design space within the thermal comfort factors framework

A clear separation showed when we looked across the four groups (Figure 14). *Personal factors* and *Environmental factors* are largely given conditions. Biology, cognition, and individual sensation change slowly and sit outside the reach of product design; temperature, humidity, air movement and the rest of the physical conditions are outcome conditions rather than direct points of design intervention. They are largely shaped by existing building systems, the building envelope, infrastructure, and the conventional solutions available within them.

Contextual factors and *Expressions*, by contrast, are closely connected to everyday practice. Contextual factors are the levers people can actually reach for, the thermostat or radiator valve they can adjust, the negotiations with others in the household, the blankets, fans, and clothing layers at hand. Expressions are what surfaces once those levers are pulled, the emotions, behaviours, and activities through which comfort becomes visible, either as the comfort people pursue or as discomfort that triggers further adjustment. The relationship between the two runs in both directions. Discomfort sends people toward the levers at hand, and the levers at hand shape which discomforts get addressed and which settle into everyday patterns. Product design works inside this exchange.

The opportunity space where design could contribute meaningfully to the lives of many was therefore identified in these two groups. Together, *Contextual factors* and *Expressions* defined the scope of the deeper user research in Stage 2 and informed the design work that followed.

3.2 Current Everyday Thermal Experience

The digital ethnography study proved very influential in shaping how conventional solutions for thermal comfort were understood throughout the project. Beyond offering an initial understanding of how people navigate heating and cooling in their homes, it helped anchor and focus our interview design by revealing the language, concerns, and solution-seeking behaviors people express online. The insights gathered contributed to identifying thermal comfort as an active process. Some observations like the influence of nature, sunlight, and airflow confirmed our previous knowledge that the subject goes beyond air temperature alone. Different takes around the psychological, social and environmental factors surrounding thermal comfort were repeatedly mentioned in the online sources, helping understand these themes from an holistic perspective.

As we will describe in detail in the following sections, the semi-structures interviews showed that many people rely on adaptable, layered strategies, while others prefer a “one fit-all” solution. Geographical location and culture largely shape the immediate solutions people are using today; this echoes our findings in Section 3.1.1 that refers to *Personal Factors* for thermal comfort. Another recurrent conversation in the interviews was how much or how little participants were willing to withstand. Our conclusion is that thermal comfort at home is, in many cases, less about controlling the whole indoor climate and more about helping people stay comfortable in specific everyday moments with simple and flexible solutions. The full quantitative data collected during the interviews can be found in Appendix E.

3.2.1 Observed trends and profiles

The 13 charts representing each participant's directed storytelling about their experiences, challenges, and strategies for thermal comfort were analyzed and compared to each other. As a result, participants were sorted into three groups based on similarities in the patterns observed in their experiences.

Group 1. Four of our participants fall into Group One: participants 1, 8, 11, and 13 (Figure 15). They live in climates where summer averages range from 20°C–24°C, with rare occasions exceeding 30°C. However, in the winter, three out of four participants experience sub-zero temperatures most of the time, with short cold waves reaching –15°C or lower. The remaining participant sits in a still cold but more temperate climate, reaching 10°C–12°C during the day, 2°C–3°C at night, and on rare occasions dropping below zero.

Their summer experience is characterized by consistent mild discomfort. When averaging their experience scores throughout a hot day, they range from 2.6 to 2.9 on a 1 to 5 scale. The evening and night are reported as the most uncomfortable times of the day, with falling asleep and sleeping as one of the main challenges. This group does not seek solutions to lessen their discomfort; some report using a fan sometimes or going outside in the afternoon. They note that their discomfort is not big enough to do something about it; they actively choose to endure it.

In winter, the group experience shows a more dynamic trend, with the cold early morning reported as a big deterrent to getting out of a warm bed, and comfort increasing as the day gets warmer. They are more equipped to face the cold weather: they all use built-in heating systems (heat pump, radiator, geothermal floor heating), and some even complement them with an electric space heater. It is relevant to point out that there is a dip in our group chart score around noon caused by the participant who sits in the less cold weather, where they report not using their heating system until they are forced by discomfort, usually after sitting still working from home for a couple of hours in the morning.

Group 2. Conformed by participants 2, 5, 6, and 7 (Figure 16). They all live in extremely hot weather in North America. Their thermal comfort at home is characterized by the usage of air-conditioning systems around the clock, both for cooling and heating. Throughout the seasons, their thermal comfort experience does not change a lot.

In summer, most participants in this group report slight discomfort (score 4) on the hottest days even if the AC is running non-stop. Another source of slight discomfort is the fact that they are not able to open windows, either because the AC is running or because heat and humidity outside are far too high; they manage this lack of airflow with ceiling fans.

During winter, participants report a high level of comfort. Participants 5 and 7 experience a dip in their comfort levels in the early morning that makes them struggle to get out of bed. Participant 7 shows the lowest comfort levels out of the group; they use a portable gas heater with a tank as a complementary solution to keep their spaces warm.

When asked about their concerns around energy use, they all said that the extreme

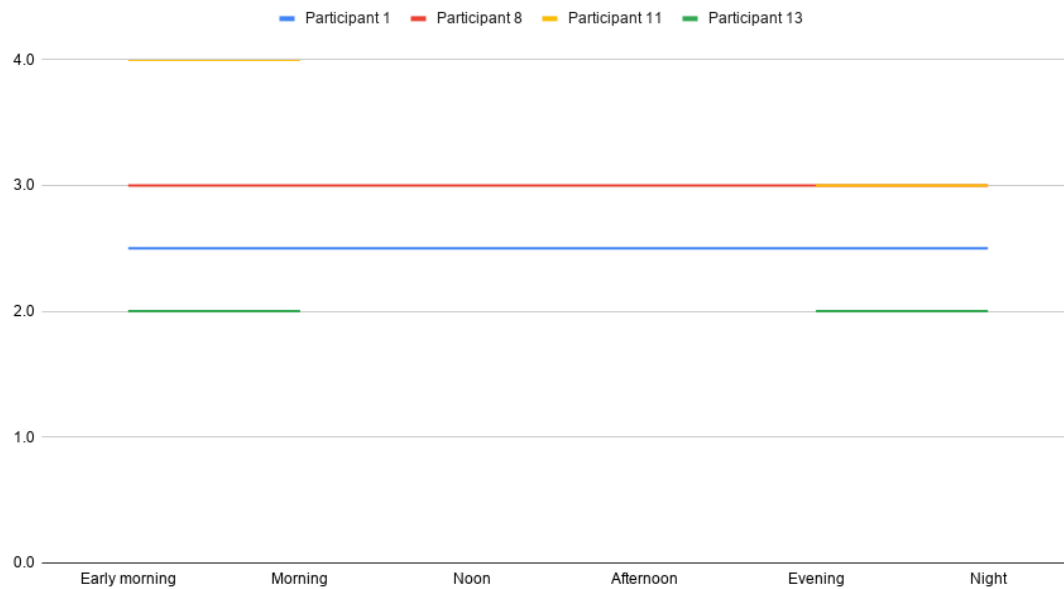
climate renders the usage of air-conditioning systems a basic need. They have become accustomed to the economic burden, or in the case of participant 7, have a solar system installed with the purpose of offsetting that cost long term. Additionally, participants 2, 5, and 6 moved into homes with a central AC unit installed, so they have never considered other options.

Group 3. Participants 3, 4, 9, 10, and 12 gather into Group Three (Figure 17). All participants in this group lived in Sweden at the time of the interview, and all but one come from an international background. Their experience chart shows a highly dynamic nature across seasons. They seem to be the ones most exposed to climate changes throughout the day, and they actively seek and adjust solutions as their comfort level fluctuates.

In summer, the least comfortable times of day are the afternoon and evening, with scores of 3.3 and 3.2, respectively, on a scale of 1 to 5. They manage discomfort by interacting with a combination of solutions ranging from opening windows to let air in, closing blinds and curtains to block the sun, using an electric fan, taking a shower, and having cold drinks or ice cream.

Their winter experience chart shows many similarities with group one's. They all rely on built-in systems that keep their homes warm effectively; however, they tend to be slow-response systems, so they can experience peaks of discomfort when the weather changes drastically. This group is mostly composed of people living in apartments, which affects their control over said built-in systems. They recur to complementary solutions like space heaters, fireplaces, and passive methods such as blankets, robes, hot drinks, and hot showers.

Summer Experience Chart Group 1



Winter Experience Chart Group 1

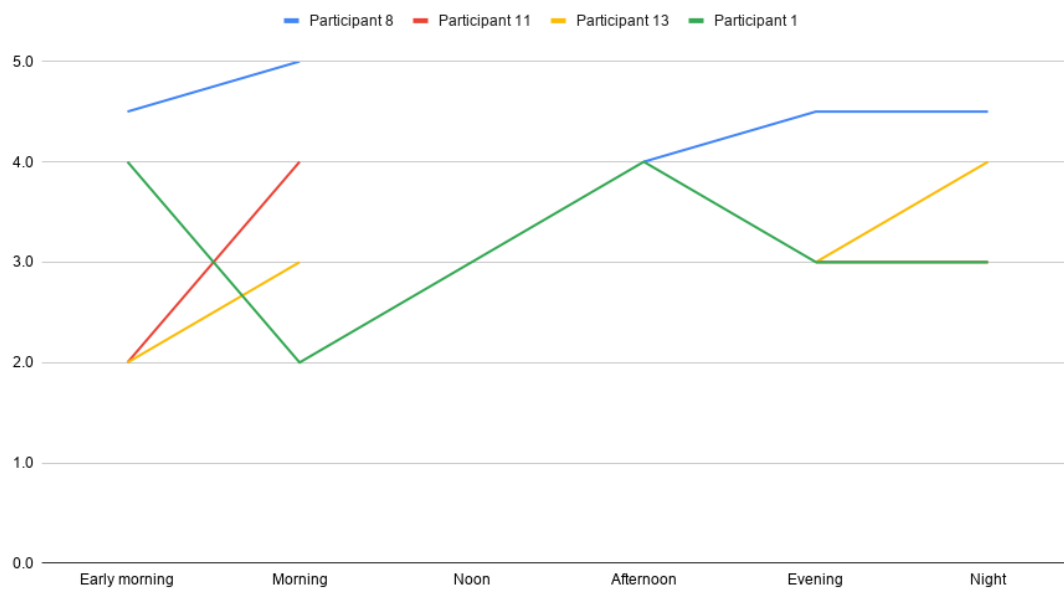
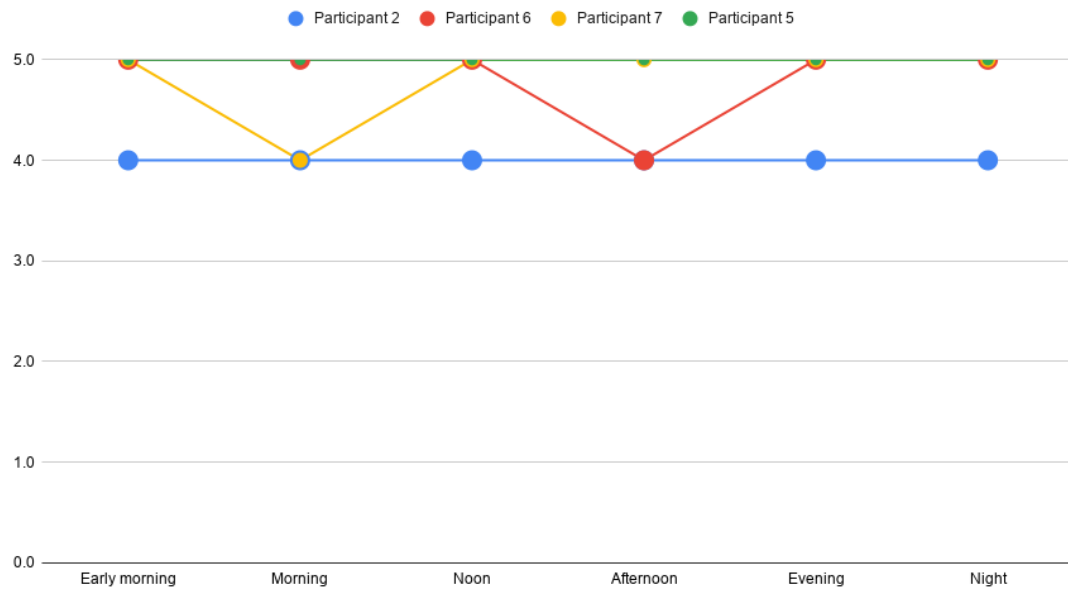


Figure 15: Group 1 - Thermal Comfort experience chart. Top: Summer. Bottom: Winter.

3. Results

Summer Experience Chart Group 2



Winter Experience Chart Group 2

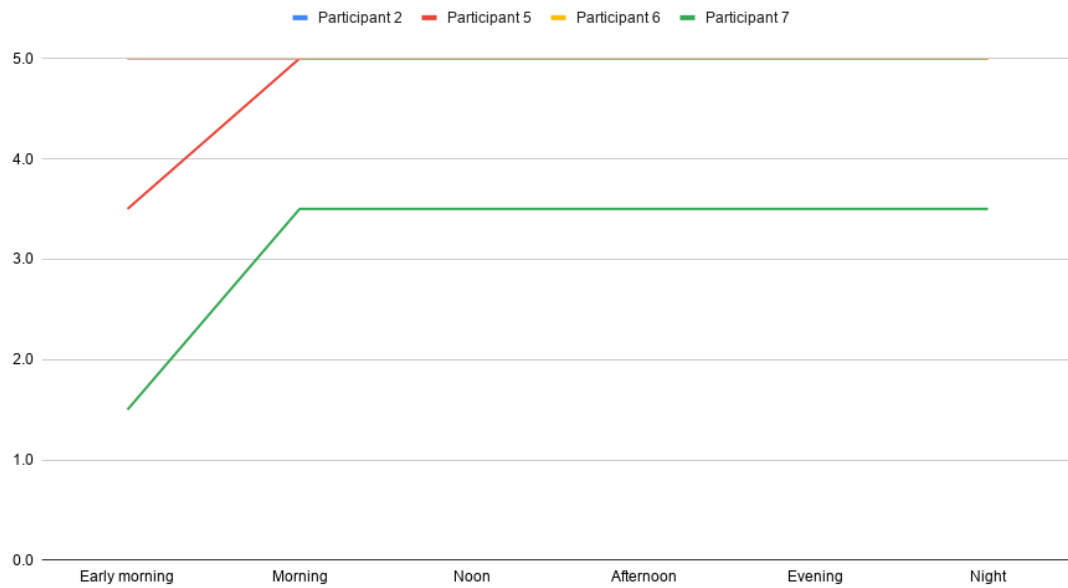
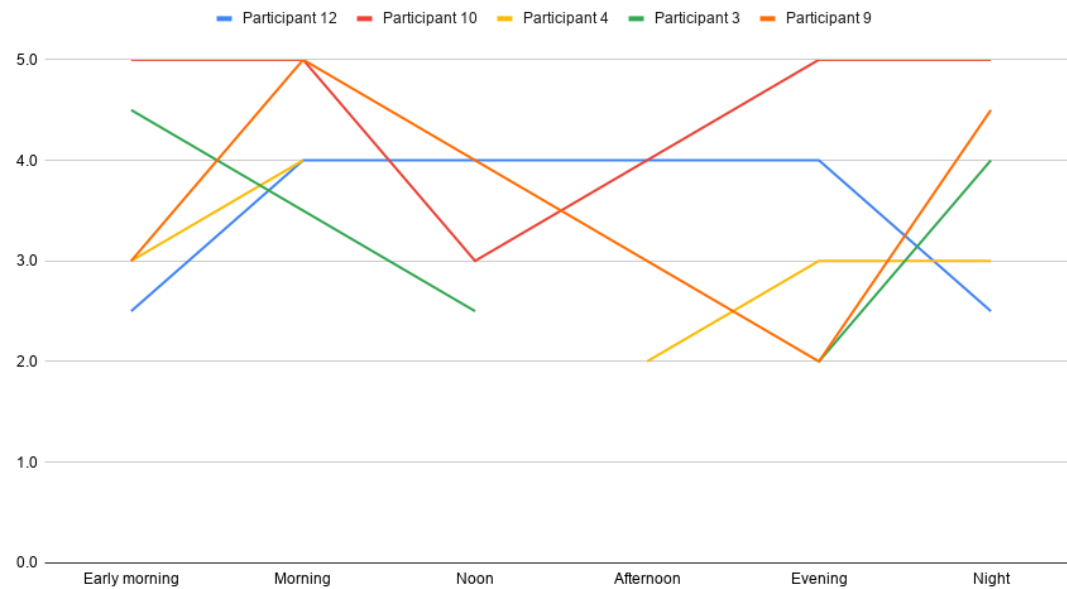


Figure 16: Group 2 - Thermal Comfort experience chart. Top: Summer. Bottom: Winter.

Summer Experience Chart Group 3



Winter Experience Chart Group 3

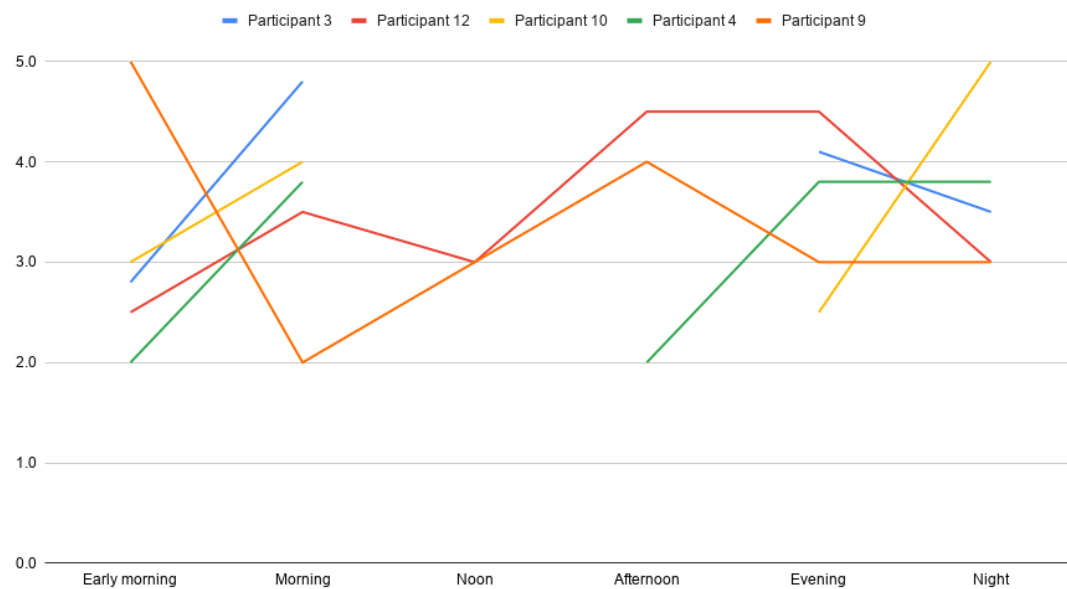


Figure 17: Group 3 - Thermal Comfort experience chart. Top: Summer. Bottom: Winter.

Together, these three groups show how differently people experience and manage thermal comfort in their everyday lives. Climate and culture shape the solutions people reach for first. Across all groups, we also see clear differences in endurance and tolerance: some participants actively adjust their environment throughout the day, while others prefer to withstand discomfort until it becomes unavoidable. These patterns highlight that thermal comfort is not a uniform experience but a dynamic interaction between personal habits, home characteristics, and environmental conditions. Figure 18 summarizes the overall trends across participants.

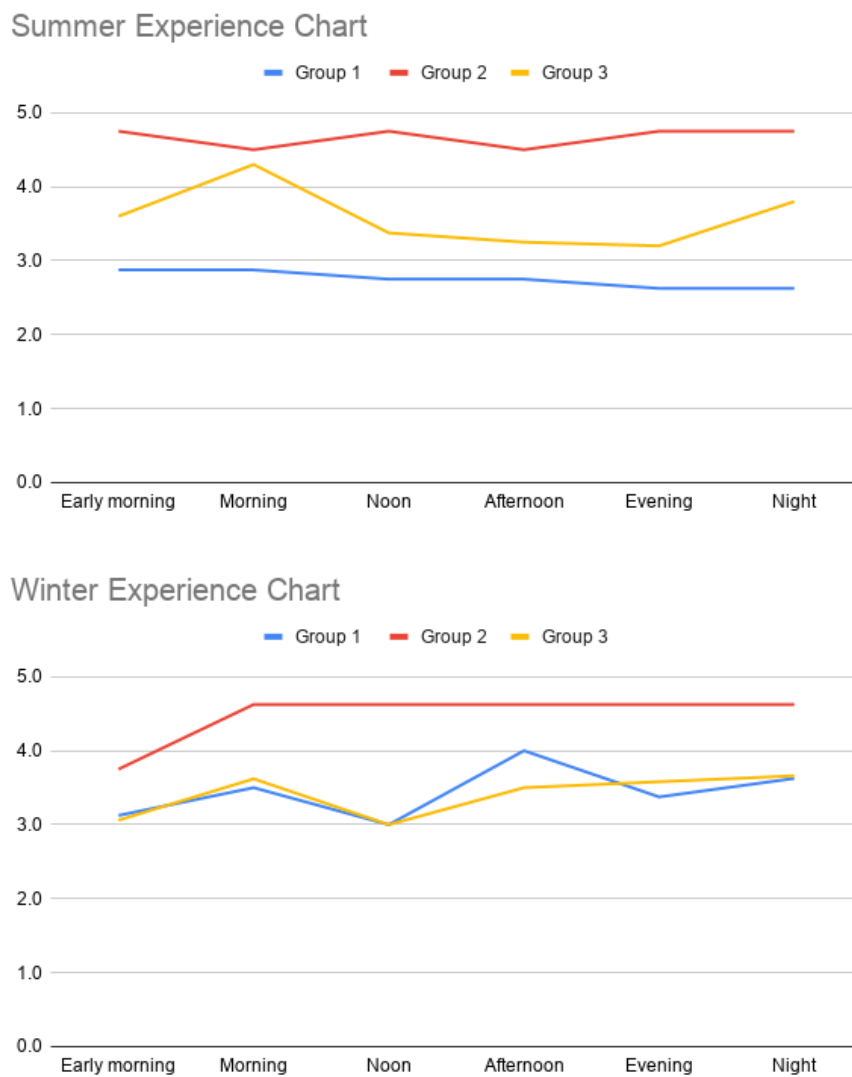


Figure 18: Overall Thermal Comfort experience chart. Top: Summer. Bottom: Winter.

3.2.2 Conventional solutions

The interviews revealed that conventional solutions, both energy and non-energy based, play an important role in the way people manage thermal comfort today.

All participants reported the use of solutions in combinations instead on relaying a single one, even participants in group 2 reported complementary use of fans in the summer and space heater or fuzzy blankets in the winter.

ENERGY RELIANT SOLUTIONS.

All interviewees participants narrate using solutions that rely on energy use at least in the most extreme weather periods of the year. These solutions are use alone or in tandem to improve thermal comfort.

Radiators

Radiators were the most common heating system among participants in Sweden, they were described as reliable but slow to respond to rapid changes in temperature. Radiator energy sources vary depending on the building or the city area; many are supplied by district heating, other by independent building systems. in many cases, the system is automatically controlled by landlord policy.

Air conditioners

Another widely used solution are air conditioning systems or heat pumps. These systems can be highly efficient and reliable. They play a central role in hotter climates, where they are use continuously throughout the year both for cooling and heating. Although most modern systems can be highly efficient, they still are an energy heavy solution and considering the usage of refrigeration gases that damage the atmosphere, the fact that many people have old models still in use, and the heat transfer cycle, they are far from being a overall sustainable solution. Participants in Sweden expressed an explicit reluctance to these kind of system, listing as reasons their appearance, noise, environmental impact and a dislike for forced air systems and drafts.

Floor Systems

One of the participants used a geothermal floor heating system. They reported their choice to be influenced by them needing to retrofit a antique house in the least invasive way. They described the system as having enough levels of control but slow to respond, being able to modify their preferences by room, but having to wait a couple of days for the system to stabilize. They considered the initial investment as high, but worth it long term.

Space Heaters (electric and gas)

Space heaters are used in many cases as complementary, targeted solutions. For example, in centrally controlled buildings, some participants report having them close in the coldest times of the day or when sitting still for long periods of time. From the digital Ethnography study, we learned that in hotter climates they are used as the main heat source in the winter and that electrical heaters are considered to be 100% efficient, meaning all the energy they consume is directly translated into heat. However, this does not mean they are not energy heavy solutions. On the other hand, gas space heaters can be both portable or stationary, and they typically generate heat through direct combustion of fuels such as natural gas, propane, or

butane. While this can make them effective in providing rapid and high-output heating, their overall efficiency depends on how and where the heat is used, since part of the energy is lost through combustion by-products and ventilation requirements. Unlike electric heaters, they introduce considerations related to indoor air quality, including the need for proper ventilation to avoid the accumulation of carbon monoxide and excess moisture. As a result, although they are often perceived as cost-effective in terms of fuel price and heating capacity, they come with additional safety and environmental trade-offs that influence their suitability across different indoor contexts and usage patterns.

Wood burning

Similar to gas heaters, fireplaces and wood-burning stoves can cause air-quality issues if used for prolonged periods, due to the release of particulate matter and other combustion by-products that can accumulate indoors. At the same time, they are often associated with a strong sense of coziness and atmosphere, shaped by the visual presence of flames, radiant heat, and the sensory experience of crackling fire. The fuel source is typically organic, such as wood logs or pellets, which can be locally sourced and perceived as low-cost or even self-supplied in some contexts. However, this apparent affordability and comfort comes with trade-offs in terms of maintenance, efficiency variability, and the need for proper ventilation and flue systems to ensure safe operation.

Fan

Fans are commonly found in most households. Participants reported using them close to windows. Fans exist in a myriad of form factors and price points. They usually don't need a lot of energy and can be reliable and durable. Our participants reported their use as a low-effort way to improve airflow or supplement other systems.

NON-ENERGY SOLUTIONS.

Window

Windows influence indoor temperature in many ways. Orientation, amount of windows, size, material, and construction are some of the variables that determine their impact.

Opening windows was one of the most common non-energy strategies across participants, used both to release accumulated heat and to create airflow between rooms. Many interviewees described it as their first instinctive action when feeling too warm, especially in the afternoon or evening during summer. However, the practice came with several constraints. Participants living in urban areas mentioned noise, insects, and light pollution as reasons to avoid keeping windows open at night, while others noted that pets could escape. In some climates, outdoor air quality or humidity made window ventilation ineffective or uncomfortable. Despite these limitations, window-based ventilation remains a widely used and highly accessible method for moment-to-moment comfort adjustments.

Curtains and blinds

Curtains and blinds were frequently used as passive tools to manage indoor temperature, particularly in homes with strong sunlight exposure. Participants reported closing blinds or curtains during the warmest hours of the day to block direct sunlight and reduce overheating, especially in small apartments where solar gain quickly raised indoor temperatures. In winter, some participants used thick curtains as an additional insulating layer to reduce drafts or retain warmth during the night. Some people also keep them open if the sun is out in an attempt to capture some of the sun radiation. While these solutions require no energy and are easy to integrate into daily routines, their effectiveness depends heavily on window orientation, materials, building insulation, and the timing of use. Still, they were consistently described as simple, low-effort strategies that help maintain a more stable indoor environment.

Clothing

Clothing adjustments emerged as one of the most immediate and personal ways participants managed thermal comfort throughout the day. Many described layering as an essential winter strategy, adding sweaters, robes, or thermal pants during cold mornings or when sitting still for long periods. In contrast, summer clothing choices tended to prioritize breathability and minimal coverage. Overall, clothing functions as a flexible, body-level adjustment that allowed participants to respond quickly to changing comfort needs without altering the entire indoor environment.

3.2.2.1 Assessment of conventional solutions

Based on our conversations with the interviews participants, a list of desirability attributes (see Figure 19) was put together to reflect people's expectations and wishes when choosing either solution. These attributes were used to evaluate a group of conventional solutions through the use of a weighted matrix. The specific weight given to each attribute was assigned based on their impact in user experience. The full detail of the weighted matrix can be found in Appendix F.

Our final results are shown in Figure 20. At a glance, it becomes evident that all solutions scored a similar rating. This shows that all solutions come with a set of tradeoffs that make them more or less ideal depending on user priorities and preferences.

Additionally, these attributes were further matured and used as a foundation for the creative process of this project, Section 3.4 Desirable Attributes expands on this matter.

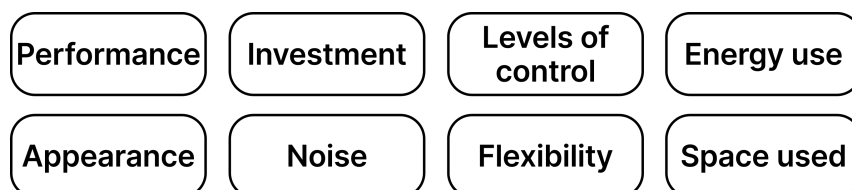


Figure 19: Desirable Attributes

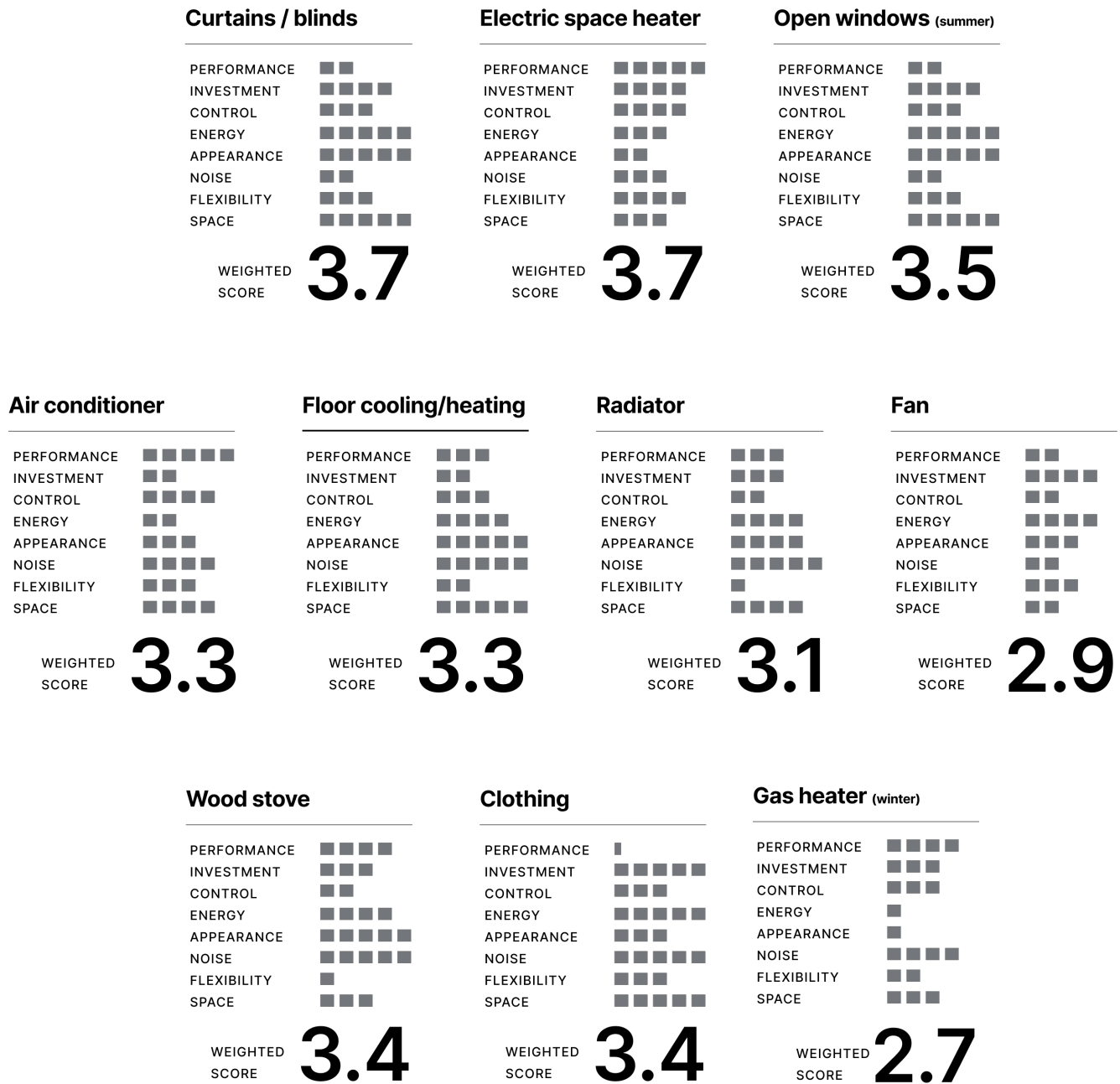


Figure 20: Conventional Solutions assessment

3.2.3 Activities and clothing

All participants were asked to list the three main activities from their daily life where thermal comfort is regarded as paramount. Table 4 shows all the activities mentioned their priority level (#1, #2, or #3) and the sum of all mentions. Sleeping and Working stand out by being mentioned by most of our participants, many times as their first or second priority.

Clothing influences and is influenced by thermal comfort. After the prioritization activity, participants were asked about the clothes they usually associate with comfort

when performing their mentioned activities.

Activities		Overall count	#1	#2	#3
Sleeping	23.81%	10	6	3	1
Working/Focus	21.43%	10	5	3	2
Cooking	9.30%	4	3	0	1
Working out	9.52%	4	0	2	2
Socializing	9.52%	4	0	1	3
Cleaning	4.76%	2	0	1	1
Getting dress	4.76%	2	0	1	1
Shower	2.38%	1	0	1	0

Table 4: Thermal comfort prioritization on daily activities

Sleep. Sleep quality impacts most aspects of people’s lives, so it is not surprising that it is the activity most often mentioned as the number-one priority by our participants. Transition moments seem to be regarded as the most dependent on ideal thermal comfort levels, i.e., falling asleep or getting out of bed. Interestingly, clothing was rarely used as an adaptation during sleep in winter; instead, participants preferred managing thermal comfort through bedding materials or localized temperature-adjusting solutions.

Working and Focus During focused activities such as working or studying, maintaining comfort directly impacts people’s ability to concentrate and be productive. In winter, staying still can increase cold sensitivity, leading people to seek adaptations to get warm, such as adding clothing layers, covering themselves with a blanket, or using a space heater. In contrast, hot weather can be harder to handle, with many people preferring to leave the house and go to a café, library, or office if they do not have systems to modify the temperature at home. Some participants who worked from home occasionally said they maintained a presentable outfit and focused on wearing breathable materials instead of removing as much clothing as possible.

Other activities Although less frequently mentioned, cooking, working out, socializing, cleaning, getting dressed, and showering were still listed among the three most important activities for several participants. Cooking or baking was appreciated during cold weather because it helped increase indoor temperature; however, on hot days people needed to open windows or use fans to compensate. Exercising increases body heat, which becomes a challenge during the summer season; moving to cooler rooms, increasing ventilation, and wearing light clothing were some of the strategies used. When more people are present in a room, temperature and air quality can be affected, so during socializing participants often increased ventilation through windows, fans, or AC systems. Cleaning, showering, and getting dressed, in contrast, were less problematic in the summer but represented a challenge in winter, since they require little to no clothing and/or involve contact with water.

3.2.4 Perceptions about non-conventional solutions

The last part of our interviews focused on probing user acceptability rates towards non-conventional solutions. Before preparing the interview materials, we noted that thermal comfort solutions are highly determined by each person's context and preferences. The purpose was to invite reflection and out of box thinking to identify possible design paths. The main question was whether they would consider using these products to manage their thermal comfort needs. The products presented on each category are shown in Figure 21 and Table 5 shows our results.

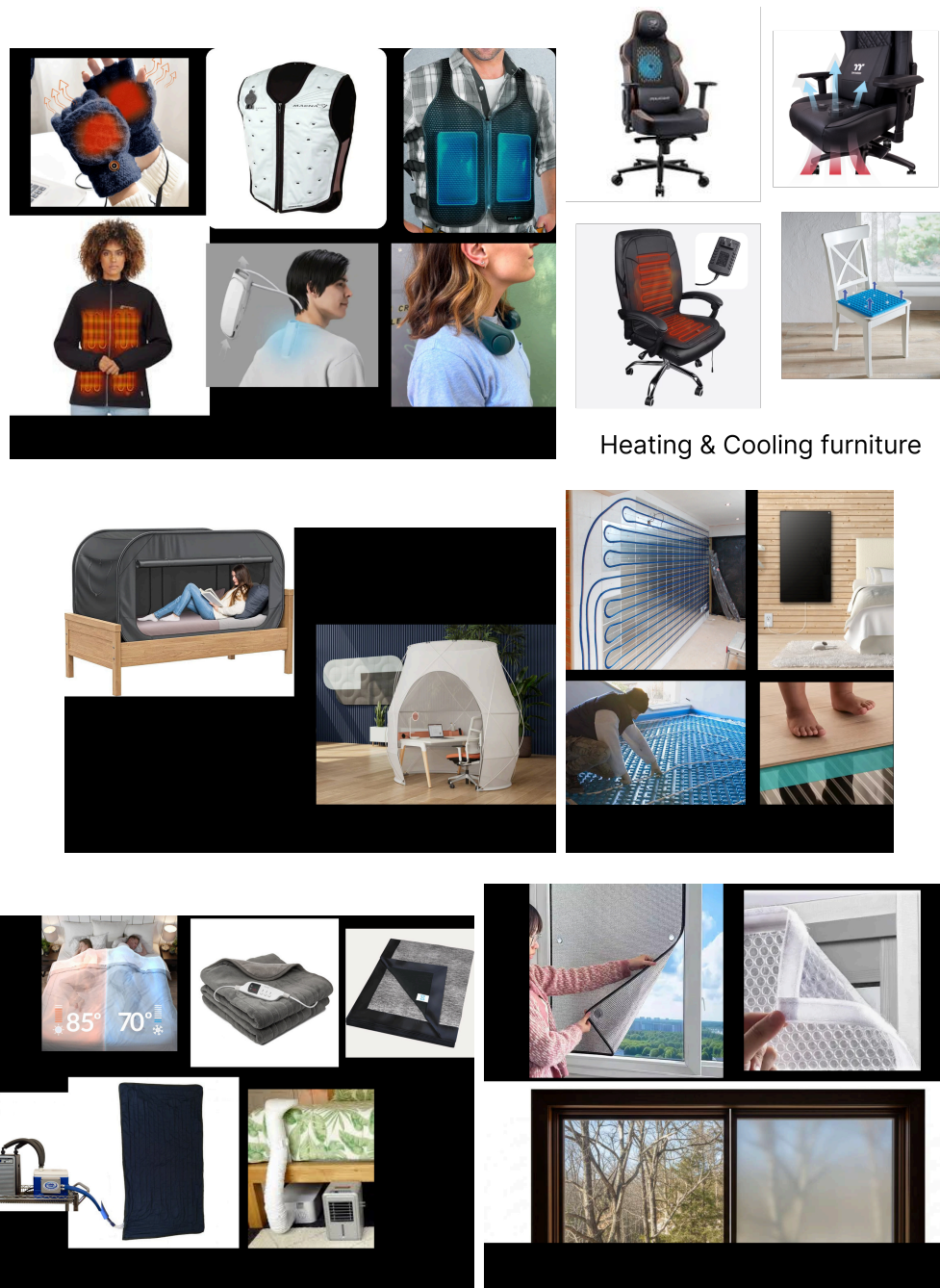


Figure 21: Selected images for future probing

Table 5: Future probing results

	YES	MAYBE	NO
Personal Devices			
Summer	54%	0%	46%
Winter	62%	0%	38%
Furniture Integrated			
Summer	69%	0%	31%
Winter	54%	8%	38%
Micro-Environments			
Summer	38%	15%	46%
Winter	62%	0%	38%
Wall/Floor Systems			
Summer	100%	0%	0%
Winter	85%	0%	15%
Heating/Cooling Blankets			
Summer	38%	8%	54%
Winter	23%	0%	77%
Window Add-ons			
Summer	31%	0%	69%
Winter	46%	0%	54%

With these results, we were able to conclude that in most cases the willingness to try these type of approach to solutions tends to be polarized. overall, these approaches had bigger acceptance in the winter than in the summer and those that are integrated into existing home elements, such as the furniture, walls and floors. The highest accepted category was wall and floor systems, these systems traditionally imply a big investment and installation efforts. To prevent that aspect from being the reason they reject the solution we asked them to ignore it and imagine they were easy to install and affordable. The high accepting level shows that clearly initial cost and effort are the biggest roadblocks of this approach. The least accepted approach was heating and cooling blankets. The cooling blankets showed were perceived not aesthetically pleasing, bulky and raised concerns about noise levels. The heating blankets in the other hand, raised concerns about safety and fire risk.

3.3 Synthesis of insights for Design

Across all research activities in this project, one working definition of thermal comfort emerged, grounded in how people described it rather than in physical parameters: *Thermal comfort is being able to wear light clothes, enable activities and relaxation at home without even noticing the temperature.*

To reach this understanding, a consolidated set of insights was gathered from the literature scan, survey, digital ethnography, and interviews, distilling the full span of information into the observations most meaningful for design. Many of these insights

are supported by more than one source. They were grouped into four overarching themes that reflect different dimensions of how people experience and manage thermal comfort at home (Table 6):

- **Sleep & Sitting Still.** Activities where comfort is most critical and disruptions are least tolerated. This theme captures how thermal conditions influence rest, concentration, and the ability to perform tasks that require sustained focus.
- **Transition Moments.** Situations where people move between different thermal conditions, such as coming home from outdoors, getting out of bed in a cold room, or passing through rooms with varying temperatures. These moments create short, intense shifts in comfort that reveal how sensitive occupants are to rapid temperature changes and how quickly discomfort can arise.
- **Season & Context.** The influence of weather patterns, building characteristics, and the systems available to occupants. This theme highlights how comfort is shaped by external conditions, architectural constraints, and the responsiveness of heating or cooling systems.
- **Household Constraints.** The social, spatial, and practical limitations that shape what people can realistically do to stay comfortable. This includes differences between renters and owners, household preferences, and the everyday negotiations involved in managing comfort.

Table 6: Insights for design categorized in four themes. (Right column shows supporting sources.)

Sleep & Sitting Still	
1. Clothing is an important adaptation during the day, but not during sleep.	Interviews
2. Many participants report sleep-related discomfort: winter discomfort is often about waking up in a cold room, while summer discomfort is more about falling asleep or staying asleep in heat.	Literature, Interviews
3. Thermal comfort is activity-dependent and becomes especially important during concentration-heavy tasks such as working or studying.	Survey, Interviews
Transition Moments	
4. Coming home from outside is a strong comfort experience: in winter the home becomes a refuge from the cold, while in summer some homes trap heat and turn the experience negative.	Interviews
5. Morning discomfort in winter often comes from cold bedrooms and the difficulty of getting out of a warm bed.	Survey, Interviews

6. In houses, thermal comfort can vary significantly between rooms, and daily routines may involve moving through several thermal zones in a short time.	Survey, Interviews
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Seasonal & Context

7. When discomfort is moderate, people prefer simple, low-investment solutions rather than complex or permanent systems.	Interviews
8. In apartments, sunlight exposure and orientation shape when overheating occurs and how long it lasts.	Interviews
9. During periods of rapid outdoor temperature change, radiator systems may respond poorly, especially in older buildings or where heating is centrally or landlord controlled.	Interviews
10. Winter discomfort is often manageable through clothing, bedding, or localized heating, while summer discomfort feels more persistent and harder to escape.	Survey, Interviews
11. Air conditioning is seen as desirable for some, but it can crowd out low-energy practices.	Literature, Interviews
12. Insulation in windows and air leaks is perceived as a practical, high-value starting point for improving home comfort.	Survey
13. Renters experience noticeably lower control over their indoor environment, since key factors like orientation, shading, and ventilation are fixed by the building rather than the occupant.	Literature, Survey, Interviews
14. People in detached homes report slightly lower winter comfort, likely because these buildings lose heat more easily and are harder to keep warm.	Survey

Household Constraints

15. Some devices are seen as useful, but participants weigh usefulness against duration of need, space, noise, cost, and whether the purchase feels necessary.	Survey, Literature
16. Opening windows at night in summer can conflict with noise, insects, light, and outdoor air quality; in some homes, pets escaping is also a concern.	Interviews, Digital Ethnography
17. During winter, some people want more windows for sunlight, while others want fewer windows to reduce air leaks and insulation issues.	Survey

18. Thermal comfort should be an invisible, background condition. Survey
When getting comfortable requires too much effort, people give up
on it.

3.4 Desirable Attributes

In Section 3.2.2.1 a list of desirability attributes was presented to use as evaluation criteria for conventional thermal comfort solutions for thermal comfort. This list includes: *Performance*, *Investment*, *Levels of Control*, *Energy Use*, *Appearance*, *Noise*, *Flexibility*, and *Space Used*. As the project progressed, these attributes underwent changes that were deemed necessary to better describe the characteristics user's seek. These changes were mostly informed by interviews conversations and by what participants expressed as valuable in their everyday experience. *Energy use* and *Performance* were maintained. *Investment* was reframed as *Initial Cost* and *Ease of Installation*. *Appearance*, *Noise*, and *Space Used* were combined into *Presence*. *Levels of control* and *Flexibility* was kept as an attribute of its own.

The final set of desirability attributes is presented in Table 7, and their relation to the Democratic Design principles in Figure 22. This second version of the attributes served as a set of design guidelines during the creative phase of the project. The list represents our interpretation of IKEA's Democratic Design principles translated into thermal-comfort terms. The purpose of this interpretation is to take the backbone of IKEA's design philosophy and articulate explicit, actionable attributes that can be easily evaluated during the development of a design solution. Each attribute captures a quality that users consistently expressed as meaningful, and together they form a practical basis for evaluating and developing design concepts that respond to real needs in the home.

Table 7: Design attributes and their descriptions.

Attribute	Description
Energy use	Favors passive principles over energy-intensive systems, and where possible lowers overall household energy use.
Performance	Offers a noticeable improvement in the daily thermal experience.
Maintenance	Requires little ongoing attention for adjustment, setup, and maintenance. Strive for "out of sight, out of mind".
Initial Cost	Keeps the purchase cost low, since high cost limits democratization.
Ease of Installation	Easy to install and set up across the varied preexisting conditions found in different households.
Presence	Integrates with the space, stays quiet, and is pleasant to look at and interact with.
Flexibility	Works across different seasons, spaces, or activities.
Control	Lets people manage their thermal comfort more easily.

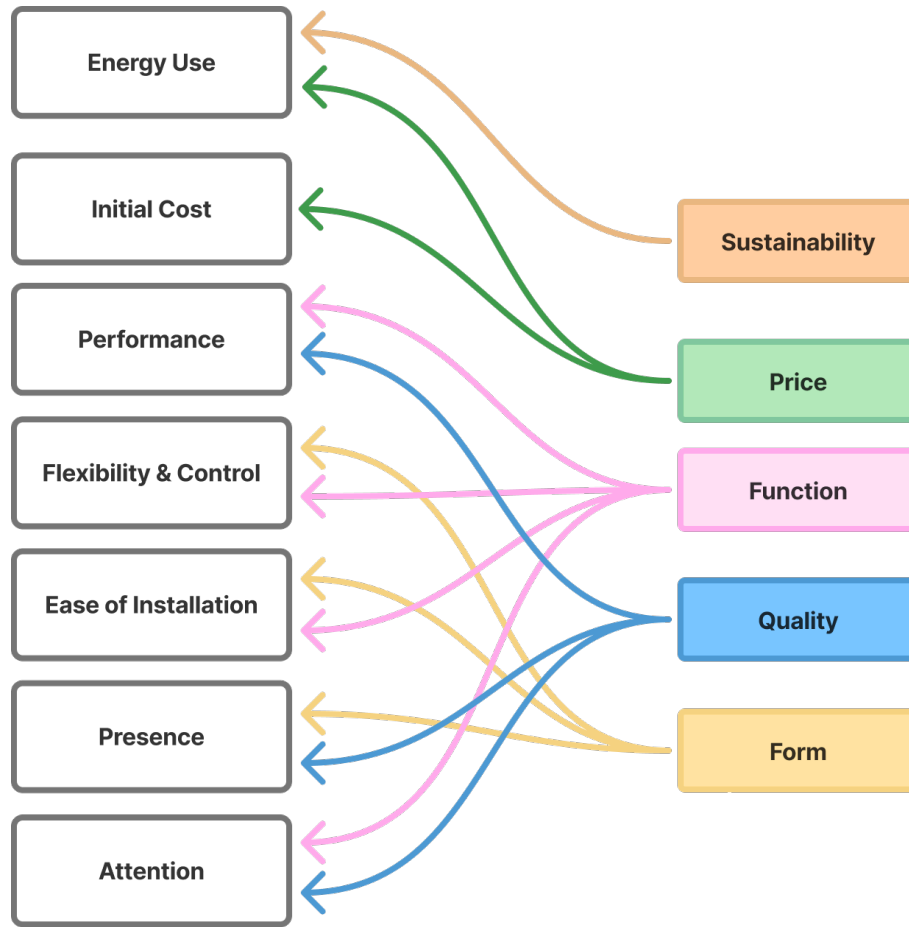


Figure 22: Design attributes and their relation to Democratic Design principles

Together, these attributes provided a clear direction for the creative phase that followed. By grounding the design work in qualities that users value and in principles aligned with IKEA’s design philosophy, the project moved from understanding existing conditions toward generating new possibilities. The next section builds on this foundation by presenting the development of concepts that respond directly to the insights and criteria outlined above.

3.5 Ten Initial Concepts

The previous stage established two sets of findings: the **insight themes**, which describe where discomfort and friction arise in everyday thermal comfort experiences, and the **desirable attributes**, which describe what users seek in a solution. The ideation stage translated these findings into concrete design concepts. This section presents the ten initial concepts that remained after Round 2 of the selection process, described in Section 2.3.3. Each concept is presented through a concept description, a summary of participants’ feedback, and an illustration. Which of these ten concepts were carried forward is reported at the end of this section.

3.5.1 Bed Ventilation Tubes

Concept description. This concept explored bringing air into the space under the covers through ventilation tubes connected to an air source (Figure 23). The tubes would be placed around the bed and channel airflow inward through or under the bedsheet, with the ventilation system potentially integrated into a newly designed headboard. Further development would need to consider how the mechanism could be integrated into the headboard, how noise could be reduced to support sleep, and how the system could remain compatible with existing beds and bedding.

Participants' feedback. Participants liked the idea of combining a blanket with airflow but doubted how it would feel in practice. Several were unsure about a noticeable airflow around the body through the night, and noted that tubes around the bed could limit movement, especially in smaller beds. Noise and easy on/off control while drowsy were also concerns. One participant added that global certification for electronic products is costly and only worth it at high volume.

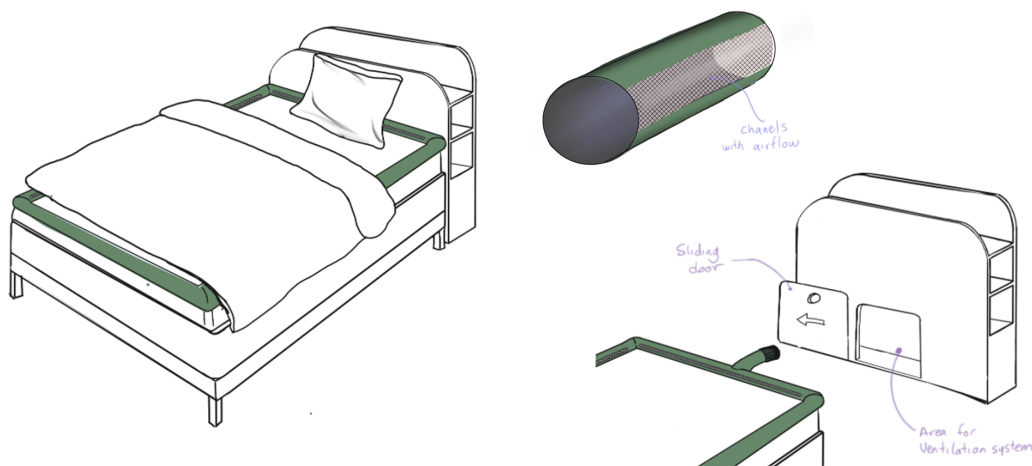


Figure 23: Illustration of the bed ventilation tubes concept.

3.5.2 Air Mattress

Concept description. This concept explored ventilating specific areas of the mattress using quiet, slow-running fans built into the slatted base of the bed (Figure 24). Instead of channeling air over the body, air would pass up through the mattress in selected zones, which would also allow different areas to be set to different temperatures. The mattress layers above the fans were proposed as a perforated thin foam layer over a TPEE gel air-fiber core so that air could pass through, and the edges of the mattress would need to stop air from escaping to the sides. Further development would need to keep the layers above the fans air-permeable, reduce the noise enough to support sleep, and work out how the smart zoning would be controlled.

Participants' feedback. Participants responded positively to this concept and saw clear advantages over the previous one. Compared with the ventilation tubes, several found it more appealing because it avoided a noticeable airflow over the body while still meeting their desired temperature, and one said they would use it and could see few disadvantages. The main doubt concerned the fan layout: ventilating a whole mattress from a single zone of fans might require powerful and therefore noisy fans, particularly if placed near the upper body. As with the previous concept, the certification cost of an electronic product and the sales volume needed to justify the investment were also raised.

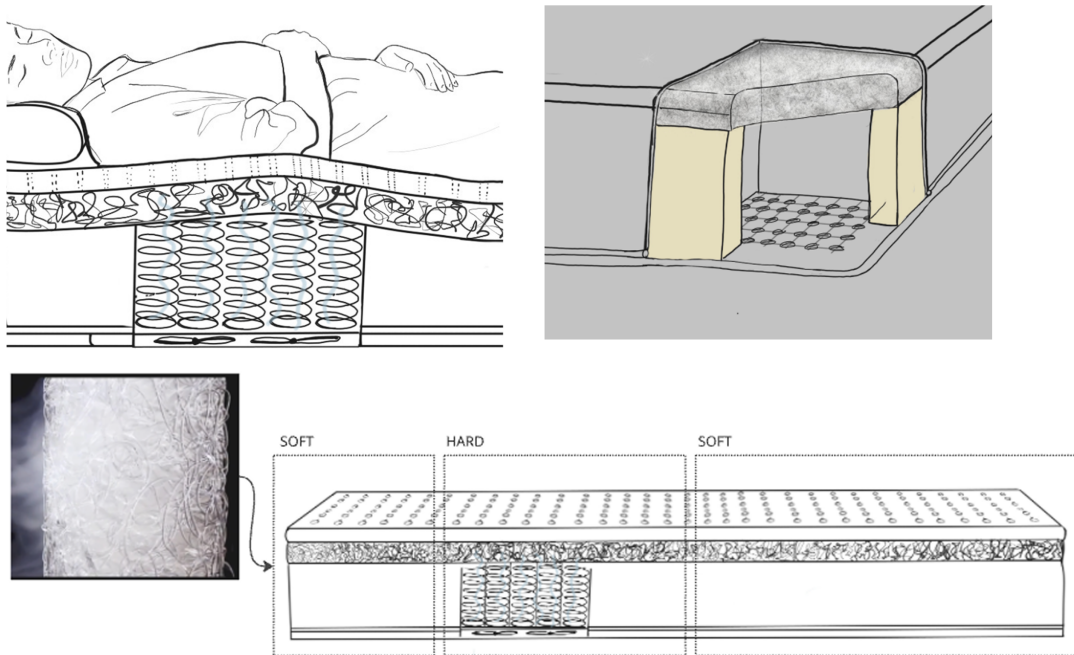


Figure 24: Illustration of the air mattress concept.

3.5.3 Woven Bamboo Mat

Concept description. This concept borrowed the cooling logic of the traditional Asian summer mat and adapted it for other contexts (Figure 25). Woven bamboo blocks draw on the high thermal conductivity of bamboo to conduct heat away from the body, while the gaps between the blocks create space for air to move through, so the cooling comes from the structure and material itself rather than any active mechanism. The same principle was sketched for other uses, such as a woven cover for an office chair. Further development would need to balance the thickness of the bamboo blocks against the need for a soft enough surface, and explore whether the weave could take on a more modern pattern.

Participants' feedback. Participants responded warmly to this concept, valuing its simplicity, low-tech nature, and low cost, and several saw it as a good match for IKEA customers and for apartments with air conditioning. A few imagined using

it beyond the bed, for example on a chair or outdoors on a hot summer day. The main reservation concerned comfort: some worried that thick blocks would feel like sleeping on hard pieces and could leave marks on the skin, and wondered whether the bamboo could be made thinner while still allowing heat and airflow to pass through. Aesthetics and a credible route to commercialisation were also raised as things to refine.



Figure 25: Illustration of the woven bamboo mat concept.

3.5.4 Warm Corner Collection

Concept description. This concept embedded low-wattage heating into soft furnishings to create a micro-warm zone in the few square metres where a person spends the most time sitting, sleeping, or resting (Figure 26). Rather than heating a whole room, a modular rug and a portable room divider would warm only the three to four square metres around the user. The rug warms through conduction, while the divider radiates far-infrared heat from one side and insulates on the other, together holding a perceived comfort zone of around 21 to 23 degrees Celsius. The heating was proposed as layered carbon heating films. Further development would need to establish how perceived thermal comfort and performance could be measured, and address the durability and safety of embedding electronics in textiles.

Participants' feedback. Participants were drawn to the idea of building warmth into furnishings they already use rather than heating a whole room. The concern

raised most often was energy: since the concept relies on embedded heating rather than a passive principle, participants questioned how much it would actually consume and whether the comfort gain was worth it. As with the bed ventilation tubes and the air mattress, the cost of certifying an electronic product also came up, together with the sales volume that would be needed to justify it.



Figure 26: Illustration of the warm corner collection concept.

3.5.5 Thermal Rhythm Broadcast

Concept description. This concept proposed a service, aiming to improve perceived controllability by making temperature changes at home predictable and understandable. Through a smart speaker and an app, it would start the day with a morning overview and follow with timely prompts, telling the user which room will be warmest and when, and suggesting simple actions such as closing the blinds before a cold night (Figure 27). The intent was to help people anticipate discomfort and act at the right moment, rather than react too late and simply endure. Further development would need to establish whether users find the prompts useful enough to act on, and how much the service could actually improve comfort.

Participants' feedback. Participants liked this concept and saw it as a smart, energy-saving solution, with several pointing to a strong fit with IKEA and its

Home Smart team and to possible links with devices such as air conditioning. A recurring question was whether a physical product is needed at all, or whether an app alone would be enough. Some also wondered whether the service falls within the client's natural scope, suggesting it might sit better with an actor such as SMHI or an energy advisor. A few saw further uses beyond comfort, such as helping people decide where to place plants or dry clothes. The main reservations matched the open questions in the concept itself: whether the prompts would be useful enough to act on, and how much the service could genuinely improve comfort.



Figure 27: Illustration of the thermal rhythm broadcast concept.

3.5.6 Inflatable Window Shade

Concept description. This concept used trapped air as insulation at the window (Figure 28). A regular roller blind would be fitted with a small integrated pump that inflates it into an insulating layer, reducing heat loss through the window. The

blind would be battery operated and roll up and down automatically, and would inflate only when fully lowered. Further development would need to keep it easy to install, confirm that it can be retrofitted to existing windows, and test how effective the insulation actually is.

Participants' feedback. Participants were interested in the concept and one said they would like to try it. Several found it convincing from a day–night perspective: in many homes heat escapes through the window, so an insulating blind fits a situation where people already lower their curtains at night. One participant asked whether the inflated blind could also store heat to release later, pointing to a possible extension of the idea.

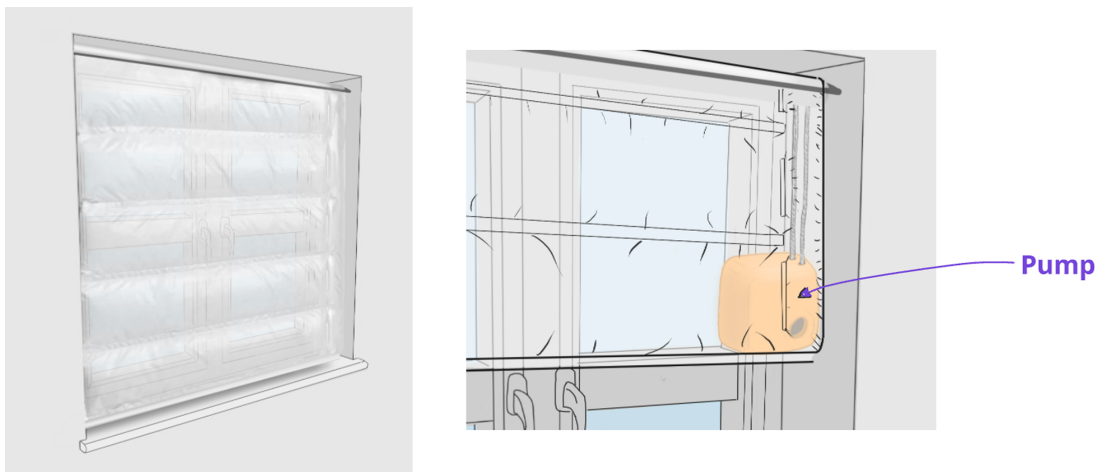


Figure 28: Illustration of the inflatable window shade concept.

3.5.7 Automatic Blind Control

Concept description. This concept was an add-on device that automates an existing blind by taking over its cords (Figure 29). As sunlight and temperature shift through the day, the device pulls the blinds to respond automatically, reducing the need for repeated manual adjustment, keeping the indoor environment comfortable, and preventing the room from overheating when no one is home. Further development would mainly need to work out how the device could fit different blind types.

Participants' feedback. Participants were positive about this concept, and one said they would certainly use it, since they adjust several blinds at home through the day. There was interest in pairing it with an app so that the blinds could either follow the current temperature or simply match a lighting preference, and one participant suggested it could also work as a straightforward up-and-down automation tied to the blind types already in the range. One participant noted that IKEA already offers something close in TREDANSEN but felt it had not sold well, which raised the question of how this concept would differ.

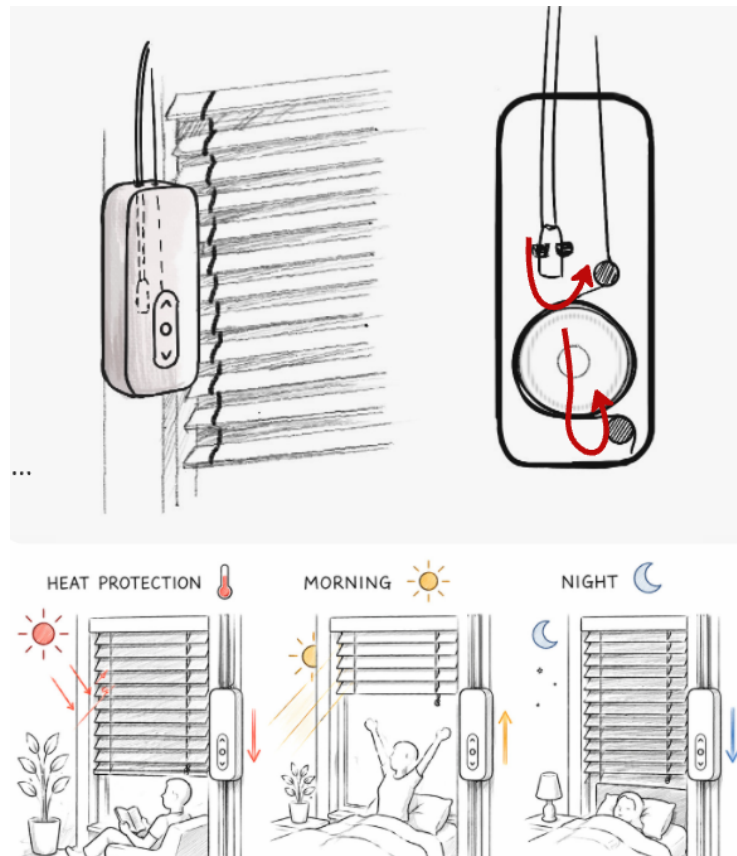


Figure 29: Illustration of the automatic blind control concept.

3.5.8 No-Drill Awning

Concept description. This concept was a window awning that provides sun coverage without blocking the view and installs without drilling, making it suitable for renters (Figure 30). It attaches to the window frame through a removable fixing rather than fixed hooks, so it can be put up and taken down easily, removed in winter, and offered in different textiles. Further development would mainly need to work out how to secure the awning so that it cannot fall down by mistake in strong wind, and how it could be removed easily when the wind is high.

Participants' feedback. Participants were enthusiastic about this concept, with several saying they would buy it and one recalling a very hot bedroom in a previous rental where it would have been useful. Beyond renters, it was seen as practical for anyone, since it would be easy to remove for winter storage and cleaning. The main concern was wind: participants worried about the awning falling in strong gusts and about not being able to take it down while away from home. Some also noted that different options could be offered with their own trade-offs in features and price.

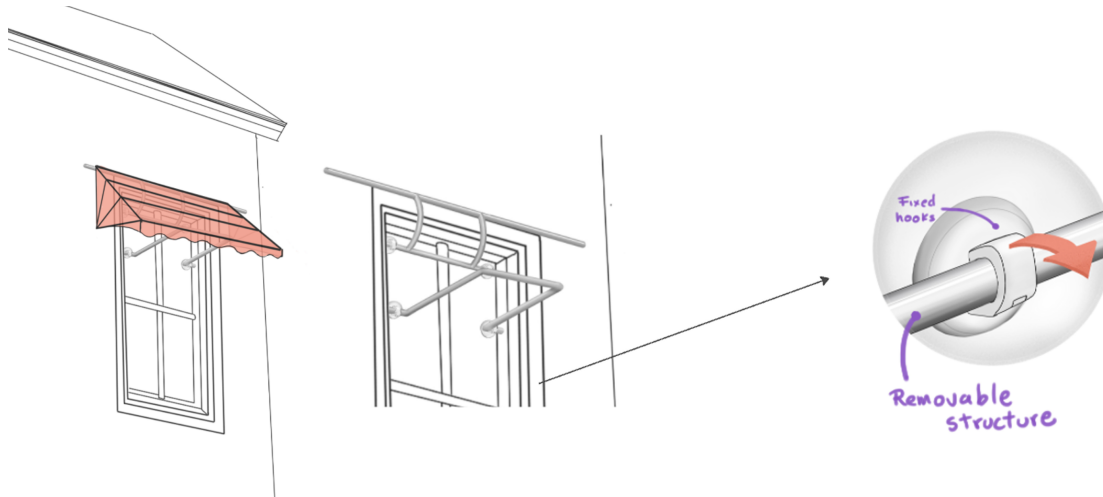


Figure 30: Illustration of the no-drill awning concept.

3.5.9 Window Fan

Concept description. This concept addressed trapped heat and poor airflow in apartments where the window is the main means of ventilation (Figure 31). A window-mounted fan would amplify natural ventilation: when the window opens, the fan swings into the gap between the frame and the sash and runs two flows at once, exhausting warm air at the top and drawing fresh air in at the bottom. It would be solar-powered and hinge-mounted so that it folds flat when the window closes. Further development would need to confirm whether the effect is a noticeable improvement and how the fan could fit across different window types.

Participants' feedback. One participant felt the concept pointed in the right direction but might be more complicated than necessary, suggesting that a simple fan fitting onto the window board could already be enough to bring fresh, cool air into the room. The same participant noted not having seen a fan made specifically for open windows, which points to a possible gap in the market.

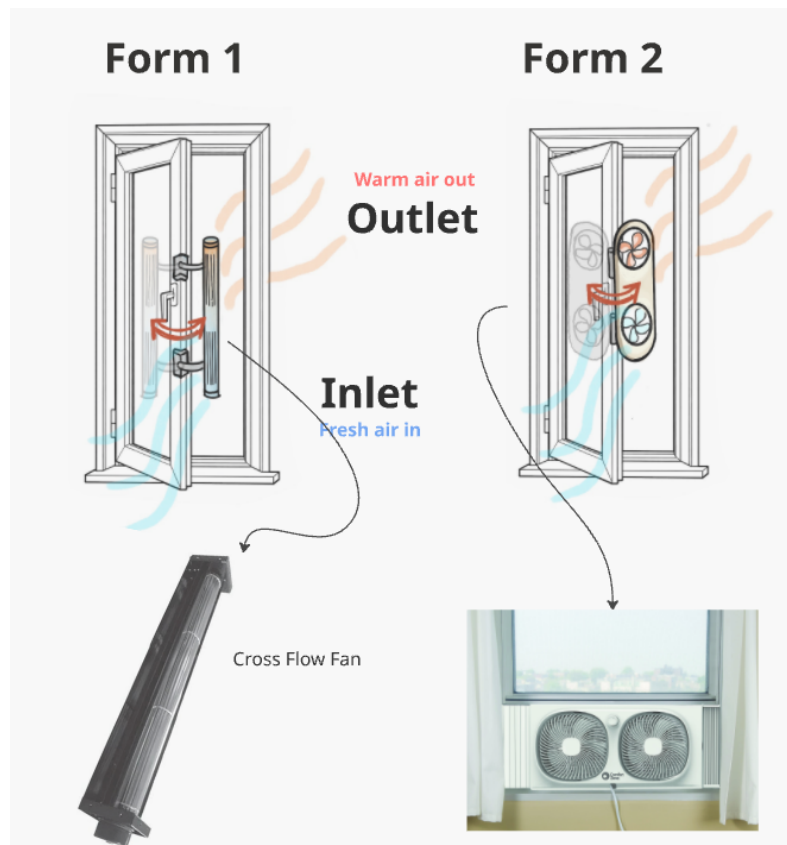


Figure 31: Illustration of the window fan concept.

3.5.10 Evaporative Cooling

Concept description. This concept adapted the principle of a swamp cooler but kept the added humidity out of the home (Figure 32). The system ran as a closed loop, with an exterior unit and an interior unit separated by a sealed barrier: a water mister and fan cooled a plate on the outside, and the cooled air was passed inside while the moisture stayed outdoors. It was designed to sit in an open window and was sketched for both vertical and horizontal window openings. Further development would need to refine the system, explore the use of solar energy, and look into whether it could be made portable.

Participants' feedback. Feedback was mixed. One participant was unsure what the concept meant, not being familiar with the idea of a swamp cooler, which suggests the explanation would need to be clearer. Another liked the idea but questioned the premise of keeping humidity out, reasoning that for a device of this size a few litres of water might not change indoor humidity much, though they were not certain of this.

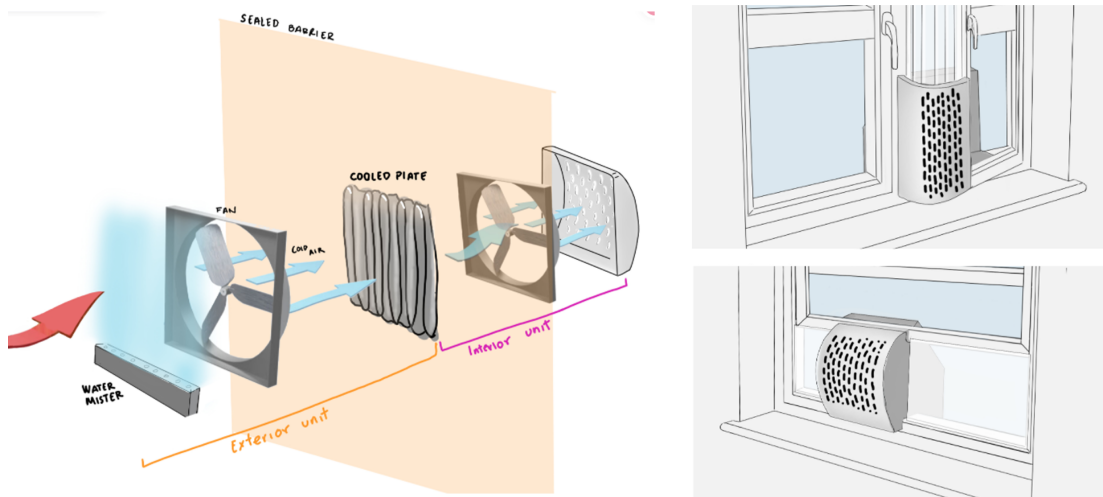


Figure 32: Illustration of the evaporative cooling concept.

3.5.11 Selection Outcome

The ten concepts were narrowed to four through Round 3 of the selection process (Section 2.3.3), which combined stakeholder voting with attribute scoring against the seven desirable attributes (Table 2). Each concept's votes and attribute score were added into a single final score, which guided the selection of the four concepts carried forward into refined design and functional prototyping.

3.5.11.1 Stakeholder Voting

The voting on the ten concepts was carried out separately with public participants and with IKEA internal participants. Each person placed dots on the concepts they preferred, with no limit on how many they could choose, so the totals indicate relative interest rather than a count of individual voters. Table 8 reports the results. The two groups broadly agreed on the strongest concepts: the woven bamboo mat drew the most support in both, followed by the thermal rhythm broadcast and the inflatable window shade. The two groups differed most on the warm corner collection and the no-drill awning, which were clearly more popular with the public than with the IKEA group.

Table 8: Voting results for the ten initial concepts. Public participants and IKEA internal participants voted separately; each could place dots on the concepts they preferred.

	Concept	Public	IKEA	Total
1	Bed ventilation tubes	1	0	1
2	Air mattress	4	1	5
3	Woven bamboo mat	9	7	16
4	Warm corner collection	8	3	11
5	Thermal rhythm broadcast	7	5	12
6	Inflatable window shade	6	5	11
7	Automatic blind control	6	2	8
8	No-drill awning	7	2	9
9	Window fan	1	2	3
10	Evaporative cooling	0	0	0
Total		49	27	76

3.5.11.2 Attribute Scoring

Each concept was scored against the seven desirable attributes using the rubric in Table 2, and we added these scores to the vote count to get a final score (Table 9). The woven bamboo mat and the thermal rhythm broadcast came out on top, both scoring well and getting plenty of votes. The rest sat closer together between 30 and 33, so picking from this group came down to judgement more than the numbers.

We left out two concepts from this group. The automatic blind control scored well, but what is left to do with it is mostly engineering work on the motor and controls, not much to explore at the concept level, so we kept the no-drill awning instead, which covers a similar need but had more room to develop. The warm corner collection runs on embedded heating and scored lowest on energy use, and since we wanted to keep the refined set low-energy, we did not take it further.

This left four concepts to develop into refined designs and functional prototypes: the woven bamboo mat, the thermal rhythm broadcast, the no-drill awning, and the inflatable window shade. They cover the furniture, window, and guidance categories, and mix passive and low-energy solutions with one information-based service. These four are described in Section 3.6.

3.6 Refined Concepts and Prototypes

Four of the ten initial concepts were taken forward for refinement and prototyping: the bamboo block mat, the no-drill awning, the air-insulated blind, and the thermal rhythm broadcast. The selection drew on the stakeholder voting results and the desirable attributes scoring from the previous section. For each concept, the prototype is presented first, followed by the implications for design that emerged during

Table 9: Final selection scores for the ten initial concepts. Each concept was rated on the seven desirable attributes using the rubric in Table 2; the attribute scores were summed and added to the vote count to give the final score. Concepts carried forward into refinement are shown in bold.

Concept	Energy use	Ease of installation	Performance/ effectiveness	Maintenance/ attention	Presence/ integration	Investment/ cost	Flexibility & control	Attributes score	Votes	Final score
Woven bamboo mat	5	5	2	3	4	3	1	23	16	39
Thermal rhythm broadcast	3	5	2	5	5	3	3	26	12	38
Automatic blind control	3	3	2	5	4	5	3	25	8	33
No-drill awning	5	3	2	3	5	3	3	24	9	33
Inflatable window shade	3	1	2	3	3	5	3	20	11	31
Warm corner collection	1	3	5	1	3	1	5	19	11	30
Air mattress	2	1	4	5	4	1	1	18	5	23
Bed ventilation tubes	2	3	4	5	3	1	3	21	1	22
Window fan	3	1	4	1	1	3	1	14	3	17
Evaporative cooling	4	1	5	3	1	1	3	18	0	18

development but fell outside the scope of this round of prototyping, and the qualitative user feedback from evaluation. A summary of the overall evaluation scores closes the section.

3.6.1 Bamboo Block Mat

This concept evolved from the woven bamboo mat. During refinement we chose to keep the thickness of the bamboo so as to retain the cooling effect of the material, and to focus instead on making the surface feel softer and on testing how acceptable it would be to users. The concept is therefore referred to here as the bamboo block mat.

3.6.1.1 Prototype detail

The first round of prototypes was made in MDF to test how block size and corner radius affected the tactile experience. Five samples of 20×20 cm were prepared, combining a small, medium, or large block size with a small, medium, or large corner radius. The team assessed them by touch and by sitting on each one, and selected the smallest block size with a medium corner radius as the basis for the bamboo prototype.

The next decision was how to fix the blocks while keeping the surface soft. Traditional bamboo mats string the blocks together with elastic cord, but we wanted to use the softness of a fabric backing instead, so the blocks were glued onto a plain fabric backing with a hot glue gun. The fabric was not specifically selected, as adhesion was the main constraint.

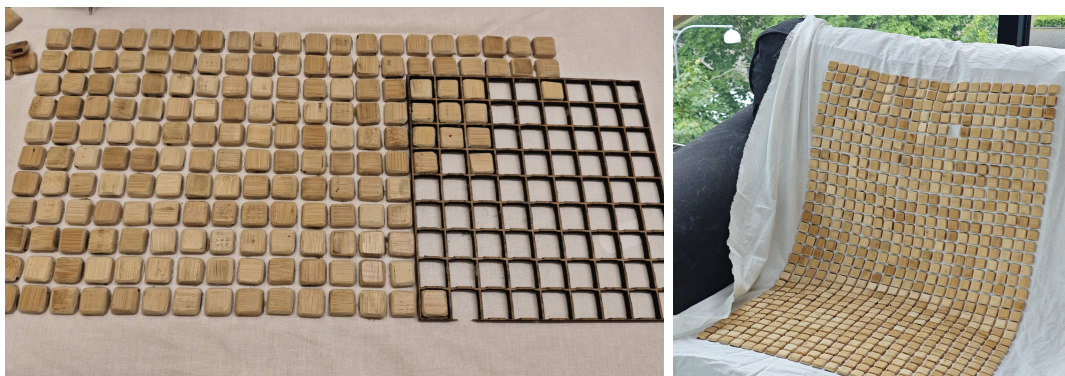


Figure 33: The bamboo block mat prototype: construction process (left) and finished prototype (right).

The final prototype was built in bamboo at 50×80 cm, a size set by the working limit of the available material and by the intention to cover roughly the width of a person's torso when lying down (Figure 33).

3.6.1.2 Implications for design

Block shape. The corner radius needs to balance comfort against contact area. A larger radius is gentler on the skin, but it also reduces the area touching the body, which becomes uncomfortable in its own way, so there is a trade-off to resolve rather than a single best value. Block shapes other than the square used here could change not only how the surface feels but also how air moves through the gaps between blocks, since a different shape could let air flow more freely (Figure 34). Testing alternative shapes was beyond the time available for this round.

Fixing method. The fabric backing used here was a functional stand-in. A better solution could be a soft foam layer that the blocks slot into through a structural design (Figure 34), so that they are held in place without a separate fixing step. This would also make the blocks easier to detach for cleaning.

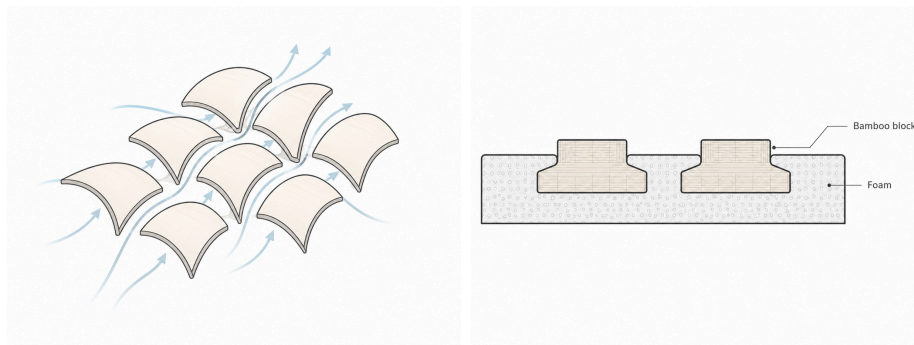


Figure 34: Future design directions: alternative block shapes (left) and a foam layer the blocks slot into (right).

3.6.1.3 User feedback

The bamboo block mat was well received in discussion with participants. Several were initially concerned about using it on a bed, expecting a block surface to feel uncomfortable to sleep on. The two participants who used it through a full night reported the opposite: noticeably less sweating during the night, without the surface feeling any harder or less pleasant to the touch. Even so, the concern about sleeping on it over longer periods remained. The cooling performance was the most consistently confirmed point, with participants describing the mat as cool both to touch and to sit on. Many also felt that a chair, such as an office chair, would be a stronger context for the concept than the bed.

3.6.2 No-Drill Awning

Window awnings are a familiar architectural element used to block direct sunlight while preserving outward visibility and airflow. Because their basic function and form are already well established, this prototype focused specifically on the installation and detachment mechanism (Figure 35), specifically how an awning could be fixed to a window frame without drilling, and how it could be safely removed during

strong winds or in winter.



Figure 35: No-drill window awning prototype

3.6.2.1 Prototype detail

The main innovation of this design lies in enabling installation with basic tools and no drilling. To explore this, a simple window model at approximately 1:10 scale was constructed. On this model, several quick prototype iterations were developed to identify the most practical attachment mechanism. Using plastic tubing, aluminum sheeting, and small fasteners allowed us to approximate the materials likely used in a final product.

The resulting design consists of a pair of telescopic tubes that, in the prototype, extend and lock using a thick thread to pull them apart. At both ends of the tubes, bracket components secure the supports to the window frame (Figure 36). Once the supports are in place, the user can attach the awning's fabric roll.

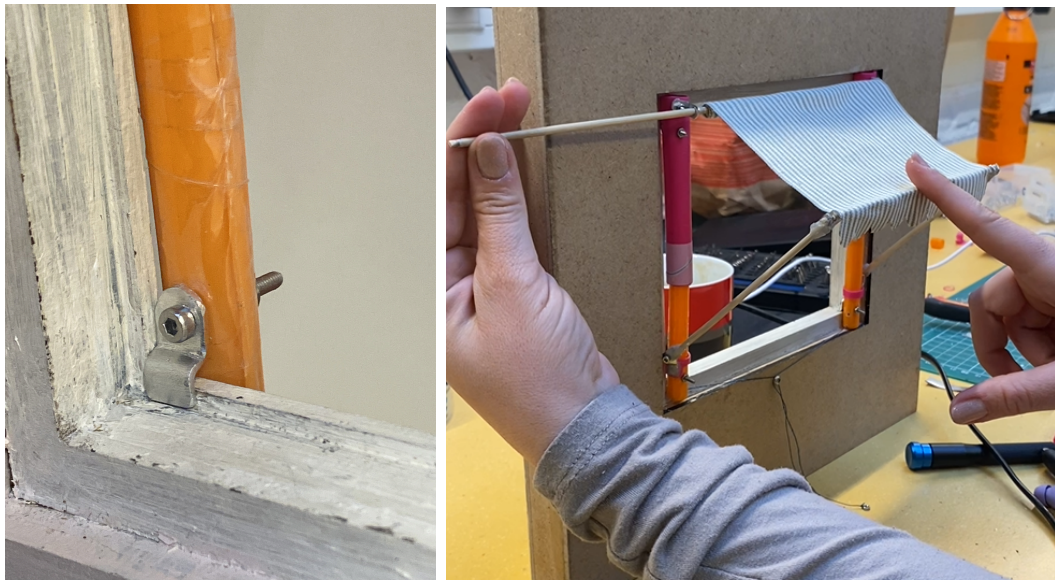


Figure 36: Details for no/drill awning. Window frame bracket for no-drill awning (Left). Rolling mechanism (Right)

3.6.2.2 Implications for design

The telescopic mechanism. The mechanism should be engineered to be self-locking to ensure stability and ease of use.

Window seal. The window's sealing edges must be considered, and the attachment brackets may need to integrate or accommodate these features.

Automation. The awning could be manually deployed, or an electronic system powered by solar energy could be developed. In the latter case, smart integration could enhance the experience by detecting and predicting optimal times for deployment and retraction, and by enabling control through a mobile app.

3.6.2.3 User feedback

Participants were already familiar with the basic function of an awning, and they expressed strong interest in the possibility of installing this solution without drilling into walls or the building façade. This feature contributed to a positive performance evaluation, as it was perceived as both practical and desirable for renters and homeowners seeking non-invasive modifications.

However, the concept received lower scores in flexibility and maintenance. During the evaluation discussions, participants raised concerns about the potential lack of compatibility with different window types, the possibility of cumbersome installation maneuvers, and the risk of accidentally dropping tools or product components through the window during setup.

A major point of concern was the system's long-term outdoor performance. Participants emphasized that the awning must withstand wind loads without detaching or becoming unstable, while also resisting degradation caused by prolonged exposure to

sunlight, rain, and moisture. Ensuring durability and safety under these conditions was considered essential for the viability of the concept.

3.6.3 Air-Insulated Blind

This concept focused on two questions during refinement stage: the visual effect of the transparent cover, and whether the trapped air layer actually provides any insulation.

3.6.3.1 Prototype detail

Transparent shower curtain material was used to preserve visibility and to examine the visual effect of the blind once inflated. Several patterned samples were made to explore different quilting patterns and to observe how the inflated geometry sat against the window plane and conformed to the window frame.

To explore the insulation effect, a simple by-hand test was used. The prototype was compared with curtain fabric by placing each one over a box containing ice and holding a hand a short distance from the surface to feel the difference in temperature passing through (Figure 37).



Figure 37: The air-insulated blind: test see-through effect on the window (left) and the evaluation setup (right).

3.6.3.2 Implications for design

Double pockets. A double-pocket structure could improve insulation by adding a second trapped air layer, slowing the transfer of cold more effectively than a single

layer. This would, however, add thickness and material, so the gain in insulation would need to be weighed against how bulky the inflated blind becomes.

Pattern design. The quilting pattern shapes the inflated geometry, so it could be designed so that the cover sits flatter against the window and conforms more closely to the frame, reducing the gaps where air leaks around the edges.

3.6.3.3 User feedback

Performance was where opinions diverged most. Some participants felt the blind insulated noticeably better than an ordinary curtain, while others sensed no difference, or even felt it was colder. This spread is partly a limitation of the simple by-hand test, and the insulating effect would need to be verified more rigorously alongside an improved prototype. Participants also noted a trade-off in the transparent material: while it preserves sight and daylight, the inflated form is still a visible object at the window and changes how the window looks, so its appearance and how well it blends into the room would need attention. Because its purpose is insulation, the blind is mainly useful in winter, which limits its flexibility across the year.

3.6.4 Thermal Rhythm Broadcast

This concept developed two things: the form of interaction and the key contexts where the service would apply. The interaction was designed around a phone app as the most basic form, potentially supported by a smart speaker and integration with smart-home devices for a richer effect.

3.6.4.1 Prototype detail

Because this concept centers on experience and service rather than on a physical artifact, with the design configured through an app and delivered through a smart speaker and a phone, there was nothing to prototype in the material sense. The challenge was instead how to convey the felt experience of using the service convincingly.

The first step was analytical and addressed where in everyday life the service would have a meaningful application. A scenario table (Figure 38) was built to think through the possible usage situations of the thermal broadcast, with each row qualitatively assessed for its comfort and energy value.

From the table, three scenes were selected for further development: a morning setup, a reminder to close the blinds before leaving the house to prevent heat building up through the window, and a forecast of the coolest spot in the home in the afternoon, suggesting the user move to that space to work. A seasonal suggestion was also included, such as moving an armchair to a warmer part of the home in winter. These were turned into a 90-second AI-generated video produced in Grok(Figure 39). The video served to convey the felt experience of the concept rather than to demonstrate the underlying system technically.

Scenario Name	Before Using	After Using	Comfort Benefits	Energy Benefits
Summer blinds before leaving	Come home to an overheated room and blast the AC to compensate	Told the day will be sunny, lower the south-facing blinds before leaving	Medium	High
Extra blanket before cold night	Wake up cold and hunt for a blanket or switch on the heater	Told the bedroom will drop to 16 °C, add a blanket before bed	High	Medium
Curtains for solar gain/heat retention	Curtains open all day and lose heat, or closed all day and miss solar gain	Prompted to open curtains at 10:00 for heat and close them at 15:00 to keep it	Medium	High
Night ventilation instead of AC	Run the AC all night to hold the temperature, at high electricity cost	Told it will be 5 °C cooler outside after 22:00, open windows and turn off the AC	Medium	High
Move to a warmer room	Stay in the cold living room and heat the whole space with a heater	See "study 20 °C, living room 17 °C" and move there to work, no heating	High	High
Seasonal furniture rearrangement	Furniture stays put year-round, seasonal thermal patterns go unused	Prompted at the season change to move the armchair to the warmest spot	Medium	Medium

Figure 38: Scenario table of the Thermal Rhythm Broadcast

3.6.4.2 User feedback

How useful the service feels depends heavily on the living context. Participants saw the most value when it could be paired with smart control, for example adjusting the blinds automatically rather than only prompting the user to act. Several who live in small apartments felt it would be less useful to them, since there is little room to move between spaces and only a few windows to control, which narrows what the service can suggest.

Investment prompted the most varied responses. Some imagined paying once for an analysis of their home, others expected a subscription, and others felt it should come free with the smart devices they already own. This range itself points to room for different service and business models around the concept.

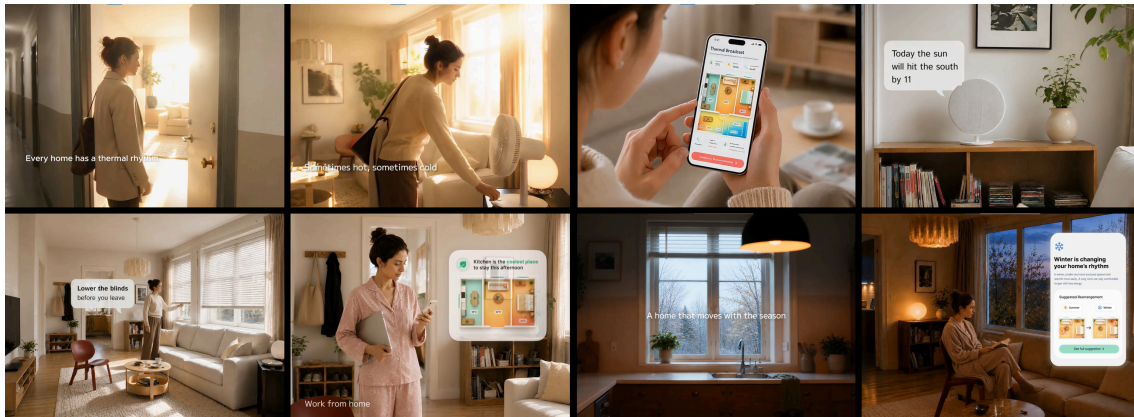


Figure 39: Screenshots from the thermal rhythm broadcast concept video.

3.6.5 Evaluation against Desirable Attributes

The twelve participants rated each refined prototype against seven desirable attributes on a five-point scale (see Appendix G), and gave a price range separately for initial cost. Table 10 shows the results as a simple average across the seven attributes and a weighted average using the weights from Table 18.

The four concepts came out close together, and weighting the attributes barely changed the order. The bamboo block mat and the thermal rhythm broadcast sit at the top either way, around 4.00 and 3.98 unweighted and 3.97 and 3.93 weighted. The no-drill awning moves up to 3.62 once performance counts for more, since that is where it does well. The air-insulated blind stays at the bottom throughout, pulled down by presence and flexibility.

The scores track the character of each concept rather than ranking them against one another, since the four address different situations: the bamboo mat leads on installation and maintenance, the broadcast on flexibility and control, the awning on performance, and the blind trails on presence and its winter-only use. The price ranges show the same spread, lowest for the bamboo mat and highest for the awning, with the width of each range pointing to real uncertainty about what these concepts are worth.

The price ranges show the same spread as the qualitative comments. Participants placed the bamboo block mat lowest, from around 171 to 529 SEK, and the no-drill awning highest, from around 492 to 1092 SEK, with the blind and the broadcast in between. The width of each range, for the broadcast in particular, the spread reflects the different service and business models participants imagined, as discussed in Section 3.6.4.2.

Table 10: Evaluation scores across the four refined concepts (12 participants).

Attribute	Bamboo	Awning	Blind	Broadcast
Energy use	3.67	3.83	3.75	3.79
Installation	4.83	2.96	3.75	3.71
Performance	3.88	4.08	3.54	3.83
Maintenance	4.67	3.00	4.08	4.00
Presence	3.92	3.71	2.42	3.92
Flexibility	3.54	3.21	2.79	4.50
Control	3.50	3.71	3.46	4.08
Average	4.00	3.50	3.40	3.98
Weighted average	3.97	3.62	3.41	3.93
Price, low (SEK)	171	492	243	296
Price, high (SEK)	529	1092	440	682

Columns: bamboo block mat, no-drill awning, air-insulated blind, thermal rhythm broadcast.

3.7 Develop Future Solutions Strategy

The project closes by stepping back from individual concepts to the design space as a whole, and offers a Design Approach Matrix (Figure 40) for future thermal comfort work: a map of where thermal discomfort arises and the kind of intervention that can address it. Paired with the desirable attributes from Section 3.4, which set out what a good solution should achieve, they work together as tools for future design efforts.

INTERVENTION APPROACHES →	On-body Direct contact with the body	Micro-space A small climate around the body	Envelope Add-ons that modulate exchange	Information & Control Transparency and a sense of agency
INSIGHT THEMES ↓				
 Sleep & Sitting still	Bamboo Block Mat ★ Air Mattress	Bed Ventilation Tubes Warm Corner Collection		
 Transition moments				
 Seasonal & context			Air-Insulated Blind ★ Automatic Blind Control Window Fan Evaporative Cooling	Thermal Rhythm Broadcast ★
 Household Constraints			No-Drill Awning ★	

Figure 40: Design Approach Matrix mapping discomfort sources against intervention approaches, with concepts marked.

3.7.1 From categories to approaches

The approaches on the matrix took shape across the whole project rather than being fixed at the outset. The interviews used a set of non-conventional solution categories,

covering *personal devices, heating and cooling furniture, micro-climate bubbles, wall and floor systems, thermal-adjusting blankets, and window insulation*. The IKEA workshop then opened a wider field of ideas, which were clustered into *Micro-space, Windows, Materials, Smart and AI, Service, Wall and Floor, and Furniture*.

Consolidating across these, four approaches captured the design space without overlap: On-body, Micro-space, Envelope, and Information & Control. The first three describe the kind of intervention by how close it sits to the person, from textiles in direct contact with the body, through the small climate immediately around it, to add-ons that modulate exchange at the building envelope. Each favors a passive, energy-efficient response to discomfort rather than active heating or cooling. Information & Control sits apart from this physical logic. It responds to one of the project's central finding, that the lack of personal control is the strongest barrier to thermal comfort, and works through transparency and a sense of agency rather than a physical product. Together the four frame how IKEA could approach thermal comfort at home.

3.7.2 How to Use Design Approach Matrix

The matrix has two axes. The rows are the four insight themes identified in Section 3.3 and mark where friction in the experience originates; the columns are the four approaches and mark the kind of intervention applied. The shaded cells mark the combinations we found most generative during ideation, while the unshaded cells represent relationships we explored less within the project.

Our focus across the insight themes was uneven, guided by the second-round selection criteria of discomfort frequency and intensity: we prioritized problems that affect the most people and affect them most strongly. From our interviews, sleep & sitting still emerged as a particularly rich area, since people spend long periods in these activities and need more comfort to rest or focus. Transition moments are also a significant source of discomfort, but their short duration made them less productive to design for directly. Seasonal & context is another focus, concentrated on the envelope and, within that, on the window, the busiest part of the home's boundary, where heat, light, and air exchange all converge. Household constraints did not produce concepts of their own in this project, but the market already contains many solutions that fall into this row, such as dual-zone duvets, so it remains a legitimate part of the design space.

3.7.3 On-body

The on-body approach covers anything in direct contact with the body during use: textiles, materials, surface structures, and worn devices such as heated vests or cooling wraps. It is the smallest scale of intervention in the matrix, and one of the most familiar. In the interviews, adjusting clothing was the most immediate response

participants reached for when they felt too cold or too warm.

This approach matters most for Sleep & sitting still. When the body is still, it becomes the dominant driver of its local climate, and bedding and seating textiles are already in contact with it, which makes them a natural site for intervention without adding new objects to the room. Redesigning the materials and surfaces around the bed became one of the focuses of ideation in this project.

On-body solutions also hold potential for Transition moments. A garment can be put on quickly when moving from the warmth of the bed into a cold room, and a personal device can travel with the body between temperature zones. The personal devices probed during the interviews, such as heated vests, cooling neck wraps, and heated chair pads, received moderate acceptance, 62% in winter and 54% in summer, which suggests room to explore even though ideation did not push in this direction. The recurring concerns were aesthetics and bulk, particularly for heating and cooling vests, and addressing those would be central to making such devices acceptable.

Within the on-body approach two logics emerge, active and passive. Active solutions move air or generate heat through mechanical means, while passive solutions rely on the properties of a material or structure to conduct heat away from or toward the body. The two concepts that follow illustrate each: an air mattress on the active side, and the Bamboo Block Mat, which was developed further.

3.7.4 Micro-space

The micro-space approach creates a small, adjustable climate around the body rather than conditioning a whole room, working through the air temperature, radiant surfaces, and air movement immediately surrounding a person. It targets the places where people stay put for long stretches at home. It also answers a pattern from the interviews: when discomfort is moderate rather than severe, people prefer simple, low-investment fixes over permanent systems, and a localized climate falls within that range.

Like the on-body approach, micro-space is most relevant to Sleep & Sitting still, where a person stays in one place long enough for a localized zone to pay off. When such a solution can be moved between locations, the same logic extends across the day to other spaces and users, which is where it also touches the personal-preference side of Household Constraints.

Two ideas were explored in this approach, Bed Ventilation Tubes and the Warm Corner Collection, both described in Section 3.5. Neither was carried into the refinement stage. Although the approach aims at minimal energy use, conditioning even a small space still relies on active input, which sat awkwardly against the project's lean toward passive solutions. This held even for the Warm Corner Collection, despite its strong showing in the public voting.

3.7.5 Envelope

In the survey question on what people would most like to improve, insulation was one of the most frequently mentioned themes, raised 21 times across the responses, which motivated this approach. The envelope approach covers add-ons to windows, walls, and floors that modulate exchange with the outside. Rather than actively changing the indoor temperature, it reduces the influence of outdoor heat or cold, which improves the thermal experience and lowers energy use at the same time. It suits renters and low-investment situations especially well, since add-ons are easy to install and reversible, offering flexibility without permanent modification.

Window In modern housing the window is the largest entry point for heat gain and heat loss, and it carries several roles at once: daylight, view, ventilation, and insulation. This makes it the busiest part of the home's boundary, and the main site of envelope-scale concepts. The interviews surfaced repeated conflicts around using the window as a thermal management tool. People opened it to ventilate but worried about the cat escaping, about outdoor noise, or about smoke drifting in from neighbours, and west-facing windows that overheated in the afternoon were often forgotten and left open when leaving the house. These tensions explain why most of the envelope-scale ideas concentrate on the window, and why this approach produced the largest share of the refined concepts: the Air-Insulated Blind and the No-drill Awning.

3.7.6 Information & Control

Across the project, the lack of personal control emerged as the strongest barrier to improve thermal comfort. People often had the means to adjust their environment but lacked the controllability or information to act on it, or felt that the controls available to them were opaque or out of reach. This approach responds to that gap. Rather than altering the physical environment, it works on the relationship between people and their environment, through two moves: making the thermal situation visible, so that people understand what is happening and what they can change, and making the act of control simple and legible, so that adjustment feels within reach.

This approach connects to the insight themes wherever the thermal situation changes faster than people can read it. Seasonal & context, and Household constraints are all information-rich in this sense: conditions shift across the day, the season, and the constraints of a given home, and much of the discomfort comes from not knowing what is happening or what to do about it. By surfacing those changes and pointing to a response, the approach helps people understand the situation and manage it, even where the physical conditions themselves cannot be fully changed.

The refined concept developed in this approach is the Thermal Rhythm Broadcast, described in Section 3.6.4.

4

Discussion

This work addresses a problem that crosses geographic and social borders, with the intention of evening out access to thermal comfort solutions for the many. Using Democratic Design as a lens let us approach that problem from a human-centered rather than a purely technical position, stepping back to ask how comfort is actually lived before asking how design might respond. The sections below reflect on what our work produced, where this approach carried us further than expected and where it reached its limits, and what it leaves for future research.

4.1 Contributions

Recalling our research questions, the following paragraphs summarize our key findings.

RQ 1: What are the common factors that shape people’s experience of thermal comfort at home?

Our contribution here is a framework of the factors that shape thermal comfort at home, organised into four interrelated groups. *Personal Factors* are the biological, economic, cognitive, knowledge-based, and sensorial characteristics a person carries into any situation, which explain why people in the same room disagree about whether it feels comfortable. *Environmental Factors* are the physical conditions of the space, temperature, humidity, airflow, and radiant heat, with temperature as the primary determinant. *Contextual Factors* are the home-environment situations that set comfort needs and the means available to act on them, including level of control, household composition, and the solutions at hand. *Expressions* are the emotions, behaviors, and activities through which comfort becomes visible and which both shape and are shaped by the experience.

What sets this framework apart from conventional thermal comfort models is where it looks. Established models describe comfort through physical and personal variables largely internal to the individual and the room. Ours ties comfort to the household context around the person, and adds an expressive and behavioural layer that these models leave out. That layer is also the part most useful to design, since emotions, behaviours, and activities are the points where a product actually meets a person’s day.

RQ 2: How do people manage thermal comfort at home today, and what are their expectations of it?

Our study shows that people approach thermal comfort through a mix of active and passive solutions. Depending on the particular region and climate, many homes are better equipped to deal with either hot or cold weather according to which presents with more frequency and intensity, but, in many cases, not both.

Existing research has explored adaptive practices and the role of everyday activities in shaping thermal comfort. However, this study extends that work by examining how these adaptations unfold within the context of lived experience. Rather than focusing solely on broad behavioral patterns, it highlights the moment-to-moment frictions people encounter and the ways they negotiate these challenges through small, situated actions. This closer examination of personal experiences provides a richer understanding of how thermal comfort is managed in everyday life.

As for what people expect, their hopes are framed not in temperature parameters but in the everyday experience comfort supports. This is what the working definition from Section 3.3 captures: thermal comfort is being able to wear light clothes, enable activities and relaxation at home without even noticing the temperature. Two activities stand out as especially sensitive to these conditions, sleep and focused work, where comfort is essential to performing them well, which is why they became a focus of our design work.

RQ 3: How can we create solutions for thermal comfort at home that align with IKEA’s Democratic Design principles?

The answer this project offers is not a single solution, but two design resources that make Democratic Design workable for thermal comfort. The first is the *Design Approach Matrix*. Rather than pursuing one definitive solution, the design work covered the opportunity space from a wide variety of angles, and these converged into a matrix that maps where thermal discomfort arises against the kind of intervention that can address it. It gives designers a way to move from a specific comfort problem to a suitable design approach, rather than starting from a technology and looking for a use.

The second resource is the list of *Desirability Attributes*, which interprets IKEA’s Democratic Design principles in thermal-comfort terms. Democratic Design sets out broad commitments, form, function, quality, sustainability, and low price, but these are not directly actionable when evaluating a comfort concept. Translating them into concrete attributes such as energy use, initial cost, and ease of installation turns the philosophy into criteria a team can actually score a concept against. Together, the matrix and the attributes work as a paired resource: one points to where and how to intervene, the other to whether a resulting concept holds up as democratic. They give future thermal comfort projects a foundation for ideation, evaluation, and

decision-making.

4.2 Approach

This study took an exploratory approach to thermal comfort, focusing on people's needs and experiences and the opportunity spaces around them rather than committing to a single direction from the start. That choice followed from the nature of the problem. Most existing thermal comfort products work by actively conditioning the whole environment and tend to be energy-intensive, so beginning from these solutions would most likely have led only to improved versions of the same energy-heavy logic. Starting instead from how people actually experience and manage discomfort left room to look for the passive, lower-energy directions that a solution-driven approach rarely surfaces, and it was this same openness that eventually produced a wide range of concepts and the project's two most transferable outcomes, the Design Approach Matrix and the Desirable Attributes. Had we narrowed onto a specific problem or product category early on, we would likely have arrived at a particular solution, but not at the structured map of the opportunity space or the set of reusable criteria that this openness made possible.

In practice, staying open meant keeping the project broad, holding several possible directions in view at once rather than resolving early onto one. This breadth was not the intuitive choice, and more than once we were tempted to narrow. At the beginning, we tried to decide whether heat (summer) or cold (winter) was the more relevant problem to focus on, and later, before the ideation phase, we felt a similar pull toward committing to a few categories such as activities, windows, or materials. Each time, our industrial supervisors encouraged us to keep the scope broad rather than settle on a single direction. From IKEA's perspective, a body of research and a reusable guideline are worth more than any individual solution, and keeping the work broad served that aim as much as it served the exploration itself.

The focus of the project also shifted over time. It was framed at the outset around the sustainability of thermal comfort management, but early on it became clear that we could not sensibly ask how behaviour might be made more sustainable before understanding what comfort means to people and what shapes it. Sustainability did not leave the project so much as change position: it moved from being the starting question to being carried through the desirable attribute of energy use, which is why the refined concepts lean deliberately toward passive, lower-energy solutions. That reordering was itself part of what we learned: understanding comfort has to come before making it sustainable.

The breadth of this project, however, brought a good deal of uncertainty into the day-to-day work. The factors framework held many dimensions at once, the insights came from several different sources, and by the ideation stage there were more themes and categories available than could reasonably be pursued together. Without a single defined problem to design against, the process often lacked an ob-

vious point of focus, we felt this most acutely during ideation, when almost every possibility seemed worth exploring.

What helped us navigate through this uncertainty was finding focus locally at each stage while keeping the overall scope open. Within the factors framework, Contextual factors and Expressions were selected on the basis of how open each group was to design influence. During ideation, we worked in short sessions focused on one theme at a time before switching to another, rather than attempting to address everything simultaneously. In the evaluation stage, the desirable attributes returned to the project's aim, comfort for the many with lower energy use, which served as a criterion applicable regardless of season or direction. These working criteria made it possible to make decisions without closing off the space prematurely. The categories themselves were never merged, ideation continued to move between working from insights and working from categories, and only toward the end did this accumulated logic consolidate into the matrix.

The same breadth also limited how deep we could go. Because the survey and interviews covered both summer and winter experiences rather than concentrating on one, no single topic was examined as thoroughly as a narrower study would have allowed. Several threads that surfaced during the research looked worth pursuing in their own right, but were left unexplored in favour of coverage across the topic as a whole. The survey in particular still holds more than we were able to draw out, producing a substantial dataset whose range of participant profiles would support further analysis beyond the scope of this project. The qualitative stages were narrower still: while the survey reached a diverse pool, the interview sample skewed toward Sweden and showed limited gender variation, so the experiences captured there should be read as illustrative rather than comprehensive. A more diverse interview sample would let future work examine how thermal comfort practices and perceptions differ across cultures, climates, and demographic groups, and how the opportunity areas identified here relate to the more established solutions this project did not cover.

4.3 Further work

The design concepts developed in this project could be taken further by focusing on more detailed development, especially around mechanisms, manufacturing, and material choices. At this stage, the concepts mainly show directions and possibilities, but they would need further refinement to become fully workable products. These efforts could focus on translating the ideas into more technically resolved prototypes, exploring how different mechanical solutions could support the intended user interactions, and investigating how material selections influence how the product is scored across the desirability attributes.

For example, one direction is the integration of the Thermal Rhythm Broadcast concept within the existing IKEA ecosystem. This would involve exploring how

the concept could connect with current IKEA products, services, and smart home solutions, as well as how it fits into existing user journeys in the home, how it could be implemented through modular or scalable components, and how it aligns with IKEA's broader approach to integrated home environments.

Another important direction for further work is quantifying the impact of the proposed concepts in terms of both comfort and energy use. This would involve measuring actual energy savings associated with implementing the ideas in real-life settings, rather than only discussing them conceptually. It would also be valuable to expand the initial concept evaluation with long-term user feedback from functional prototypes. Bringing these two perspectives together could help validate the effectiveness of the concepts.

Additionally, there were several interesting directions that emerged during the process but were not explored in depth due to time and scope limitations. These could be revisited in future work, as they may open up additional ways of thinking about thermal comfort or lead to alternative solution paths that complement the ones developed in this project.

5

Conclusion

Approaching this project from an exploratory perspective resulted in a rewarding and fruitful experience as designers and researchers. Working on a topic as broad and complex as thermal comfort at home required us to adjust our approach constantly, and it allowed us to focus on people's everyday experiences and to find opportunities away from conventional solutions.

Throughout the project, we carried out a wide range of research and design activities. A literature scan and an exploratory survey made it possible to build a framework of the factors that shape people's thermal comfort experience. We then explored how people manage thermal comfort in their daily lives and how they perceive the solutions available to them. Finally, these findings were translated into design concepts through an ideation workshop, iterative design sessions, and three selection rounds. This process produced four refined concepts and functional prototypes, alongside two transferable resources: the Design Approach Matrix, which maps where thermal discomfort arises against the kinds of intervention that can address it, and the Desirable Attributes, which translate IKEA's Democratic Design principles into criteria a design team can act on.

On a personal and professional level, this project strengthened our ability to navigate uncertainty and abstract thinking. We faced the challenge of synthesising large amounts of quantitative and qualitative information and transforming findings into design opportunities and strategies.

This project was made possible by the collaboration and mentorship of supervisors, designers, peers, IKEA employees, users, and other stakeholders who contributed their insight and experience. Their input helped challenge assumptions, simplify notions, and keep the work aligned with everyday realities.

We hope the knowledge, findings, and approaches of this work will serve as a starting point for future design efforts towards more accessible, sustainable, and relevant thermal comfort solutions for the many.

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A

Exploratory Survey Questionnaire

The following questionnaire was translated, distributed online via Google Forms to participants in Sweden, China, and Mexico.

Thermal Comfort at Home

We want to understand how people adjust their home temperature throughout the year, and what everyday choices they make to stay comfortable. In this survey, thermal comfort means feeling that the temperature at home is “just right.”

This survey will take around 10 minutes to complete.

All responses will be collected anonymously. An optional section at the end of the questionnaire allows you to provide contact details if you wish to be invited to participate in a follow-up stage of the study.

Part 1. Comfort Self-evaluation

In this section, we ask about your personal experience of thermal comfort at home. There are no right or wrong answers; please answer based on what feels true for you.

- Q1.** What does being comfortable at home mean to you, in terms of temperature?
Can you describe it? (*Your personal thermal comfort definition*) [*Open-ended*]
- Q2.** Do you generally feel colder, warmer, or neutral compared to others around you? [*Single choice*]
☐ Much colder ☐ Slightly colder ☐ About the same ☐ Slightly warmer
☐ Much warmer ☐ Not sure
- Q3.** During **summer**, how often do you feel thermally comfortable at home?
[*Likert scale: 1 (Never) – 5 (Always)*]
- Q4.** During **winter**, how often do you feel thermally comfortable at home?
[*Likert scale: 1 (Never) – 5 (Always)*]
- Q5.** When I feel **too warm** at home, it affects my mood... [*Likert scale: 1 (Not at all) – 5 (Extremely)*]
- Q6.** When I feel **too cold** at home, it affects my mood... [*Likert scale: 1 (Not at all) – 5 (Extremely)*]

- Q7.** At what indoor temperature do you feel most comfortable? (*You can select more than one*) [*Multiple choice*]
☐ 18 °C or below ☐ 19 °C ☐ 20 °C ☐ 21 °C ☐ 22 °C ☐ 23 °C
☐ 24 °C ☐ 25 °C ☐ 26 °C or above ☐ It depends / varies (e.g., activity, season) ☐ I don't know
- Q8.** Under what weather conditions is it harder to feel comfortable at home? [*Multiple choice*]
☐ Very hot days ☐ Very cold days ☐ Humid days ☐ Windy days
☐ None
- Q9.** What thermal comfort problems do you experience at home? (*Select all that apply*) [*Multiple choice*]
☐ Too cold ☐ Too hot ☐ Too dry ☐ Too humid ☐ Drafts / cold air leaks ☐ Uneven temperature (between rooms) ☐ Other
- Q10.** In which situations do you most often feel thermally uncomfortable at home? [*Multiple choice*]
☐ Waking up / getting out of bed ☐ Sitting still (studying, working, watching TV) ☐ Cooking ☐ Doing housework / moving around
☐ Showering / bathing or after shower ☐ Sleeping ☐ Other

Part 2. Activities Around Thermal Comfort

Now, we will explore how you usually manage and adapt your spaces to achieve thermal comfort.

- Q11.** How much control do you feel you have over your home temperature? [*Likert scale: 1 (No control) – 5 (Full control)*]
- Q12.** What makes it hard to improve the temperature comfort in your home? [*Multiple choice*]
☐ Cost (bill) ☐ Limited control (building / landlord / system controls settings) ☐ Need to compromise with people I live with ☐ Not sustainable ☐ Not sure what to do ☐ Not worth the effort ☐ No difficulties, I have enough control ☐ Other
- Q13.** How often do you actively adjust something to improve thermal comfort at home? [*Likert scale: 1 (Never) – 5 (Always)*]
- Q14.** When you feel uncomfortable, what is the most common way you use to improve your comfort? [*Single choice*]
☐ Adjust the temperature of the whole home ☐ Adjust the temperature of a specific room / zone ☐ Adjust body exposure to temperature (clothing, blanket, cold / hot drink) ☐ I don't do anything about it ☐ Not sure
- Q15.** What do you do when your home is **too hot**? [*Multiple choice*]

☐ Modify / remove clothing ☐ Use a device to change temperature or adjust thermostat ☐ Open window(s) ☐ Use curtains / close blinds
☐ Change room ☐ Take a shower ☐ Drink cold beverages ☐ Do nothing ☐ Go to a commercial or public place ☐ Other

Q16. What do you do when your home is **too cold**? [*Multiple choice*]

☐ Modify / add clothing ☐ Use a device to change temperature or adjust thermostat ☐ Get a blanket ☐ Change to another room ☐ Drink hot beverages ☐ Do nothing ☐ Go to a commercial or public place ☐ Other

Q17. What **devices** do you use when your home is **too hot**? [*Multiple choice*]

☐ Air conditioner (cooling mode) ☐ Fan ☐ Swamp cooler / evaporator
☐ None ☐ Other

Q18. What **devices** do you use when your home is **too cold**? [*Multiple choice*]

☐ Air conditioning (heating mode) ☐ Gas heater / gas fireplace ☐ District heating ☐ Electric space heater ☐ Fireplace or wood-burning stove
☐ Radiator (in-house water boiler) ☐ Floor heating ☐ None ☐ Other

Q19. In your opinion, how sustainable are the solutions you currently use to improve your thermal comfort at home? [*Likert scale: 1 (Not sustainable) – 5 (Very sustainable)*]

Q20. What is one thing you would like to change to improve your thermal comfort in your home? [*Open-ended*]

Part 3. Context Information

Q21. Which country do you live in? * [*Open-ended*]

Q22. What city do you live in? * [*Open-ended*]

Q23. Which best describes where you live? * [*Single choice*]

○ High-density urban area ○ Suburbs or city outskirts ○ Countryside

Q24. What is your housing type? * [*Single choice*]

○ Apartment ($\leq 50 \text{ m}^2$) ○ Apartment ($> 50 \text{ m}^2$) ○ Townhouse (row house)
○ Detached house ○ Other

Q25. How old is your house? [*Single choice*]

○ New (built 2015 or later) ○ Recent (built 2000–2014) ○ Mid-age (built 1970–1999) ○ Older (built 1950–1969) ○ Very old / historic (built before 1950) ○ I don't know

Q26. Who owns your home? * [*Single choice*]

○ I rent ○ I own it ○ My partner / family ○ Other

Q27. Who do you live with? [*Single choice*]

A. Exploratory Survey Questionnaire

- I live alone ◦ I live with my romantic partner ◦ I live with my family
- I live with my roommates ◦ Other

Q28. Does your household include any of the following? (*Select all that apply*)
[Multiple choice]

- ☐ Children ☐ Elderly people ☐ Pets ☐ None of the above

Q29. Age * [Open-ended, numeric]

Q30. Sex assigned at birth * [Single choice]

- Male ◦ Female ◦ Intersex ◦ Prefer not to say

Q31. How many hours are you typically at home on a weekday? [Single choice]

- Less than half day ◦ Half day ◦ Most of the day ◦ All day ◦ Not sure

Q32. Do you work / study from home most weekdays? [Single choice]

- Yes, mainly at home ◦ Partly (hybrid) ◦ No (mostly outside) ◦ Not applicable

Further Participation (*Optional*)

Q33. Would you be willing to participate in a later stage of this study? This would involve being contacted for a short interview. You may withdraw your participation at any time without providing a reason. [Single choice]

- Yes ◦ No

If “Yes,” participants were asked to optionally provide their name, email, and phone number.

B

Insight Cards from Stage 1 Synthesis

This appendix lists all insight cards used as input for the affinity synthesis described in Section 2.1.3. Each card represents one insight extracted from earlier work, coded by source so that grouping decisions can be traced back to their origin. Cards are grouped by source type and ordered by source ID.

B.1 Literature insights (L-cards)

Source	Content
L-1	Apartment dwellers lack control over orientation, shading, and ventilation systems.
L-1	Treating heat adaptation as a reconfiguration of everyday practices rather than a technology problem (daily routines and micro-decisions).
L-1	Heatwaves in Sweden affect everyday life (sleep, daily energy levels, and overall wellbeing).
L-1	Conflicts between summer values in Sweden and heat-adaptation advice; closing blinds is a thermal benefit but an experiential loss.
L-2	There are more artefacts that are energy-reliant than those used for energy management in a home.
L-7	Heatwaves impact urban areas more than rural areas (Sweden).
L-7	Some managers know guidelines exist, but frontline staff often lack awareness, training, and experience in applying advice under real constraints (comfort related to preparedness).
L-10	Overheating in Dutch homes, affecting comfort especially for sleeping and working.
L-10	Air conditioning can crowd out low-energy practices because it is low-effort, and conflicts with ventilation (closed windows), increasing lock-in risk.
L-10	Cooling adoption may also reshape lifestyles (more time in cooled spaces).
L-10	Overheating risk and coping options vary by housing type and socio-economic conditions.

Source	Content
L-11	There was a significant willingness-to-pay (WTP) for thermal comfort.
L-11	Relative importance: 51% for thermal comfort (WTP = 377.94 EUR/m ²).
L-11	Indoor comfort includes thermal, visual, and acoustic comfort, and indoor air quality.
L-15	Among all problems, most were related to temperature: cold floors (22%), too high temperature in summer (20%), condensation on windows (16%), too low temperature in winter (14%), noise from outside or neighbours (14%), and draught (12%).
L-15	Gender and ownership of the dwelling influenced the way people control the indoor environment.
L-15	Open windows were a way of expressing love and care for the family and the home, and connecting with nature.
L-15	The 10 most frequently mentioned factors (in own words) included light, temperature, air quality, and noise level.
L-15	Beyond IEQ metrics: peace and silence, contact with nature and view.
L-15	In China, it was observed that people did not understand well how thermostatic radiator valves function and used them as they would manually controlled valves.
L-15	Occupants did not know how to operate thermostatic radiator valves, and as a result overheating often occurred in households.
L-15	Finnish occupants felt quite confident about their knowledge of heating and ventilation systems in homes.
L-15	More than half of people did not seek information, because the problem did not seem serious enough to act on.
L-15	Among those who did seek information, the internet was the most common source.
L-15	Improving people's knowledge on how to ensure a good indoor climate is needed.
L-15	Window opening was higher in families with a housewife at home and increased with family size.
L-15	Manual control was preferred, but people were more positive towards automatic or mixed control for temperature.
L-15	Air conditioning use differed by origin, childhood experience, and attitude towards air conditioning.
L-15	Radiator use was associated with thermostat type, the presence of elderly people, and past residence.
L-15	Respondents valued natural ventilation highly, and it was very important for them that they could open a window in their home.
L-20	Conventional thermal comfort includes personal factors (clothing insulation, metabolic rate) and environmental factors (air temperature, humidity, air velocity, and mean radiant temperature).

Source	Content
L-22	Ergonomics definition of comfort: aesthetics and plushness, relaxation, well-being, and relief and energy.
L-22	Habits and controllability are paramount in the links between comfort and energy consumption.
L-22	Because energy use is often not directly visible, habits can persist and become difficult to change.
L-22	The home environment can provide contextual cues that trigger automatic behaviours and habits.
L-22	Personal factors: type of clothing worn, overall movement and activity, metabolic rate (age, health, and body composition).
L-22	Comfort (including thermal comfort) is framed as maintaining or restoring homeostasis.
L-22	IEQ definition: physiological, visual, and other dimensions.
L-22	Indoor comfort includes thermal, visual, and acoustic comfort, and indoor air quality.
L-22	Comfort is a cognitive-behavioural process.
L-22	Holistic definition of comfort, cognitive dimension: “a pleasant state of physiological, psychological and physical harmony between a human being and its environment”.
L-22	Domestic definition of comfort: perceptual, interactive, facilitative, and personalisation comfort (Heijs and Stringer).
L-22	Healthcare definition of comfort, three states: relief (specific needs are met), ease (calm and contentment), transcendence (going beyond problems or pain).
L-22	Comfort-making activities: loss of homeostasis, behaviours (habits/control), restored comfort, wellbeing/health.
L-22	Feeling in control (e.g., adjusting heating, opening windows, managing privacy) reduces stress and increases comfort.
L-22	Emotions are tightly linked to behaviours and decision-making. Feeling emotions enables making decisions and motivating behaviours.
L-25	Behaviours, activities, and visual design in a space can shape perceived comfort. The canteen achieved higher perceived visual and thermal comfort despite lower measured illuminance.
L-25	Indoor environmental quality was generally acceptable and complied with comfort ranges suggested by regulations.
L-26	Indoor thermal factors: temperature, humidity, air movement.
L-27	Behavioural schema/representations are linked to physical responses (actions, coping, habituation).
L-27	Comfort is explicitly a “state of mind”.
L-27	People do not respond to temperature directly; they interpret it through past experience, seasonal memory, expectations, and adaptation.
L-27	In each season, specific “mental codes” are categorised in long-term memory and are activated when similar or related stimuli occur.

Source	Content
L-27	Schema consistency shapes what is noticed and how it is interpreted.
L-27	Seasonal memory and seasonal context, together with expectations, are key schema factors.
L-27	Perceptual schema/representations are linked to non-physical responses (attitudes, perceived control, expectations).
L-27	Thermal sensation is first evaluated against perceptual schema.

B.2 Survey insights (S-cards, Q-prefix)

Source	Content
S-Q1	Thermal sensation varies by individual, but most people like to stay in the middle.
S-Q1	People's comfort degree varies; some like cold, some like warm.
S-Q1	Thermal comfort should be experienced as an invisible, background condition.
S-Q1	People don't want to be bothered by temperature management.
S-Q1	Thermal comfort is needed for a calm, stable mood.
S-Q1	Thermal comfort supports people's daily activities at home.
S-Q1	Most people (32%) want to wear less (T-shirt) at home under good temperature conditions.
S-Q1	Clothing freedom symbolises the level of comfort (32%).
S-Q1	Thermal comfort is associated with air flows, air freshness, and humidity.
S-Q1	24% of people define their base on a specific temperature (range).
S-Q1	Higher humidity levels seem to be more desirable in winter.
S-Q2	More than half of respondents (54.6%) feel colder than others, while only 24.4% feel warmer.
S-Q3	Cold is the biggest issue at home, with 59.7% reporting "too cold," followed by 47.4% reporting "too hot," showing that temperature discomfort is common in both directions, but cold stands out most.
S-Q4	58.8% struggle on very hot days and 51.8% on very cold days, while humid (17.5%) and windy days (7.9%) matter far less.
S-Q5	Summer comfort frequency: in summer, 52.9% of respondents rate their home comfort as high (4–5), compared with 25.2% rating it low (1–2).
S-Q6	Winter comfort frequency: in winter, 46.2% of respondents rate their home comfort as high (4–5), while 29.9% rate it low (1–2).
S-Q7	Feeling too warm at home has a strong mood impact for most respondents, with 63.0% rating the effect as high (4–5), while only 17.6% rate it low (1–2).

Source	Content
S-Q8	Feeling too cold at home also affects mood, with 50.8% rating the effect as high (4–5) compared with 22.0% rating it low (1–2), though the impact is weaker than for heat.
S-Q9	Temperature numbers show a certain level of comfort (most respondents identified a preferred indoor temperature).
S-Q10	Thermal discomfort is most common when waking up or getting out of bed (46.5%), followed by sitting still (35.1%), showering or after shower (28.1%), sleeping (23.7%), and doing housework (18.4%).
S-Q12	The biggest barrier to improvement is limited control (50.9%), followed by cost (35.1%), with smaller groups mentioning other reasons (17.5%), sustainability concerns (14.9%), compromising with others (14.0%), or not knowing what to do (13.2%).
S-Q12	13.16% lack knowledge to improve thermal comfort.
S-Q14	More than half of respondents (54.6%) improve comfort by adjusting their own body first, while fewer change a specific room (29.4%) or the whole home (12.6%).
S-Q14	Overall action: own body 54.6%, specific room 29.4%, whole home 12.6%.
S-Q15	Cooling actions: most common responses are removing clothing (58.8%) and opening windows (58.8%), followed by drinking cold beverages (44.7%) and adjusting a device or thermostat (40.4%), while fewer use curtains (36.0%) or take a shower (28.1%).
S-Q16	Heating actions: people mainly rely on personal warming strategies, with adding clothing (73.7%) and getting a blanket (68.4%) as the top responses, followed by drinking hot beverages (46.5%), while only 23.7% use a device to change the temperature.
S-Q17	Cooling devices: fans (59.6%) and air conditioning in cooling mode (51.8%) are the most commonly used devices, while 17.5% use no device at all.
S-Q18	Heating devices: when the home is too cold, the most commonly used heating systems are radiators (37.7%), electric space heaters (27.2%), and air conditioning in heating used by 14.9%, with floor heating used by 7.0% and only 7.0% reporting no heating device.
S-Q20	One thing people want to improve: (1) device, (2) insulation, (3) control.
S-Q20	21% responded they wish to improve insulation in their homes.
S-Q20	Insulation problems ranking: (1) windows and air leaks, (2) house materials, (3) protection against sun.
S-Q20	14% wish to increase their control over thermal comfort.
S-Q20	Landlord-controlled spaces represent a limitation.
S-Q20	Air conditioners seem to be a desirable solution (both stand-alone and central systems).
S-Q20	Lots of variations in the types of heaters people want.
S-Q20	Ventilation promotes air quality.

Source	Content
S-Q20	Ventilation helps even out temperatures across rooms.
S-Q20	During winter, some people want more windows to let sunlight in; some want less windows to reduce air leaks and insulation issues.
S-Q20	Convenience and coordination with everyday tasks are important elements of control.
S-Q20	Most people want to improve something (90% above).
S-Q20	Only 4% are satisfied with keeping things as they are.

B.3 Survey cross-comparison findings (S-cards, C-prefix)

Source	Content
S-C1	Extreme temperature sensation affects people’s mood.
S-C2	Ownership status does not influence thermal comfort.
S-C4	Home temperature control contributes more to thermal comfort during winter than summer.
S-C5	During winter, people living in detached homes seem to experience slightly less thermal comfort.
S-C6	The majority of people report feeling slightly colder or much colder than the people around them: 63.49% female and 36.51% male.
S-C7	People who report feeling colder than others (54.62%) have their mood affected equally by extreme cold and extreme heat, slightly more affected by the cold (53.33% vs 65%).
S-C8	Levels of control are lower in renters (avg 2.85/5); most of them report medium-to-low control.

B.4 Digital ethnography insights (D-cards)

Source	Content
D-25	Temperature matters because it supports feeling “just right,” especially for sleep, relaxation, and a sense of control, within a broader multisensory and emotional understanding of comfort.
D-26	Getting comfortable takes effort, and gets in the way of rest. When comfort feels like too much work, people give up on it.
D-26	When shared with others, comfort can feel like a scarcity, a finite resource where if someone gets more, someone else gets less.
D-26	Comfort is an active process of making an environment your own.

Source	Content
D-26	Bringing nature inside the home introduces change and flow to a home and keeps a space alive.
D-28	Mean Radiant Temperature (MRT) strongly influences how warm or cool you feel regardless of the air temperature.
D-28	Windows and sunlight play an important role in MRT comfort. In modern buildings, especially with large glazed faces, MRT is often dominated by window temperatures.
D-29	Psychological factors: this component of thermal comfort refers to personal preferences and the ability to adjust one's surrounding environment to increase or reduce the current temperature or flow of air.
D-29	Healthcare definition of comfort, context of comfort: physical (bodily feelings), psychospiritual (inner self), social (family/cultural relationships), environmental (light, noise, temperature, sensations).
D-29	Personal factors: type of clothing worn, overall movement and activity, metabolic rate (age, health, and body composition).
D-29	Environmental factors: air temperature, humidity, surface/radiant temperature, ventilation.

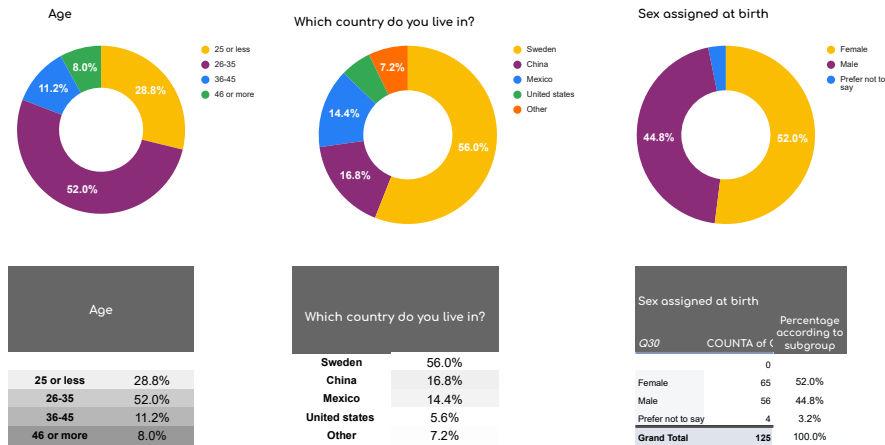
C

Survey Data Analysis

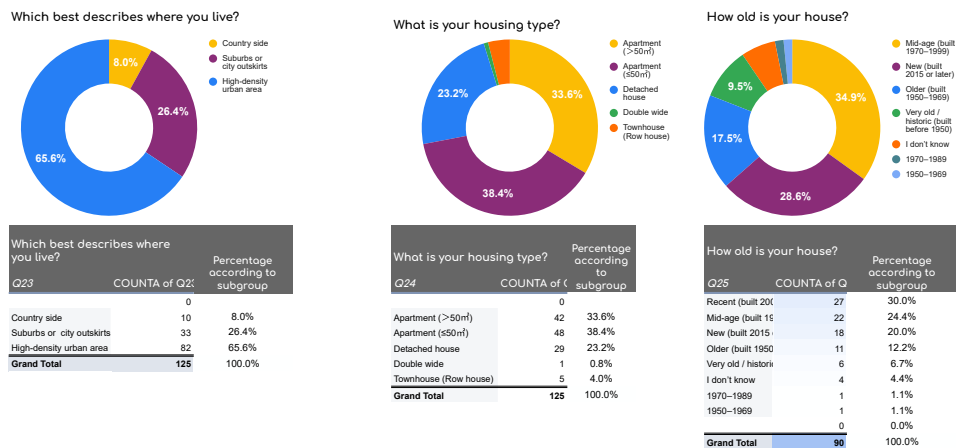
The following pages present a summary of all 125 survey responses. The analysis was conducted in Excel and is organized into four groups: general information, Likert scale ratings, single-choice questions, and multiple-choice questions.

C.1 General Information

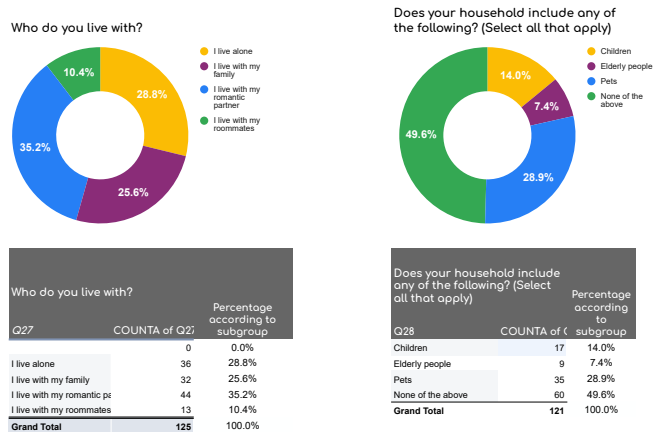
Demographics



Home features

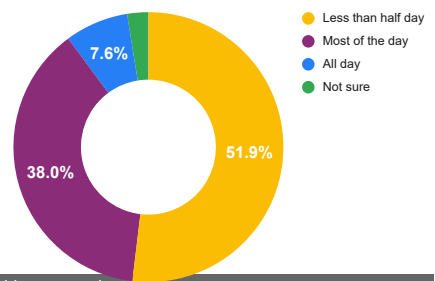


Household composition



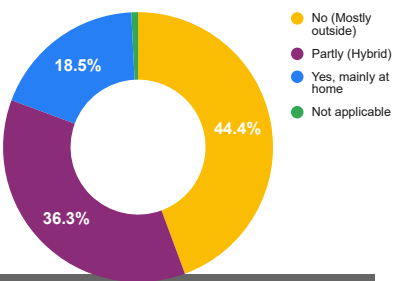
Lifestyle

How many hours are you typically at home on a weekday?



How many hours are you typically at home on a weekday?		
Q31	COUNTA of Q31	Percentage according to subgroup
Half day	44	35.2%
Less than half day	41	33.3%
Most of the day	30	24.4%
All day	6	4.9%
Not sure	2	1.6%
	0	0.0%
Grand Total	123	100.0%

Do you work/study from home most weekdays?



Do you work/study from home most weekdays?		
Q32	COUNTA of Q32	Percentage according to subgroup
No (Mostly outside)	55	44.0%
Partly (Hybrid)	45	36.0%
Yes, mainly at home	23	18.4%
Not applicable	1	0.8%
	0	0.0%
Grand Total	124	99.2%

C.2 Likert Scale Ratings

During summer, how often do you feel thermally comfortable at home	1-5 scale (Never-Always)	1 2 3 4 5	Q5	1	2	3	4	5
			125	7	25	27	47	19
			100%	5.60%	20.00%	21.60%	37.60%	15.20%
							52.80%	
During winter, how often do you feel thermally comfortable at home	1-5 scale (Never-Always)	1 2 3 4 5	Q6	1	2	3	4	5
			123	8	28	31	42	14
			100%	6.50%	22.76%	25.20%	34.15%	11.38%
							45.53%	
When I felt too warm at home, it affects my mood...	1-5 scale (Not at all-Extremely)	1 2 3 4 5	Q7	1	2	3	4	5
			125	7	16	25	36	41
			100%	5.60%	12.80%	20.00%	28.80%	32.80%
When I felt too cold at home, it affects my mood...	1-5 scale (Not at all-Extremely)	1 2 3 4 5	Q8	1	2	3	4	5
			124	7	21	35	26	35
			100%	5.65%	16.94%	28.23%	20.97%	28.23%
How much control do you feel you have over your home temperature?	1-5 scale (No control-Full control)	1 2 3 4 5	Q11	1	2	3	4	5
			125	10	29	43	31	12
			100%	8.00%	23.20%	34.40%	24.80%	9.60%
How often do you actively adjust something to improve thermal comfort at home?	1-5 scale (Never-Always)	1 2 3 4 5	Q13	1	2	3	4	5
			125	7	28	37	32	21
			100%	5.60%	22.40%	29.60%	25.60%	16.80%
In your opinion, how sustainable are the solutions you currently use to improve your thermal comfort at home?	1-5 scale (Not sustainable-Very sustainable)	1 2 3 4 5	Q19	1	2	3	4	5
			124	9	18	43	33	21
			100%	7.26%	14.52%	34.68%	26.61%	16.94%

C.3 Single-choice Questions

Do you generally feel colder, warmer, or neutral compared to others around you?	Much colder Slightly colder About the same Slightly warmer Much warmer Not sure	Q2	Much colder	Slightly colder	About the same	Slightly warmer	Much warmer	Not sure	
		125	15	54	24	19	11	2	
		100%	12.00%	43.20%	19.20%	15.20%	8.80%	1.60%	
			55.20%						
When you feel uncomfortable, what is the most common way you use to improve your comfort?	Adjust the temperature of the whole home Adjust the temperature of a specific room/zone Adjust body exposure to temperature (clothing blanket cold/hot drink) I don't do anything about it	Q14	Adjust the temperature of the whole home	Adjust the temperature of a specific room/zone	Adjust body exposure to temperature (clothing blanket cold/hot drink)	I don't do anything about it	Not sure		
		125	16	36	65	1	3		
		100%	12.80%	28.80%	52.00%	0.80%	2.40%		
Which best describes where you live?	High-density urban area Suburbs or city outskirts Country side	Q23	High-density urban area	Suburbs or city outskirts	Country side				
		125	82	33	10				
		100%	65.60%	26.40%	8.00%				
What is your housing type?	Apartment (≤50m²) Apartment (>50m²) Townhouse (Row house) Detached house Other	Q24	Apartment (≤50 m²)	Apartment (> 50m²)	Townhouse (Row house)	Detached house	Other		
		125	48	42	5	29	1		
		100%	38.40%	33.60%	4.00%	23.20%	0.80%		
How old is your house?	New (built 2015 or later) Recent (built 2000–2014) Mid-age (built 1970–1999) Older (built 1950–1969) Very old / historic (built before 1950) I don't know	Q25	New (built 2015 or later)	Recent (built 2000–2014)	Mid-age (built 1970–1999)	Older (built 1950–1969)	Very old / historic (built before 1950)	I don't know	No
		90	16	25	21	11	5	4	8
		100%	17.78%	27.78%	23.33%	12.22%	5.56%	4.44%	
Who owns your home?	I rent I own it My partner/family Other	Q26	I rent	I own it	My partner/family	Other			
		125	73	31	18	3			
		100%	58.40%	24.80%	14.40%	2.40%			
Who do you live with?	I live alone I live with my romantic partner I live with my family I live with my roommates Other	Q27	I live alone	I live with my romantic partner	I live with my family	I live with my roommates	Other		
		125	36	44	32	13	0		
		100%	28.80%	35.20%	25.60%	10.40%	0.00%		
Sex assigned at birth	Male Female Intersex Prefer not to say	Q30	Male	Female	Intersex	Prefer not to say			
		125	56	65	0	4			
		100%	44.80%	52.00%	0.00%	3.20%			
How many hours are you typically at home on a weekday?	Less than half day Half day Most of the day All day Not sure	Q31	Less than half day	Half day	Most of the day	All day	Not sure		
		123	41	44	30	6	2		
		100%	33.33%	35.77%	24.39%	4.88%	1.63%		
Do you work/study from home most weekdays?	Yes, mainly at home Partly (Hybrid) No (Mostly outside) Not applicable	Q32	Yes, mainly at home	Partly (Hybrid)	No (Mostly outside)	Not applicable			
		124	23	45	55	1			
		100%	18.55%	36.29%	44.35%	0.81%			

C.4 Multiple-choice Questions

What thermal comfort problems do you experience at home? (Select all that apply)	Too cold Too hot Too dry Too humid Drafts / cold air leaks Uneven temperature (between rooms) None Other	Q3	Too cold	Too hot	Too dry	Too humid	Drafts / cold air leaks	Uneven temperature (between rooms)	None	Other						
		122	74	57	32	27	33	40	1	4						
			60.66%	46.72%	26.23%	22.13%	27.05%	32.79%	0.82%	3.28%						
		100%														
Under what weather conditions is it harder to feel comfortable at home?	Very hot days Very cold days Humid addays Windy days None	Q4	Very hot days	Very cold days	Humid addays	Windy days	None									
		122	67	58	20	9	3									
		100%	54.92%	47.54%	16.39%	7.38%	2.46%									
At what indoor temperature do you feel most comfortable? (You can select more than one)	18 °C 20 °C 21 °C 22 °C 23 °C 24 °C 25 °C 26 °C or above It depends / varies (e.g. activity season)	Q9	18 °C or below	19 °C	20 °C	21 °C	22 °C	23 °C	24 °C	25 °C	26 °C or above	It depends / varies (e.g. activity season)	I don't know			
		122	4	13	25	27	41	30	24	16	5	27	4			
		100%	3.28%	10.66%	20.49%	22.13%	33.61%	24.59%	19.67%	13.11%	4.10%	22.13%	3.28%			
In which situations do you most often feel thermally uncomfortable at home?	Sitting still (Studying, working, watching TV) Cooking Doing housework / Moving around Showering / bathing or after shower	Q10	Waking up / getting out of bed	Sitting still (Studying, working, watching TV)	Cooking	Doing housework	Showering / bathing or after shower	Sleeping	Other							
		122	52	40	14	21	31	27	12							
		100%	42.62%	32.79%	11.48%	17.21%	25.41%	22.13%	9.84%							
What makes it hard to improve the temperature comfort in your home?	No system (e.g. no radiator) / system controls settings Need to compromise with people I live with Not sustainable Not sure what to do Not worth the effort No difficulties, I have enough control	Q12	Cost (bill)	Limited control (building/landlord/system controls settings)	Need to compromise with people I live with	Not sustainable	Not sure what to do	Not worth the effort	No difficulties, I have enough control	Other						
		122	40	57	16	17	15	3	8	20						
		100%	32.79%	46.72%	13.11%	13.93%	12.30%	2.46%	6.56%	16.39%						
What do you do when your home is too hot?	Use a device to change temperature or adjust thermostat of installed system Open window/s Use curtains / close blinds Change room Take a shower Drink cold beverages Do nothing Go to a commercial or public place	Q15	Modify/Remove clothing	Use a device to change temperature or adjust thermostat of installed system	Open window/s	Use curtains / close blinds	Change room	Take a shower	Drink cold beverages	Do nothing	Go to a commercial or public place	Other				
		122	66	45	66	40	9	32	50	0	12	5				
		100%	54.10%	36.89%	54.10%	32.79%	7.38%	26.23%	40.98%	0.00%	9.84%	4.10%				
What do you do when your home is too cold?	Use a device to change temperature Get a blanket Change to another room Drink hot beverages Do nothing Go to a commercial or public place	Q16	Modify/Add clothing	Use a device to change temperature	Get a blanket	Change to another room	Drink hot beverages	Do nothing	Go to a commercial or public place	Other						
		122	83	27	77	10	52	1	1	47						
		100%	68.03%	22.13%	63.11%	8.20%	42.62%	0.82%	0.82%	38.52%						
What devices do you use when your home is too hot?	Air conditioner (Cooling mode) Fan Swamp cooler / Evaporator None Other	Q17	Air conditioner (Cooling mode)	Fan	Swamp cooler / Evaporator	None	Other									
		122	59	67	10	20	2									
		100%	48.36%	54.92%	8.20%	16.39%	1.64%									
What devices do you use when your home is too cold?	Fireplace District Heating Electric space heater Fireplace or wood-burning stove Radiator (in-house water boiler)	Q18	Air conditioner (Heating mode)	Gas heater/Gas fireplace	District Heating	Electric space heater	Fireplace or wood-burning stove	Radiator (in-house water boiler)	Floor heating	None	Other					
		122	27	11	9	31	7	43	17	7	34					
		100%	22.13%	9.02%	7.38%	25.41%	5.74%	35.25%	13.93%	5.74%	27.87%					
Does your household include any of the following? (Select all that apply)	Children Elderly people Pets None of the above	Q28	Children	Elderly people	Pets	None of the above										
		122	17	9	35	60										
		100%	13.93%	7.38%	28.69%	49.18%										

D

Interview Materials

Day Mapping

Please talk us through a typical day at home, including:

- which spaces you use
- what activities you do
- when you feel more or less comfortable

Space	Bedroom	Living room	Kitchen	Dining room			
	Bathroom	Study/work area	Hallway	Balcony			
Feeling	Too cold	A bit cold	Comfortable	A bit warm	Too warm	Dry	
Activity	Sleeping	Waking up	Getting dress	Cooking	Eating	Exercising	
	Working	Relaxing	Cleaning	Socializing	Watching TV		

1

Cold Experience Map

Please describe your typical winter day at home. We will map your spaces, activities, and comfort levels on the timeline together.

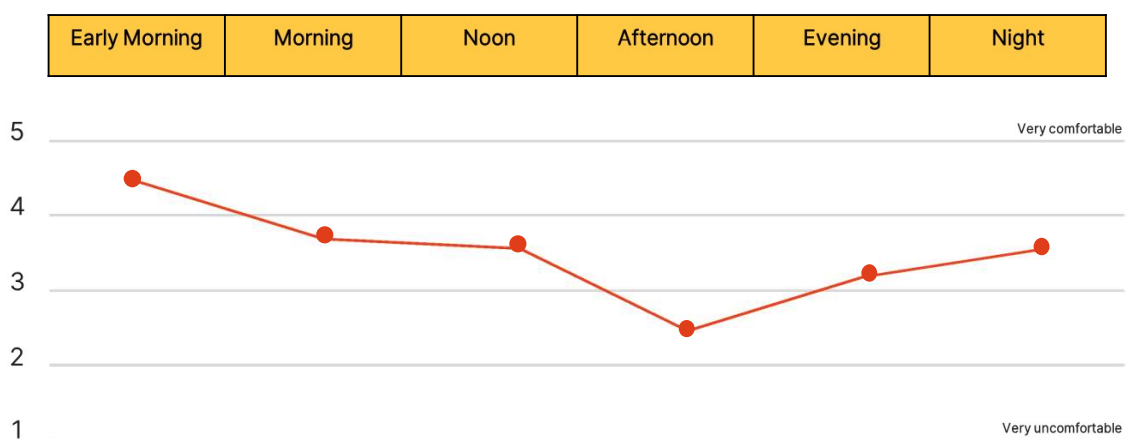


2

1

Heat Experience Map

Please describe your typical summer day at home. We will map your spaces, activities, and comfort levels on the timeline together.



3

Activity ranking

List 3 activities you regularly do at home where thermal comfort has higher impact.

- 1.
- 2.
- 3.

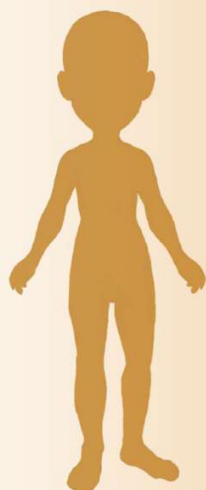
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4

Activity 1

Summer

Winter

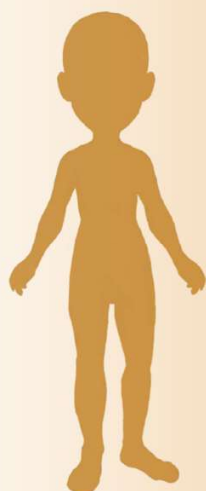


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Activity 2

Summer

Winter

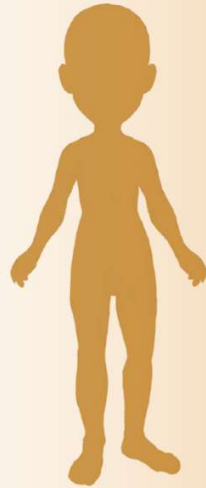


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Activity 3

Summer

Winter



7

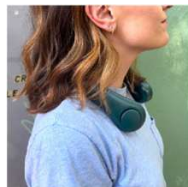
Possible solutions

What are your thoughts on this solution?



for the winter

for the summer



Personal devices

4

8

Possible solutions

What are your thoughts on this solution?



Heating & Cooling furniture

for the winter

for the summer

9

Possible solutions

What are your thoughts on this solution?



micro/climate bubbles

for the winter

for the summer

5

10

Possible solutions

What are your thoughts on this solution?



wall/floor system

for the winter

for the summer

11

Possible solutions

What are your thoughts on this solution?



Thermal adjusting blankets

for the winter

for the summer

12

Possible solutions

What are your thoughts on this solution?



window insulation

for the winter

for the summer

13

Possible solutions

is there any additional solutions you can think of?

for the winter

for the summer

?

7

14

E

Interview Quantitative Data

The following pages present the quantitative data collected during the interviews, covering the experience-map scores behind the group charts in Section 3.2.1 and the responses to the activities, clothing, and future-probing exercises.

	Participant 1		Participant 2	
Sex	Female		Male	
Age	38		34	
Country	New Zealand		USA	
Home type	Detached house		Apartment (> 50m²)	
Living context	I rent		I rent	
Experience Scores				
	Summer	Winter	Summer	Winter
Early morning	2.5	4	4	5
Morning	2.5	2	4	5
Noon	2.5	3	4	5
Afternoon	2.5	4	4	5
Evening	2.5	3	4	5
Night	2.5	3	4	5
Worse time of day	All day	Morning	None	None
Used devices	None	Air conditioner	AC, Fan	AC
Prioritized Activities				
Activity 1	Sleeping		Cooking	
Activity 2	Shower		Working	
Activity 3	Working		Working out	
Clothing				
	Summer	Winter	Summer	Winter
Sleeping	Tank, shorts	Long sleeve, sweater, thermal pants	T-Shirt and Shorts	Long Sleeve and Shorts + Light sweater
Shower	N/A	N/A	T-Shirt and Shorts	Long sleeve, jeans + blanket
Working	T-shirt, Sweatpants	Long sleeve, winter jacket, sweatpants	Tank top and shorts	Tank top and shorts
Future probing for non-conventional devices				
	Summer	Winter	Summer	Winter
Personal Devices	YES	NO	YES	YES
Furniture	NO	NO	NO	NO
Micro Spaces	YES	YES	YES	YES
Wall/Floor system	YES	YES	YES	YES
Blankets	YES	YES	MAYBE	NO
Window insulation	YES	NO	NO	NO

	Participant 3		Participant 4	
Sex	Male		Male	
Age	24		31	
Country	Sweden		Sweden	
Home type	Apartment (≤50m²)		Detached house	
Living context	I own it		I own it	
Experience Scores				
	Summer	Winter	Summer	Winter
Early morning	4.5	2.8	3	2
Morning	3.5	4.8	4	3.8
Noon	2.5	/	/	/
Afternoon	/	/	2	2
Evening	2	4.1	3	3.8
Night	4	3.5	3	3.8
Worse time of day	Evening	Early morning & Night	Afternoon	Early morning, Afternoon
Used devices	Open windows, close blinds	Radiator, passive methods (robe, hot tea, hot shower)	Curtains, Window	Floor heating, Fireplace
Prioritized Activities				
Activity 1	Sleeping (falling asleep)		Cooking	
Activity 2	Cleaning		Socializing	
Activity 3	Cooking		Getting dress	
Clothing				
	Summer	Winter	Summer	Winter
Sleeping	Shors and T-Shirt	Long Sleeve and Sweatpants	Shorts, T-Shirt	Jeans, T-shirt, Long sleeve
Shower	Shors and T-Shirt	T-Shirt and Sweatpants	Shorts, T-Shirt	Jeans, T-shirt, Long sleeve
Working	Shors and T-Shirt	T-Shirt and Sweatpants	N/A	N/A
Future probing for non-convetional devices				
	Summer	Winter	Summer	Winter
Personal Devices	YES	YES	NO	NO
Furniture	YES	MAYBE	YES	YES
Micro Spaces	NO	YES	NO	NO
Wall/Floor system	YES	NO	YES	YES
Blankets	YES	NO	NO	NO
Window insulation	NO	YES	NO	NO

	Participant 5		Participant 6	
Sex	Female		Male	
Age	50		44	
Country	USA		United States	
Home type	Townhouse (Row house)		Townhouse (Row house)	
Living context	I own it		I own it	
Experience Scores				
	Summer	Winter	Summer	Winter
Early morning	5	3.5	5	5
Morning	5	5	5	5
Noon	5	5	5	5
Afternoon	5	5	4	5
Evening	5	5	5	5
Night	5	5	5	5
Worse time of day	None	Early morning	Afternoon	None
Used devices	AC	AC	AC	AC
Prioritized Activities				
Activity 1	Sleeping		Sleeping	
Activity 2	Working out		Getting dress	
Activity 3	Cleaning		Socializing	
Clothing				
	Summer	Winter	Summer	Winter
Sleeping	T-shirt, Shorts	Longsleet and thermal pants	Shorts	Sweatpants and long sleeve
Shower	T-shirt, Shorts	Longsleet and legging	/	/
Working	Tank, shorts	Sweatpants, sweater	T-shirt, shorts	Jeans, jacket
Future probing for non-convetional devices				
	Summer	Winter	Summer	Winter
Personal Devices	YES	YES	NO	YES
Furniture	YES	NO	YES	YES
Micro Spaces	MAYBE	YES	YES	YES
Wall/Floor system	YES	YES	YES	YES
Blankets	YES	YES	NO	NO
Window insulation	YES	YES	NO	NO

	Participant 7		Participant 8	
Sex	Male		Female	
Age	32		42	
Country	Mexico		Sweden	
Home type	Detached house		Detached house	
Living context	I own it		I own it	
Experience Scores				
	Summer	Winter	Summer	Winter
Early morning	5	1.5	3	4.5
Morning	4	3.5	3	5
Noon	5	3.5	3	/
Afternoon	5	3.5	3	4
Evening	5	3.5	3	4.5
Night	5	3.5	3	4.5
Worse time of day	Morning	Early morning	All day	Afternoon
Used devices	Fan, AC, blanket	AC, Gas heater	Fan	bergvärme system, buildt-in radiator
Prioritized Activities				
Activity 1	Working		Working	
Activity 2	Sleeping		Sleeping	
Activity 3	Working out		Socializing	
Clothing				
	Summer	Winter	Summer	Winter
Sleeping	T-Shirt and Shorts	Long sleeve and Sweatpants	Light dress	Long sleeve and Jeans + Sweater
Shower	T-Shirt and Shorts	T-Shirt and Sweatpants	Tank top and Shorts	Tank top and Shorts
Working	T-Shirt and Shorts	T-Shirt and Sweatpants	Light dress	Long sleeve and Jeans + Sweater
Future probing for non-convetional devices				
	Summer	Winter	Summer	Winter
Personal Devices	YES	NO	NO	YES
Furniture	YES	YES	YES	YES
Micro Spaces	MAYBE	YES	YES	YES
Wall/Floor system	YES	YES	YES	YES
Blankets	NO	YES	NO	NO
Window insulation	NO	NO	NO	YES

	Participant 9		Participant 10	
Sex	Male		Female	
Age	29		25	
Country	Sweden		China mostly	
Home type	Apartment (≤50m²)		Apartment (≤50m²)	
Living context	I rent		My partner/family	
Experience Scores				
	Summer	Winter	Summer	Winter
Early morning	3	5	5	3
Morning	5	2	5	4
Noon	4	3	3	/
Afternoon	3	4	4	/
Evening	2	3	5	2.5
Night	4.5	3	5	5
Worse time of day	Evening	Morning	Noon	Evening
Used devices	None	Radiator heating system	Fan, Open Window, Shower, cold drinks/food	Radiator heating system, Electric fan heater
Prioritized Activities				
Activity 1	Working		Cooking	
Activity 2	Focus reading		Sleeping	
Activity 3	/		Working	
Clothing				
	Summer	Winter	Summer	Winter
Sleeping	T-shirt, Thin pants	Long sleeves, Thermal underwear	Long sleeve and Sweatpants	Long sleeve and Sweatpants
Shower	T-shirt, Thin pants	Long sleeves, Thermal underwear	Long sleeve and Sweatpants	Long sleeve and Sweatpants
Working	/	/	Long sleeve and Sweatpants + light sweater	Long sleeve and Sweatpants + Jacket
Future probing for non-convetional devices				
	Summer	Winter	Summer	Winter
Personal Devices	NO	NO	YES	YES
Furniture	NO	YES	YES	YES
Micro Spaces	NO	NO	YES	YES
Wall/Floor system	YES	YES	YES	NO
Blankets	YES	NO	YES	NO
Window insulation	NO	YES	NO	YES

	Participant 11		Participant 12	
Sex	Male		Male	
Age	43		33	
Country	Sweden		Sweden	
Home type	Townhouse (Row house)		Apartment (> 50m ²)	
Living context	I own it		I rent	
Experience Scores				
	Summer	Winter	Summer	Winter
Early morning	4	2	2.5	2.5
Morning	4	4	4	3.5
Noon	/	/	4	3
Afternoon	/	/	4	4.5
Evening	3	3	4	4.5
Night	3	3	2.5	3
Worse time of day	Evening & Night	Early Morning	Early morning & night	Early Morning
Used devices	None	Built-in radiator system	Window, Fan	Space heater, hot shower
Prioritized Activities				
Activity 1	Sleeping		Working	
Activity 2	Working		Working out	
Activity 3	Socializing		Sleeping	
Clothing				
	Summer	Winter	Summer	Winter
Sleeping	Shorts	T-shirt & shorts	T-shirt & shorts	Long sleeve, Vest, and Sweatpants
Shower	T-shirt & shorts	Sweater & Pants	T-shirt & shorts	T-shirt & shorts
Working	/	/	T-shirt & shorts	T-shirt & shorts
Future probing for non-convetional devices				
	Summer	Winter	Summer	Winter
Personal Devices	NO	YES	YES	YES
Furniture	YES	NO	YES	YES
Micro Spaces	NO	NO	NO	NO
Wall/Floor system	YES	YES	YES	YES
Blankets	NO	NO	NO	NO
Window insulation	YES	NO	YES	YES

	Participant 13	
Sex	Male	
Age	27	
Country	Sweden	
Home type	Apartment (> 50m ²)	
Living context	I rent	
Experience Scores		
	Summer	Winter
Early morning	2	2
Morning	2	3
Noon	/	/
Afternoon	/	/
Evening	2	3
Night	2	4
Worse time of day	All day	Early Morning
Used devices	Fan	Built-in radiator, electric heater
Prioritized Activities		
Activity 1	Sleeping	
Activity 2	Working/Sitting at the computer	
Activity 3	/	
Clothing		
	Summer	Winter
Sleeping	very little	pajamas
Shower	Shorts	Sweater, Jeans
Working	/	/
Future probing for non-convetional devices		
	Summer	Winter
Personal Devices	NO	NO
Furniture	NO	NO
Micro Spaces	NO	NO
Wall/Floor system	YES	YES
Blankets	NO	NO
Window insulation	NO	NO

F

Evaluation of conventional solutions

Table 15: Attribute weight comparison

Criteria	Level of control	Energy use	Investment	Flexibility	Appearance	Performance	Noise	Space used
Level of control	X	0	1	0	0.5	1	0.5	0
Energy use	1	X	0.5	0	1	0.5	0.5	0
Investment	0	0.5	X	0.5	0.5	1	0	0
Flexibility	1	1	0.5	X	0.5	1	0	0.5
Appearance	0.5	0	0.5	0.5	X	1	1	0.5
Performance	0	0.5	0	0	0	X	0	0
Noise	0.5	0.5	1	1	0	1	X	0
Space used	1	1	1	0.5	0.5	1	1	X
Total	4	3.5	4.5	2.5	3	6.5	3	1

Table 16: Criteria scores for conventional thermal comfort solutions.

Criteria	Add/ remove clothing	Open windows	Curtains /blinds	Air cond.	Fan	Floor heat/cool	Gas heater	Radiator	Electric heater	Wood stove
Level of control	4	3	3	4	3	3	3	2	4	2
Energy use	5	5	5	2	4	4	1	4	3	5
Investment	5	5	4	2	4	2	3	3	4	2
Flexibility	3	3	3	3	3	2	2	1	3	1
Appearance	3	5	3	3	3	5	1	4	2	5
Performance	0.5	2	2	5	2	4	4	3	4	4
Noise	5	2	5	4	5	5	4	5	4	5
Space used	5	5	5	4	2	5	3	4	3	3

Table 17: Weighted comparison of conventional thermal comfort solutions.

Criteria (Weight)	Add/remove clothing	Open windows (summer)	Curtains/blinds	Air conditioner	Fan	Floor cooling/heating	Gas heater (winter)	Radiator	Electric space heater	Wood stove
Level of control (14%)	0.57	0.43	0.43	0.57	0.43	0.43	0.43	0.29	0.57	0.29
Energy use (13%)	0.63	0.63	0.63	0.25	0.50	0.50	0.13	0.50	0.38	0.63
Investment (16%)	0.80	0.80	0.64	0.32	0.64	0.32	0.48	0.48	0.64	0.32
Flexibility (9%)	0.27	0.27	0.27	0.27	0.27	0.18	0.18	0.09	0.27	0.09
Appearance (11%)	0.32	0.54	0.54	0.32	0.32	0.54	0.11	0.43	0.21	0.54
Performance (23%)	0.12	0.46	0.46	1.16	0.46	0.93	0.93	0.70	0.93	0.93
Noise (11%)	0.54	0.21	0.54	0.32	0.21	0.54	0.43	0.54	0.43	0.54
Space used (4%)	0.18	0.18	0.18	0.14	0.07	0.18	0.11	0.14	0.11	0.11
Total	3.42	3.52	3.68	3.36	2.91	3.61	2.79	3.16	3.54	3.43

G

Evaluation Form and Outcome

The same evaluation structure was used for all four concepts, with concept-specific descriptions and context images.

Energy Use	- The energy use of this concept feels reasonable for everyday use. - This concept could help reduce the overall energy use in my home.
Installation	This concept is easy to install or set up in my home.
Performance	This concept can bring noticeable improvements to my daily thermal comfort experience
Maintenance	This concept is easy to use and does not require much attention or maintenance.
Investment	At what price range would this concept feel worth it to you?
From _____ (I'd start to consider it) to _____ (too expensive, not worth it)	
Presence	This concept can fit naturally into my home without feeling disruptive.
Flexibility	This concept can be used flexibly across different situation (spaces, activities, or seasons).
Control	This concept enables me to manage or influence my thermal comfort more easily.

Figure 41: Evaluation form used for the four refined concepts.

Table 18: Attribute weight comparison for final evaluation

Criteria	Control	Energy use	Initial Cost	Flexibility	Presence	Performance	Ease of installation	Maintenance
Control	X	0	1	0	0.5	1	0.5	0
Energy use	1	X	0.5	0	1	0.5	1	0
Initial Cost	0	0.5	X	0.5	0.5	1	0.5	0.5
Flexibility	1	1	0.5	X	1	1	0	0.5
Presence	0.5	0	0.5	0	X	1	1	0.5
Performance	0	0.5	0	0	0	X	0	0
Ease of installation	0.5	0	0.5	1	0	1	X	0.5
Maintenance	1	1	0.5	0.5	0.5	1	0.5	X
Total	4	3	3.5	2	3.5	6.5	3.5	2

G. Evaluation Form and Outcome

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	TOTAL
Bamboo mat													
Energy Use	4	4	5	5	4	2	3	3	4.0	2.0	5.0	3.0	3.7
Installation	5	5	5	5	5	5	4	5	5.0	4.0	5.0	5.0	4.8
Performance	4	3	3.5	3	4	4	3	4	4.0	5.0	5.0	4.0	3.9
Maintenance	5	5	5	5	4	5	4	5	4.0	4.0	5.0	5.0	4.7
Investment (low)	300	200	300	100	500	150	200	80	20.0	100.0	0.0	100.0	170.8
Investment (high)	400	500	700	300	1500	700	600	350	200.0	400.0	500.0	200.0	529.2
Presence	5	4	4	5	3	4	4	4	2.0	3.0	4.0	5.0	3.9
Flexibility	4	3	2.5	3	4	3	4	5	2.0	4.0	3.0	5.0	3.5
Control	4	3	2.5	3	3.5	4	3	4	3.0	4.0	5.0	3.0	3.5
Average	4.43	3.86	3.93	4.14	3.93	3.86	3.57	4.29	3.43	3.71	4.57	4.29	4.00
Weighted Average	4.37	3.71	3.85	3.98	3.92	3.90	3.45	4.18	3.53	3.88	4.69	4.16	3.97
Inflatable blind													
Energy Use	5	4	5	5	4	2	3	3	5.0	2.0	3.0	4.0	3.8
Installation	4	4	4	5	4	4	3	2	5.0	3.0	4.0	3.0	3.8
Performance	5	3	3.5	5	3	3	4	3	4.0	2.0	3.0	4.0	3.5
Maintenance	5	4	5	4	5	5	4	4	5.0	3.0	3.0	2.0	4.1
Investment (low)	500	400	1000	100	300	100	100	200	20.0	100.0	0.0	100.0	243.3
Investment (high)	500	800	1000	100	1000	250	300	250	80.0	400.0	300.0	300.0	440.0
Presence	2	3	3	2	2	1	4	2	3.0	3.0	2.0	2.0	2.4
Flexibility	3	2	3.5	3	1	2	4	3	3.0	4.0	3.0	2.0	2.8
Control	4	2	3.5	5	3	5	4	3	4.0	2.0	3.0	3.0	3.5
Average	4.00	3.14	3.93	4.14	3.14	3.14	3.71	2.86	4.14	2.71	3.00	2.86	3.40
Weighted Average	4.10	3.10	3.81	4.33	3.12	3.14	3.73	2.80	4.12	2.53	3.00	3.08	3.41
Thermal Broadcast													
Energy Use	5	4	5	3	4	5	4	2	3.0	5.0	3.0	2.5	3.8
Installation	2	3	4.5	5	3	4	4	5	2.0	2.0	5.0	5.0	3.7
Performance	5	4	3.5	4	4	5	3	5	3.0	5.0	3.0	1.5	3.8
Maintenance	3	4	5	2	4	5	4	5	2.0	4.0	5.0	5.0	4.0
Investment (low)	1000	1000	0	0	200	0	0	800	0.0	500.0	0.0	50.0	
Investment (high)	1500	1500	0	0	1000	0	500	1800	1000.0	800.0	0.0	80.0	
Presence	4	5	5	3	4	3	4	5	2.0	2.0	5.0	5.0	3.9
Flexibility	3	5	5	4	5	5	4	5	5.0	5.0	5.0	3.0	4.5
Control	5	4	5	4	5	5	4	4	3.0	5.0	3.0	2.0	4.1
Average	3.86	4.14	4.71	3.57	4.14	4.57	3.86	4.43	2.86	4.00	4.14	3.43	3.98
Weighted Average	4.10	4.08	4.53	3.71	4.10	4.57	3.73	4.47	2.80	4.06	3.90	3.11	3.93
No-drill Awning													
Energy Use	4	2	5	3	3	5	4	4	4.0	4.0	4.0	4.0	3.8
Installation	4	2	4.5	3	2	2	4	3	3.0	3.0	3.0	2.0	3.0
Performance	4	3	4	3	5	5	4	4	4.0	4.0	4.0	5.0	4.1
Maintenance	2	2	4.5	2	2	2.5	4	2	3.0	5.0	4.0	3.0	3.0
Investment (low)	100	1000	2000	200	500	600	300	500	100.0	300.0	0.0	300.0	491.7
Investment (high)	100	1500	2000	500	3000	1000	800	1300	800.0	600.0	1000.0	500.0	1091.7
Presence	4	2	3.5	5	4	5	4	2	4.0	5.0	3.0	3.0	3.7
Flexibility	1	3	3.5	2	3	4	4	2	4.0	4.0	4.0	4.0	3.2
Control	4	2	2.5	5	5	5	4	4	4.0	2.0	3.0	4.0	3.7
Average	3.29	2.29	3.93	3.29	3.43	4.07	4.00	3.00	3.71	3.86	3.57	3.57	3.50
Weighted Average	3.59	2.35	3.88	3.45	3.78	4.29	4.00	3.24	3.78	3.76	3.55	3.76	3.62

Figure 42: Evaluation scores across the four refined concepts.



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