Close a door to open a window:

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ABSTRACT

Together with 11 lower-income households, we explored how assumptions embedded in domestic energy interfaces match their needs, expectations, and everyday practices around domestic energy use and comfort. Catalyzed by cultural probes, residents (1) shared the diverse strategies and know-how involved in making themselves comfortable, (2) offered arguments for their everyday futures, and (3) explained what we can learn from *them*. A first tentative definition of energy interfaces opens the door to *what* we consider interfaces, how they support developing know-how and how they co-construct everyday practices. Residents' resourceful solutions elicit reflections on what is considered valid participation in the energy transition. From the findings, we synthesize alternative starting points for the design of energy interfaces: We outline design opportunities to expand the (un)comfortable by revisiting comfort as fluid and multi-sensory. Furthermore, we sensitize how design can build on residents' existing strategies for making comfortable, rather than replace them.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); Empirical studies in HCI.

KEYWORDS

Domestic energy interfaces, Energy transition, Comfort, Social Practices, Cultural Probes

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1 INTRODUCTION

The design of effective energy interfaces in domestic environments has been an ongoing challenge in sustainable HCI. While there is an abundance of literature that looks at how we can adapt the design of energy interfaces by considering levels of control, user-friendly interfaces, or consumption feedback, we observe that current approaches to designing energy interfaces often fail to recognize the diversity of everyday practices that directly or indirectly, demand energy. In recent years, scholars in both energy research [20] and HCI [11] have argued for a more deliberate prioritization of the 'home' rather than the house or households. A focus on the home broadens our understanding of the social and physical aspects that shape energy demand [20] and embraces more diverse and multifaceted directions for the future of domestic technologies [1, 14, 44]. When we consider that energy is not used for its own sake, but as an ingredient of diverse everyday practices [60], design's sensibilities to the home presents a unique opportunity to explore a much broader range of strategies to reduce energy demand. Conversely, by taking energy *demand* for granted [60], strategies that focus only on the technical sphere of the 'house' [20] risk further escalating social expectations and norms that shape everyday routines and practices [57] such as increasingly energy-intensive expectations for homogenous indoor climates [1]. We argue that the (often normative) assumptions behind energy interfaces, which tend to brush over the diverse needs, expectations, and practices of residents, risk missing opportunities that build on existing strategies of residents to save energy.

For example, a widely documented performance gap between the expected energy savings of retrofit measures and actual energy consumption [7, 11, 19, 31, 68] was found to be larger for households with lower incomes in a large-scale study in the Netherlands [7], which is also the context for this study. This group, often tenants, generally does not have access to hi-tech energy-saving solutions such as heat-pumps, solar panels, electrics cars, energy-efficient appliances, as well as energy consumption feedback and personalized programs optimized to their routines and lifestyles. This lower level of adoption of 'energy saving' measures make lower-income households, an important target group for energy transition policies. However, due to a lack of research into the needs, expectations and practices of this group, these policies tend to result in technology push situations. This lack of understanding not only leads to mismatches between energy interfaces and the everyday realities of lower income households, but also to missed opportunities for the energy transition. While many energy-related studies in HCI work with (affluent) groups of people that are actively participating in the energy transition [26, 28, 29, 49], studies by e.g. Dillahunt et al. [16, 17] show that people in low-income households often have great practical know-how and skills to deal with problems and adopt a variety of resourceful, creative and low-tech ways to save on energy and other resources [67]. Likewise, (Design-)Ethnographic studies illustrate the variety of ways in which residents appropriate for example the 'things', infrastructures and architecture of the

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building in relation to e.g. making home [6, 44], disruptions [29, 35] and heating [24, 36, 54, 55]. To provide an idea of what we consider to be an energy interface, but remain open to interpretation, we used the following tentative definition: (material) place of interactions between dwellers and the (home) environment that directly or indirectly affects energy demand or consumption. This everyday working definition is inclusive of interactions beyond buttons and displays, like closing a door to open a window, and encourages expansion through a plurality of perspectives.

In this paper, we present a study using cultural probes in which we worked together with tenants from 11 low-income Dutch households during the summer of 2023. Situated in the Netherlands, a Northern European country historically familiar with a relatively cool climate, dwellings and practices are not adjusted to increasingly hot summers. This issue is even more prominent for those without access to (expensive) artificial cooling. The set of probes we developed for the study takes the diversity of 'what [residents'] energy is [not] [expected to be] for' [32, 60], and their know-how and strategies to keep cool and reduce demand as a premise to explore our research question: 'how can we design energy interfaces that build on the existing strategies and everyday practices of residents in a heterogeneity of homes and households'. Our contributions are the following: First, this work provides an in-depth insight into mundane ways of knowing and the existing strategies that residents in lower-income neighborhoods deploy to make themselves comfortable. More specifically, the examples offer a lens through which we revisit notions of comfort and related know-how to broaden current assumptions underlying the design of energy interfaces in current HCI practice. Second, we synthesize the dimensions and particularities of the diverse practices, ways of knowing-how and strategies into alternative perspectives to consider when designing for sustainability in and around the home. These perspectives are not meant to be taken as singular starting points or guidelines, but rather as a to-be-expanded and co-extensive (in parallel, each complementing another) collection of alternative starting points to expand opportunities for designing (domestic) energy interfaces and beyond.

2 RELATED WORK

In this section we first review the relation between energy, comfort, and technologies in energy research to synthesize why design research offers an interesting lens to find alternative strategies. We then zoom in on design research's potentials to unpack diverse needs, expectations, and situated performances of residents to position this work.

2.1 Situating comfort and energy *in* the home

With the phrase 'what energy is for', Shove and Walker [60] reframe that energy is not used for its own sake but as an ingredient of practice, and that "energy demand is consequently dynamic, social, cultural, political and historical". In the area of sustainable HCI [33], this implies a shift away from approaches that focus on increasing the efficiency of energy-related technologies or behavioral change [58] to the more challenging task of understanding, questioning, and debating normal and taken-for-granted practices and conventions that drive energy demand such as comfort.

Viewing comfort as a social construct that bundles together a set of energy-intensive practices offers a critical reflection on energy-related interfaces and technologies. As argued by Shove: "in determining what people 'need', the science of comfort has allowed designers to produce buildings and systems that meet and at the same time create [narrow] expectations of comfort" [57]. Moreover, by demanding as little effort and adjustment from end-users as possible [13], technologies such as air-conditioning problematize and suppress alternative solutions that require people to adapt and learn [34]. Noting that "fundamental domestic infrastructure, such as central heating and cooling systems that deliver a consistent climate throughout the home, reinforces the assumption that the domestic environment should be consistent and homogeneous.", Aipperspach et al. [1] and others [14, 44] call for design to instead support a heterogeneity of practices inside and materiality of the home.

Next to calls in energy research [20] to prioritize 'home' and explore the meaning of comfort to different groups and in different contexts, we argue that design research offers valuable methods to revisit comfort as situated in social and material complexities of the home, the body and social norms as well as the sensibilities to explore alternative perspectives on the future of comfort. The recent energy crisis in Europe combined with increasingly hot summers provide a good background to understand how dwellers adapt to higher temperatures [11, 30, 43, 66, 67] and "make themselves comfortable as an alternative discourse to thermal standards" [20] and mechanical solutions such as air-conditioning. This requires that we don't just systematically analyze the links between expectations of comfort and energy consumption (like thermal, air quality and lighting), but build an empirical understanding of making comfortable by inquiring e.g. negotiations between dwellers [20], bodies as malleable, changing and intimately connected to the environment [70], and agency [16]. More fundamentally, this implies a shift away from the common focus on (dis)comfort as (strictly) thermal to find other ways of conceptualizing comfort that might challenge "the model of rationally calculated action that dominates energy policy" [70] and concurrently assumptions about the way design approaches domestic energy (technologies) to support residents in reducing energy demand.

2.2 Supporting alternative ways of knowing in design research

In answer to questions of what people need to participate in the energy transition, notions like 'energy literacy' [8] uphold the common perception that many people lack awareness and know-how of their house and its common infrastructures to save energy. In line with this, design has long focused on *making visible* and helping people understand their energy consumption becoming somewhat of a topic in its own right [4, 48]. When we understand that "people are never just using energy", as Shove and Royston [59] put it, "the kind of knowledge that [interfaces like] smart meters provide is narrow in scope and of limited relevance to the routines and rhythms of everyday life."

The diverse range of resourceful strategies residents use to save energy or deal with hardships [17, 18, 29, 35] as well as practices rooted in resource-scarcity [67] depend on various forms of know-how [55], "sometimes held by people, but sometimes embedded in

objects, such as heating controls" [59]. Likewise, knowing-how to make yourself comfortable is not the same as knowing how much energy a gas stove consumes. As such, we attempt to investigate the embodied knowledges [70] and 'ordinary' ways of knowing [55] that are crucial to understanding the role technologies play in reducing (or increasing) energy demand.

In addition to a call for attention to the body in energy research [70], it is difficult to adequately represent the experience of directly engaging with energy and 'what energy is for' [32]. Consequently, there is a risk of marginalizing the more embodied, self-evident, and sensorial features that constitute people's engagement with energy and comfort, and so the lived-experiences and know-how of people who do not have access to consumption feedback, infrastructures, or decision-making (such as tenants [16, 39]). In the context of energy research, this requires decentering expert knowledge (of e.g. housing corporations, energy data and advisors) and dismantling implicit knowledge-power relations [16]. Researchers in other areas have given voice to alternative ways of knowing by attending to e.g. the body, mess, materiality, and relationality [3, 37, 38, 40, 45, 46, 62, 63]. We think that actively seeking these partial perspectives and situated knowledges is necessary for a more embodied and less abstract approach to engaging with energy futures, – "not partiality for its own sake but, rather, for the sake of the connections and unexpected openings situated knowledges make possible." as Haraway writes [25]. We aim to challenge our own assumptions of what 'home' and comfort is by, like Desjardins et al. [15], "relying on the physicality of each home and the participants embodied knowledge of their experience of that space".

Here we see potential in Gaver et al.'s [23] cultural probes as being 'disruptive' of the expectations and assumptions surrounding energy and comfort, for researchers and residents alike. Moreso, the plural and fragmentary nature of probes [6] helps abandon notions of hierarchy in knowledge about what energy is and 'what it is [supposed to be] for' [60], and to instead embrace the many ways of knowing about energy and the everyday life. At the same time, probes offer an "open-ended and attentive inquiry" [65] by creating a co-creative, empathic, and shared context [69] that legitimizes questions, imaginations, and solutions that are otherwise easily put to the side. Because both people, energy and know-how 'flow' [61] through the home, rather than sitting still [52, 53, 55], we see potential in integrating methods from Pink's [51] sensory ethnography that emphasize *sensing* to evoke a different way of moving in and around their home as a way of 'seeing' [25, 40]. In the context of energy, things like floorplans can give insights into the "resident's improvisation with systems and everyday design in the home" [51] that are self-evident yet crucial in understanding *making* comfortable as part of the sensory narratives of residents.

Central to our use of probes is a relationship of trust with participants and sense of conversation. The inquiry as shaped by the probes is in this sense cross-cultural, by levelling the playing field between academic, expert, and everyday ways of knowing and part of that is developing a shared understanding of goals and questions.

3 PROBE STUDY

The purpose of the study was to explore how residents keep themselves comfortable in warmer weather, the know-how involved and 'what (residents') energy is (not) (expected to be) for' - referring to residents' expected futures. We developed a kit with four cultural probes [23] presented as an 'Exploration kit for keeping cool in the summer'. Our use of design probes involved small artifacts that were designed to invoke diverse responses in a co-creative, empathic, and shared context [69] that emphasizes curiosity and for us to learn from residents' ways of doing.

3.1 Probe kit contents

The probe kits include 4 probes (See 1, 2 , 3 *&* 4), instructions and a small present in the form of a 15 EUR voucher.

In the context of energy research, we position probes as attentive and open-ended. As such, the different probes do not triangulate to offer a 'holistic' overview of everyday practices, but complement each other as partial, situated, and subjective snapshots of resident's idiosyncratic and household-shared know-how as well as the *kinds of ways* residents make themselves comfortable. The curious nature of probes provided a playful way to address an ambiguous topic like energy that is surrounded by expectations and preconceptions and is at the same time self-evident and sensorial, giving a glimpse of how resident's expectations relate to wider social and technical contexts. The probes include:

Postcards. 4 Postcards featuring open questions to write and draw:

- Write instructions for the next inhabitants of your house: What should they know? What are the secrets, insider tips and golden advice? (See 1)
- A love letter to your favorite appliance.
- An appliance that you would always leave on if it would not use energy.
- An appliance that is important for other dwellers in your home but that you would have no problem getting rid of.

To get insight into participants' process of knowing-how as they 'learn their home' [55], we asked them to share their experience-based, household or culturally shared know-how with future inhabitants of their house. The other postcards offer different starting points to think about what participants' energy *is* and *is not* for, giving us insight into their beliefs, norms, and perspectives as well as the household negotiations surrounding energy.

Camera. A camera with 14 prompts to take pictures of, ranging from capturing things, routines and places to prompts that require interpretation and reflection: *Where you cool down, the warmest place, What you eat on a hot day, favorite place in the neighborhood, Summer-y outfit, where you get together, Oldest device, Newest device, a moment of rest, a beautiful place in the house, a point of energy in the house, an (own) invention, an unsolved problem, something you don't understand.*

Inspired by Gaver et al.'s camera [23], the range of prompts invite participants to walk in and around their homes and 'see' through different lenses. The pictures offer insight into the materials and things that are part of practices performed during summer. They also explore the aesthetics of comfort, resourcefulness and what residents cherish in making home and feeling at home.

Floorplan. A Floorplan of the home, with a red/blue pencil, a pen and 3 tasks:

(1) Draw a floorplan of your home. Sketch where you: eat, sleep, come together, etc.

Figure 1: Left: Probe kit and contents. Right: Set of postcards and card with instructions for the next inhabitants of your house.

Figure 2: Camera probe and included instruction booklet.

(2) Indicate where it is warm / cold. How do you move through the home on a hot day?
(3) Where do you want it to be warm / cold? How would that change where you go in your home?

Drawing on theories of movement and place [50, 51, 53], this task aims to give insight into participants' know-how and desires surrounding thermal flows in their homes, how they appropriate them in making themselves comfortable, and how they adapt their performances of everyday practices to warmer weather.

Speculative newspaper. A Future Edition of their Neighborhood Local Newspaper, with local reporting, gossips and the invitation for participants to: *Leave comments underneath articles local developments (e.g. municipality plans to hang giant sunshades in the city center, an interview with a local resident digging an underground home office), react to statements around keeping cool (e.g. introducing siesta's during the hottest hours of the day), come up with exciting news headlines, fill in on propositions for the future and write a short article about the local deeds of their future selves.*
Inspired by an uproar of comments, suggestions and conspiracies underneath an online article that reported on future developments in one of the neighborhoods, we developed two versions of this fictional newspaper (one for each neighborhood) that challenge current norms in a playful way. The contents of the articles are written to be fun to read and offer a low-threshold way to elicit people's anticipation, attitudes, and desires towards their local Everyday Futures [64]. The layout of the pages invites participants to leave comments and emoji's underneath articles and to draw in the margins. Presented as a future glossy of the local newspaper residents know, this probe was made to be shared with other neighbors as well.

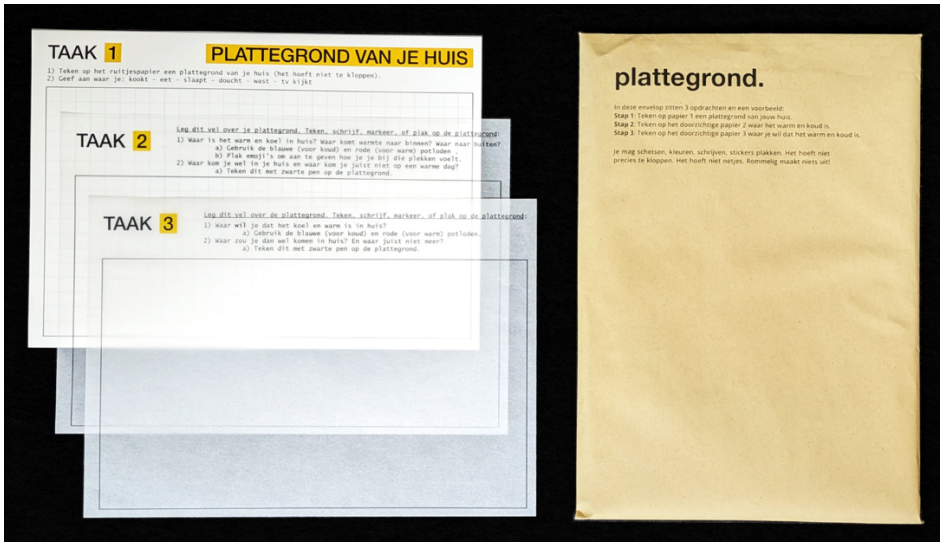

Figure 3: Floorplan exercise with translucent overlays for subsequent tasks and envelope with instructions.

Figure 4: Left: Cover of the Speculative newspaper. Right: Propositions for the future (left) and an interview with a fictional resident about digging an underground office in his backyard (right).

3.2 Study set-up

The study took place in the end of the summer 2023 in the Netherlands over the course of 4 weeks in the cities of Nijmegen and Gemert and received approval by our institutions' Ethical Review Board. While earlier in the summer it had been rainy and cold, this 4-week period at the end of summer had temperatures move between 20 and 32 degrees Celsius, with 2 weeks being especially warm for Dutch standards. Overall, we visited 10 homes, and talked with 15 people from 13 households whose ages ranged from early twenties to early seventies. We collected data on three occasions. During a first visit, we delivered the probe kits to the participating households. Participants received instructions and we (1) had open conversations about their experiences as tenants, what things are central to their home life, making themselves comfortable in warm weather and more. These conversations were documented in field notes made immediately after the visits. (2) After delivering the probe kits, participants had 2 to 4 weeks in which they used and filled in the probes. To understand the particularities and dimensions of the diversities in participants responses, the probe study was followed by a home visit and recorded exit interview (3) in

which the probes served as 'domestic tour stops' to naturally dwell on things that were relevant to participants. At the end of the interviews, we explicitly asked participants what questions they have for us scholars that we need to address with the intention of sustaining the conversation.

3.3 Participants

The locations complement each other in their different building history, sociocultural composition, housing politics and approach to energy transition. Because we are interested in varied strategies in residents' resourcefulness within the energy transition over other forms of diversity, we prioritized households with varied living situations, including tenants in social housing and lower-income homeowners, different house types, buildings of varying energy-efficiency, different stages of renovation and in different stages of their housing. Participants were recruited through local partners and professionals working in these neighborhoods, people we interviewed before as well as through a local event. Most of our participants had a Dutch cultural background. The participating households featured a variety in building type and (expected) energy efficiency as well as the time they had been living in their homes, see table 1 for an overview.

The conversations that we had with participants before and after the probe study were central in developing a relationship of trust with participants that in itself "enabled shared understandings in relation to challenging, intimate and real aspects of lived experience" [69] beyond inspirations for design. This was especially true for participants that had lived for a long period in a neighborhood with a history of failed energy transition measures imposed by the municipality.

3.4 Analysis

The data includes notes, audio recordings and transcripts of the first contextual interview and exit interview, participants' pictures in and around their home, drawing and writing on the floorplans and written answers and comments on the postcards and newspapers. To keep alive the social complexity as well as acknowledge their partiality, our effort was to analyze the kinds of data in their peculiarity without reducing it to another. For example, we set to embrace the expressivity of the pictures without reducing them to words and meanings [41]. We used open coding [12] to reveal self-evident, summative, and salient features in the transcripts on ATLAS.ti as well as evocative features in the in the pictures, writings, and sketches. In a second round we used axial coding to organize and understand the relations between codes, e.g. as part of social practices in and outside the home, in iterative fashion. Here we used sketching, visual mapping and collage to move between the variety of sensory data and codes to explore and further solidify our themes. Because the aim of this paper is to learn from how people make themselves comfortable, we see the data not as static descriptions as to (the diversity of) what comfort is but as to-be-interpreted divergences that are partial in themselves.

4 FINDINGS

The at times unexpected interpretations of the probes and stories around practices required us to reconsider the way we look and ask questions. As dialogical [63], the open conversations around the probes also helped us challenge assumptions and preconceptions about our participants, and vice versa, (helped to) challenge residents' preconceptions about scholars and energy research. Because we are interested in understanding the sensory narratives of residents not just in isolation but in relation to wider social and technical contexts, we organize the findings and present subsequent discussions around the dimensions and particularities of residents' diverse strategies and know-how.

4.1 Dimensions of comfort in everyday life

Revisiting the responses to the collected probe kits in participants homes, we noticed that conversations about making yourself comfortable often organically extended from warm or cold to other aspects of life at home. Below we outline three dimensions of (summer) comfort that are crucial in our exploration of how people make themselves comfortable as integrated in and dispersed through everyday practices: privacy, multi-sensory experience and aesthetics.

4.1.1 Privacy. For several residents, their perceived privacy was an important dimension of making themselves comfortable in everyday practices and through the materiality of their home.

For example, Chris writes his love letter, which he turned into a "love-hate letter", to his computer. This device, and the desk it sits on are a central to his job, which he mainly performs from home, but also to the way he spends his free time. These practices in turn affect his use of space. When he moved in some years ago, he logically installed his desk in the designated office. However, the large windows directly face the neighborhood playground with sounds from children playing, and music from teenagers in the evenings, and the proximity to shared space placed his desk in direct view of his neighbors. All of this made him feel uncomfortable and led him to move his desk set-up. As he explains by referring to the floorplan, the current place of his desk, in the living room, is one of the warmest places in the home, not near to any windows and not in the draft between his front and back door. Yet, for Chris, privacy is more important for feeling at home "in your own home". Similarly, Thomas both blocks the sun and sight between him and his neighbor's balcony, whom he has issues with, using stacked flowerboxes on his balcony and window foil on the living room windows behind.

When talking about airing from the balcony door, Juliette, who is part of the first-generation residents of the newly built apartment block, recalls accidently looking inside her neighbor's bedroom from her balcony, "Yes, I imagine he thought: why is that old tart looking in on me? He always has his curtains closed since. This also shouldn't be like that [in a newly built apartment]."

Conversely, Nick invited us to see for ourselves how the much broader bars of their new balcony railing (see Figure 12), installed for privacy reasons by the municipality as compensation for creating a walking path behind their apartments, turned out to block the sun and made it possible to "finally stand on the concrete balcony in the summer". Karin also discusses her appreciation for the trees surrounding her dwelling. These trees – while blocking her solar panels – provide both shade and privacy. The municipality wants

Table 1: Overview of participants and their homes

Pseudo-nym	Age/Gen-der	Contract/ Building Year (decade)/ House type	Renovation and housing details	Other
Maria	50+ (F)	Social housing, 1970s, Terraced house		Lives with two small dogs and has children that moved out.
Jana	50+ (F)	Social housing, 1970s, Low-rise apartment	Sunscreen and minor repairs. Returning issues with cracks in walls and leakage make for some tension with the housing corporation.	Lives with two small dogs and provides home care for her demented mother (80+) that came to the Netherlands from eastern Europe. While this demands most of her time and attention, she is actively involved with the direct neighborhood and has a lot of visitors come over for a cup of coffee.
Thomas	50+ (M)	Social housing. 1970s, Maisonette apartment (city)	The apartment was recently renovated by the housing corporation. He has some issues with behavior and nuisance of people in his neighborhood.	Has no children or partner. His volunteer work in the same neighborhood brings him in contact with all sorts of people in the neighborhood.
Karin	50+ (F)	Social housing, 1970's, Terraced housing		Lives with a white German Shepard and does volunteer work in the same city. She has adult children that moved out.
Andrea Sjors	40+ (F) 40+ (M)	Privately owned (bought from former social housing) 1970's Low-rise apartment		Andrea does social work in the same neighborhood.
Theo Adria	60+ (M) 60+ (F)	Privately owned 1920's Single-family detached house with a garden	Moved in less than 1 year ago. House was fully renovated by previous owner 7 years ago. Preparing room for handicapped son moving in soon. Installing solar panels.	Are both just retired and moved from a farmhouse outside the city to the town center. They live with a small dog and have lots of plants. They have a bigger budget than other participants are actively concerned with sustainability.
Chris	40+ (M)	Social housing (Late) 2000's Terraced housing	Moved in around 7 years ago. He is looking into solar panels for private use (even) as tenant. He returned to live in this city where he also grew up as a kid and teenager and knows its history, culture, and the people well.	Is self-employed and works from home, with no children or partner. He has an impressive collection of things he loves. He actively contributes to the local community by sharing his interests in a nearby venue.
Juliette	70+ (F)	Social housing 2020's High-rise apartment (for remaining life course)	Moved in just approx. 1 year ago. Everything is built to newest standards. For 20+ years, she lived in a terribly isolated rental apartment in the same neighborhood.	lives with a small dog that is very important to her. Despite her retirement, she is still very active and regularly hangs out and organizes events with and for neighbors from the building's shared 'living room' on the ground floor.

Olaf Sofie	40+ (M) 40+ (F)	Social housing 70s apartment in maisonette	Lived there for 15+ years. The apartment was renovated by the housing corporation 4 years ago with isolation, kitchen, ventilation system and sunblinds.	Are both visually handicapped. Olaf does voluntary work and Sofie works for the municipality from her office at home. Despite the 'bad' reputation of the neighborhood, they find it very peaceful and are involved with what is going on and are on good terms with their neighbors.
Nick	40+ (M)	Social housing 70s apartment in maisonette	Lived there for 15+ years. His apartment was renovated by the housing corporation 4 years ago with isolation, ventilation system and sunblinds. To his discontent, his 15+ year old kitchen was skipped in the renovation because he "cared for it too well".	Is a teacher in the same city. He has a lot (of knowledge) of plants and no wife or children. Both him, Olaf and Sofie know they neighborhood well and are skeptical of the municipality's plans to change things near their apartments.
Alex Liz	20+ (F) 20+ (M)	Social housing 70s apartment in maisonette	Moved in just before summer. The apartment was renovated by the housing corporation 4 years ago with isolation, kitchen, ventilation system and sunblinds.	Liz is following education and Alex recently graduated. As they are learning their home, they have to deal with choices made (e.g. during the renovation) by previous tenants.

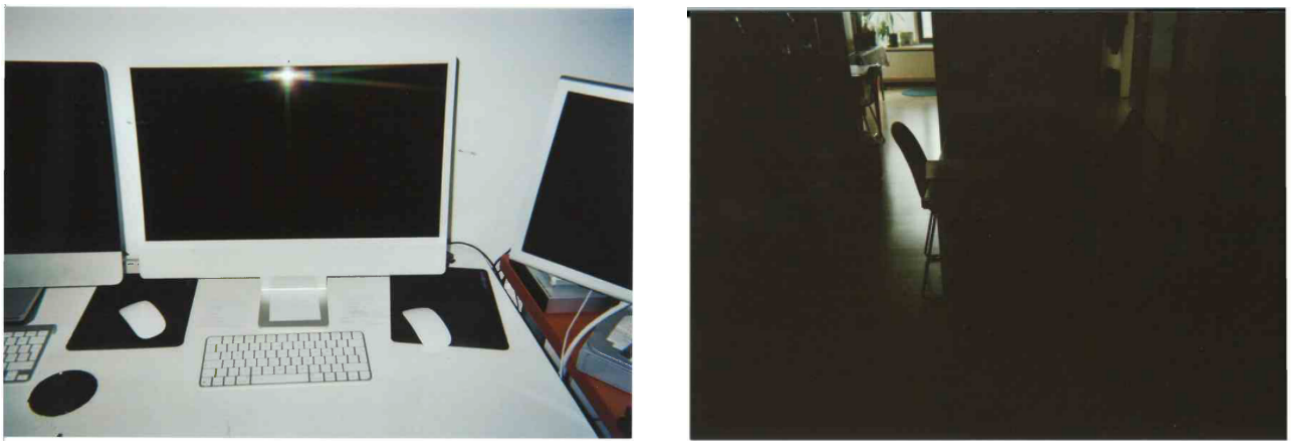

Figure 5: Chris' computer and living room.

to cut down these trees for a new apartment building, but new residents can then look directly into her garden.

Precisely because the (physical) boundaries of the home are porous [14], the materiality of the building is not just restricted to block or let in heat or air, but also sounds from the street, light and neighbors viewing in.

4.1.2 Comfort as a multi-sensory negotiation. Our data exemplifies that comfort is not just about thermal sensation but is a multi-sensory negotiation. Our participants negotiated between different senses to make themselves comfortable in countless kinds of ways while integrating intimate know-how of their homes.

For example, Maria explains that she would "gladly give up some centimeters of [her] living room" to insulate the "thin concrete walls" of the apartment she rents to keep out heat and sound. Displaying the role of intimate knowledge of the fabric of a dwelling she adds that "me and the old neighbors were considerate of the sound", but the "people that just moved in don't realize how noisy it is".

Multiple participants highlighted the value of airing not just for cooling, but for getting rid of smells. Alex mentions that his "ventilation system gets rid of [cigarette] smoke but not the smells it leaves behind. So you just open everything against each other [front-, backdoor and kitchen window] for 3 minutes". And while

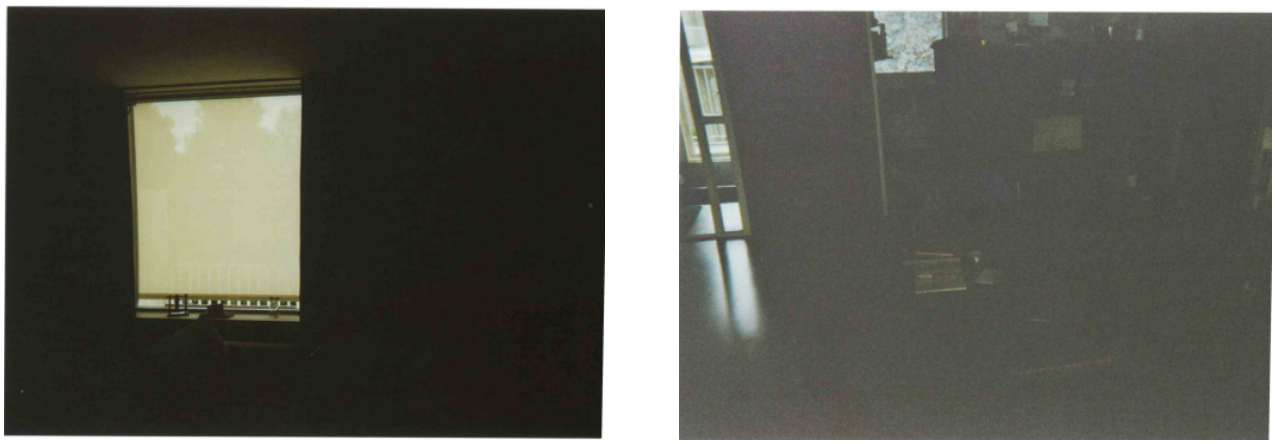

Figure 6: Olaf & Sofie's pictures showing their thick out-of-fashion vintage winter curtains blocking the sun but leaving room for light that comes through the sunblinds for the part of the living room where they sit.

Figure 7: Chris' & Maria's places to cool down and get together.

Juliette was advised to "keep everything closed" to keep the warmth inside her insulated apartment and let "systems" do the work, she still "opens the windows on the tilting-mode" to let in fresh air, even if this means shearing the sounds of the nearby road.

Adria & Theo's (mostly glass) conservatory in their newly bought home is both their hottest place in the summer and coldest place in the winter. However, it has "a very pleasant lighting", meaning that their large collection of plants "do incredibly well there". This makes it their place of comfort, where they spend most of their time.

Considering comfort as a multisensory negotiation also means that (despite assistance of technologies) making yourself and others comfortable is an ongoing process of both feeling, listening, seeing, and smelling as well as using a variety of tactics, techniques, habits, and skills.

4.1.3 Aesthetics of Comfort. The aesthetics of comfort as captured and conveyed by participants challenge the dominant imagery of comfort [13, 34].

Theo & Adria, Thomas and Olaf use the word "behaaglijk" – similar to the *hygge* [26] - to describe making the atmosphere comfortable through a particular configuration of light (candle lights), warmth (preferably fireplace) and the feeling of space (making the space smaller). In contrast to the stable and slow comfort of floor heating (Juliette: "it's a bit weird to lie on the floor when you want to feel a little cozy"), this was generally a low-tech, intimate (other bodies), situated need for comfort (cold evenings).

Photographs taken by participants capture comfort as messy and mundane, opposing the (techno-hedonist) smart-home visions [27] that link comfort to (the need for) convenience and control. The places where Nick sits in the shade to drink his coffee and meet his neighbors (see Figure 8) do not directly fit common imageries of comfort, but aptly illustrate sensory and social dimensions that complement thermal comfort.

Pictures like Figure 9 strikingly capture the intimate, bodily and living role of 'things' in finding comfort: pillows and blankets

Figure 8: Left: Nick's place of comfort as well as where he cools down: a blue plastic stool on a concrete balcony with shade from the building and trees. Right: His view on the neighborhood below as well as where he and other neighbors meet.

Figure 9: Chris' place of comfort.

suggest a comfortable position, textures and materials and the lamp behind the couch provides light for reading a favorite magazine.

Ultimately, the aesthetics of comfort as captured by participants shows that comfort is not a static outcome experienced in a single way or through a single modality, but ongoing, diverse, and situated in everyday practices. Making comfort requires energy or effort in the sense that it is a "form of 'work"' [55] that participants are willing to put in. Coping with warmer weather does not necessarily consume energy, as Theo explains: "The best thing to do [when it is extremely hot] is going for a bike ride, generating your own nice cooling breeze".

4.2 Diverse strategies and know-how in making oneself comfortable

By emphasizing the value of uncommon or self-evident solutions, residents shared their many material and social configurations to save energy, create temporary drafts, prevent heat from entering, cool their body or others, accept the heat etc. In contrast to the assumption embedded in optimized systems treating residents as passive consumers, the diverse range of strategies show both a willingness to invest effort in making themselves and others comfortable, as well as acceptance to not be comfortable all the time.

4.2.1 Situated improvisations & orchestrations. Building on a pragmatic understanding of the environment - e.g. the sun, architectural elements, drafts, nearby trees - residents' improvisations resourcefully make use of available materials to manage their situation.

Juliette was restricted by the social housing corporation in her choice of shading options, which were very expensive, required maintenance, and partially blocked access to the balcony. Like many others in the neighborhood (see Figure 10) she therefore improvised: "I now have a parasol [on the balcony] yes, I have it all chained up, because otherwise it flies in all directions and I am now getting a tarp, one with clamps so I can clamp it in between [her own and top neighbors' balconies]."

Nick has blocked the ventilation vents in his kitchen and living room - installed during the full-scale renovation of his rental apartment - with a shirt. He did this because he removed the wall between his living room and bedroom, which made "the tiny sound of the ventilation randomly switching on" drive him "totally crazy at night". That he now has to open the windows for fresh air during winters doesn't bother him: he is "not cold natured" and happy to "put on an extra sweater".

Similarly, participants shared very situated orchestrations of cooling the home in their letters to future inhabitants of the house. While Karin relates that: "On days when it is over 32 degrees Celsius in the back [sun South of the home], you really had to make sure that in the morning everything blows through and then from 11 o'clock you start closing everything. Otherwise, the heat stays in the house." Maria uses similar elements but a different type of routine to keep her dwelling cool: "I have in the morning, there I have the back door open and then before the sun turns, then there

Figure 10: Pictures of makeshift shading taken by one of the authors during the study.

Figure 11: Maria's oldest device, a ceiling fan, that is cleaned twice per year and is extensively used during the summer. During the probe study she realized that while its effectiveness at cooling leaves much to be desired, she has a new appreciation for it.

everything [heat] goes away. The sunblind goes down early and then I open everything in the front [of the house]".
As they 'get to know their home', residents came up with tactical alternatives to more permanent, structural, and commercially provided (often expensive) options for saving energy or making themselves comfortable. Maria: "Well, you know, there is a really bad draught upstairs ... you can feel it on the couch" "So I made a wall, I hung a curtain in-between. When it becomes cold later on, then the curtains will be closed, and it stays nice and cozy here. Because this is where I live [downstairs]." Rather than homogenous solutions, Maria's curtains anticipate on conditions when they become relevant to her life downstairs and provides an elegant, temporary solution that builds on deep sensory know-how and an understanding of heat flows in *her* home.

Building on highly situated know-how, the orchestrations show an understanding of warm and cool that is not absolute, but sensitive to the role objects, other dwellers, and spatiotemporal situatedness of the home play (in the neighborhood, infrastructures, seasons). They also show the mundane ways in which both bodies and material elements in the home change over time and transform one another. The pragmatic solutions require but also stimulate new ways of knowing that connect (what) energy (is for) as naturally integrated in, or dispersed between, everyday practices.

4.2.2 Embodied ways of knowing-how. While improvisations and orchestrations integrate know-how and lead to new know-how, there were also ways in which interfaces were used to support *knowing*-how.

When Chris moved in his rental apartment, most lightbulbs that had been left by the previous tenant were old. While the energy advisor pointed him to replace nearly everything, Chris scanned the floorplan and mapped all the light-connections in the house. With an overview of which he lights he used most often he could purposefully replace old bulbs over time matching his budget as "good LEDs are expensive". This "making your own advice", as Chris called it, shows a deep reciprocity between sensory know-how and exploring your own needs to come to an *effective* solution that is inextricably situated. Similarly, the configuration of Olaf & Sofie's thick out-of-fashion vintage winter curtains and sunblinds (see Figure 6) worked for them: Olaf can read his computer better if it's dark and he doesn't mind the atmosphere because he will light a candle "[I'm] a romantic anyway".

When systems do not support residents understanding, it causes frustration and distrust. For example, Juliette is not allowed to change (nor understands) the settings of her automated floor heating. In response to the housing corporation's clarification that the "standard 22 degrees is a nice and acceptable temperature",

she comments: "Yes, it's a nice temperature, and if you're doing things you won't say anything, but when you're a little older and sitting down a little more ...". In addition, she is distrustful of the actual temperature, since "it says 22 on the display but when we [together with other residents] put a thermometer right next to it, it said 18 degrees!". While being told that "you should not be able to feel it heating because it's a different type of warmth they said", she has found out that "you can feel when it's on when the bottles of water on the floor get warm". This example shows the importance of sensing in enabling residents' situated understanding between their bodies, and bodily needs, and (technological) artefacts.

Furthermore, the body as a complex set of 'materials' [32, 70] features and requires different temperatures in different body parts and in different states. Alex, who used to live in a "terribly hot" student housing with no option to cool or air, explains that to cope with the heat in the hottest week his approach is to "play a game, accept that you're slippery with sweat" and aiming a little desk fan on his head. While, Maria, who is in her menopause, keeps a hand fan ready and "stands under the shower 3 times per day". At the same time, she notes that in the winter she only turns on the radiators once per day and turns them off when it is warm as "I am not so cold, I will just put on an extra sweater". Others, among whom Theo, use an electric heater underneath their desk "for my hands and feet when I was working upstairs [where it's poorly insulated]". These fluid qualities of the body afford 'mundane' ways of knowing that are itself fluid and evolve along with the practices that someone is engaged in and the material arrangements they are embedded in.

4.2.3 Human-plant collaborations in everyday futures. Participants' responses to the future newspapers, as well as residents' questions for us scholars and designers, offer fragmented understandings of the ongoing negotiations (and collaborations) in their local environment, now and in their everyday futures.

Olaf & Sofie and neighbors Nick, Alex & Liz attested to the effectiveness of the neighborhood trees giving "a much nicer shade" than sunshades or tarps, suggesting underneath the newspaper headline 'Municipality installs big sunshades [in the city]' that "instead of awning, trees [and] plants" should be installed. In discussing the responses afterwards, they speculated on growing trees with more effective canopy for the city. Similarly, in the unfinished statements 'More ... in the neighborhood to keep comfortable in the summer"' there was a surprising amount of calls for "trees/plants", "more green", "", and the majority of 'commenters' would use 'future funds for cooling should go to ...' "more green in public space". Thomas clarified that it would be a more effective and fair use of money and has benefits beyond cooling, such as improving air quality and increasing biodiversity.

Nick, who lives in his rented apartment for over 15 years, has built his combined know-how of the home and hobby of growing plants over the years: "[I am] now trying to make a kind of green curtain with winter hardy plants, hanging plants and planters on my balcony" (see Figure 12). Part of this plant configuration consists of "citronella plants (-> geraniums, lavender)", which, as he advises the future inhabitants, help combat mosquitos from the nearby pond "halfway Aug-Sept".

Figure 12: Nick's collection of (hardy) plants on his balcony.

Theo & Adria are "making an organic awning of a pergola with vines" in their backyard, inspired by their trip to southern Europe. Since they just moved in, they are also using ivy to create an extra layer of sun-protective green outside of the room for their son.

The reciprocity of human-plant collaborations offers an interesting starting point to think about making comfortable as a process that can be slower than full comfort on-demand. It is a process of tuning, in which actually feeling the heat (discomfort) plays an important role in creating a satisfactory solution.

5 DISCUSSION

5.1 Revisiting comfort in the home

Research on comfort in domestic environments is often pulled apart into a distinct set of conditions defined beforehand [9], with a dominant focus on thermal comfort [20, 36, 55]. The standardization of thermally homogenous spaces leads not only to a standardization of bodily perceptions of comfort, but even to "a kind of oblivion of the body" [70]: bodily capacities to adapt and strategies to satisfy one's own comfort needs are often not even considered. Examples like menopause, accepting sweat, and various improvisations show that making oneself comfortable is intimately connected to the (ever-changing) materiality of the body [32, 55, 70] and its sensory experiences. Rather than being a static outcome of a single practice like cooling, the kind of ways participants made themselves comfortable were fluidly integrated and dispersed in everyday practices that are itself "partly constituted by, and always embedded in material arrangements." [61] Moreso, we thus argue that the ongoing negotiations of making oneself comfortable are inextricably multi-sensorial, as are the know-how's involved. In some cases, it is in fact the interrelationship between different senses that shape the mundane embodied ways of knowing in the home: knowing which doors or windows to open to air a room without letting heat in, when to close the shading, etc. This means that despite the assistance of technologies making oneself comfortable is an ongoing process of feeling, listening, seeing, and smelling, using a variety of tactics, techniques, habits, and skills. The examples also show that *specifications matter*, for both low-tech and hi-tech interfaces: the sound qualities of a ventilation system, the tilting

stand on the window or hardy qualities of a plant all afford different interventions depending on the more-than-thermal context.

In contrast to the techno-hedonist persona [13], a presumed user preferring low-effort, customized and pleasurable aesthetic forms of comfort [34] that is commonly catered to in the Heating Ventilation and Air Conditioning industry (HVAC), participants' negotiations showed both a willingness and competence to invest effort, experiment and adapt as well as work with discomfort. In fact, discomfort played an important role in finding what works for them within certain practices and is therefore not necessarily the opposite of comfort. For example, residents accepted certain levels of discomfort in catering to others, negotiating between senses or manually adjusting a solution over time. This opens possibilities for energy interfaces that do not cater to comfort as immediate, controlled, and homogenous, but instead build on underexplored qualities of *making* oneself comfortable. Inspiration can be found in examples like human-plant collaborations, taking a shower or going for a bike ride. What if energy interfaces are: slow and local, offer only the necessary momentary release from heat or cold, and require user's effort and adaptation to be effective?

We also see value in critical design to playfully expand feelings of discomfort around unsustainable practices and comfort norms by drawing on tradition and common sense. Examples could be leveraging the 'it is what it is' - attitude regarding things like sweating, thereby empowering Dutch sobriety to "put on an extra sweater" instead of upping the thermostat, or extrapolating participant's general discomfort with the consequences of the statement in the future newspaper probe that "every Dutch household receives a free air-conditioner".

5.2 Building on existing strategies

As other studies have found [5, 17], bodily and embodied ways of knowing [70] were deemed highly trustworthy and supported residents' pragmatic understanding of how they could appropriate infrastructures and interfaces through and in their everyday practices. However, this know-how often contested expert knowledge of for example energy advisors, Home Energy Management Systems or building standards. While this factual and theoretical know-how can enable residents' understanding of how their everyday routines relate to their energy consumption [5, 32], they exist *in* the situated social and material context of the home. Centering infrastructures and interfaces around expert knowledge can lead to a mismatch with situated understandings, which require residents to either dismiss their own know-how, or find ways to work around expert rules imposed by domestic energy systems and interfaces. Examples like tenants having to abide by the 22 degrees of their automated floor heating, or blocking a ventilation system with a shirt, illustrate how this mismatch leads to residents' feeling invalidated, and undermines the expected energy savings of renovations [7]. Conversely, Maria's curtainwall and Chris' light-map illustrate the effectiveness of interfaces that make use of embodied knowledge in making sense of energy demand [70]. This type of interfaces stands in contrast to interfaces purposely designed to understand energy consumption. We think that by intentionally supporting and pragmatizing residents' situated know-how, design can develop energy interfaces that build on, rather than replace, existing strategies of people to make themselves comfortable and reduce energy demand. As to how new interfaces and energy data can be made part of residents' existing systems of diverse (low-tech) interfaces and know-how without centralizing them, we see a great resource for inspiration in the *kind of ways* residents use existing energy interfaces.

The situated improvisations afforded by interfaces such as windows, t-shirts to block airflows and wind, and makeshift curtains to block the sun are not just creative ends borne out of necessity (as they are often viewed), but actualized opportunities that bring together unexpected interfaces, expectations and knowing-how to explore change. Through this 'living-change' [56] people develop and use know-how that changes their expectations and performances of certain practices, in the context of their own home within the available infrastructures. This raises new questions for design, such as: How can energy data (as plural and local) match the rhythms and temporalities of improvisations? What are hi-tech interfaces when they are not used as energy interface? Do they just take up space, or disappear in the background? Can they take on a different function, or be modified to accommodate different needs instead?

What we describe as orchestration refers to the ways in which residents routinely coordinate highly situated performances of everyday practices through experiential know-how, thereby integrating architectural elements, the position of the sun, and hi-tech and low-tech interfaces. In what becomes an effective system, these orchestrations provide greater 'adaptive opportunity' [66] than elements do in isolation; and context enabling people to control their own environment such as adapting to thermal stress [10, 66], or orchestrating intimate atmospheres (like hygge [26]). While 'adaptive opportunity' usually refers to the potential of a building and its infrastructures to control the *thermal* environment, residents' orchestrations required but also stimulated new know-how beyond just cooling and heating. From the effectiveness of resident's orchestrations, their advice to next inhabitants of their homes and us as designers, we plea for an integration of architecture and design. Drawing on 'undesign' [47] and resourcefulness in smart systems [35], we see potential in combining open-ended interfaces with elements that can 'hook-on' architectural and ecological elements to tap into latent affordances situated in and around the house. In considering how interfaces can take part in orchestrations, we prompt the following questions: What skills and know-how are required and produced in orchestrating a system that includes plant-collaborations, low-tech, hi-tech interfaces and IoT data? Can such a system be used to reconfigure practices? How can smart interfaces synchronize with low-tech interfaces (such a windows or doors) to afford a crude kind of pragmatism? What are the specs that matter in this synchronization? What opportunities arise when these systems do not avoid but rather work with discomfort? Can their repertoire (gradually) grow as residents adopt new know-how and 'learn their home'?

5.3 Design for everyday futures; challenging norms

In response to the observation that "the majority of energy research perceives households as homogenous and overlooks interaction

that is part of home management" [20], we found value in how the provocations afforded by the probes addressed the negotiations within and outside the household. Residents' interpretations of the probes and stories around practices required us to reflect on the ways we look around these spaces and ask questions as researchers, especially in the context of landlord-tenant, and other knowledge-power relations. Conversely, by explicitly asking residents what questions they had for us as scholars, their preconceptions about research and alternative energy futures were challenged. The probes were dialogical [63] in that they helped to sustain a conversation and shared interest beyond the initial responses. They were also *dialectical*, creating a space of legitimacy where conflicting views on for example responsibility, sustainability, energy, or comfort could be playfully addressed in the in-situ conversations. This dialectic quality of design probes enabled residents to share not only their expectations, but also *embodied arguments* for everyday futures [64] that would hold little power outside the situatedness of their homes. This manifested, for example, in entrusting us with intimate bodily needs, being able to point at a light, let us *feel* the effects of a draught or the shading of a tree, or demonstrate the intelligibility of a smart thermostat display. These embodied arguments gave power to what they would change, and to their questions and suggestions for us as academic 'experts'. On doing ethnography *with* people, Akama et al. [2] suggest that "perhaps HCI could also consider a wide range of experiences rather than affirming pleasurable, convenient, efficient and useful qualities". This approach opens a direction for design-based research methods that is both sensitive to empirical value of experience without catering to escalating techno-hedonistic expectations. We think there is participatory potential in - and a need for - design methods that combine dialectic qualities (e.g. critical design) and an attentive situatedness (e.g. ethnography or participatory action-research). Such methods can decenter, but not dismiss, the expert knowledges that underpin "the model of rationally calculated action that dominates energy policy" [70], in which the role of interface design is mostly limited to affirming pleasurable and efficient qualities.

To illustrate, the aesthetics of comfort as captured through participants' way of 'seeing' in and around the home are exemplary of the fluid ways in which the value of lived experiences (of comfort in this case) are entwined with corporality, uncertainty, mess(iness) and discomfort. People's willingness to engage with and feel the world around them beyond just the pleasurable, efficient, and useful insists that designers reflect on our role in framing people's relationship with technology in the energy transition and the extents to which we engage people in imagining new energy practices. Together with the empirical insights of other studies across various disciplines [5, 17, 35, 39, 42], we see these examples as building a catalogue of counter-aesthetics that offer starting points to legitimize a wider range of experiences and ways of knowing within current energy transition.

In our efforts to narrow down complex stories towards less abstract, more embodied insights, we chose to leave out many observations around power relations and political interactions between design, participation in energy transitions and energy futures that, in practice, can't be separated from dweller's sensory experiences, in-home technologies and the everyday practices they are part of. An example we think is worthwhile to mention here is that negotiations of privacy and public space in relation to comfort might be especially important for our participants because in the neighborhoods we visited, as in many other lower-income neighborhoods in the Netherlands, the density of residential units is often high and apartments small. Moreover, in social housing people generally have little choice about where and so whom they live with. While leaving these political interactions out limits the potential of this work to foster much needed debates on responsibility and visions as we move towards more participatory design and research practice [22], we think this is better addressed in future work that reflects on e.g. spatial justice in the home and the creation and implementation of energy technologies as political arena.

Finally, noting the limited diversity of cultural backgrounds between the people we were able to work with in this study despite our efforts, we call for more diverse empirical perspectives on what energy is for in and around the home. We see this as a relevant shortcoming in considering whom we design for, and whose futures are listened to. In addition, cultural diversity in understanding situated comfort making and how we 'see' energy present untapped opportunity to gain valuable inspiration from existing perspectives and practices.

6 CONCLUSION

Our study in two lower-income neighborhoods collected diverse strategies and know-how regarding the ways in which residents make themselves comfortable. We present these insights as alternative discourse to an increasingly energy intensive and narrow idea of comfort. The cultural probes and the conversations around them incorporate sensibilities from Sensory Ethnography and Everyday Futures to legitimize mundane ways of knowing and helped to better understand 'what residents' energy is (expected to be) for'. Findings reveal (1) the fluidity of comfort as multi-sensory negotiation, and (2) the sometimes-crude energy interfaces residents use to support making comfortable and energy-related knowing-how. Both involve effective collaborations, improvisation, and orchestration beyond displays and buttons. The willingness of residents to invest effort, work with discomfort and adapt, opens the space for alternative starting points to domestic (energy) interfaces that expand on values beyond just pleasurable and efficient. For design to build on, rather than replace, residents' existing strategies we plea for the integration of architecture and interface design, and to support ways of knowing-how available in and around the home. Synthesizing our own experiences, we stress the value and need for design-based research methods that legitimize alternative ways of participating in the energy transition.

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