A study of urban heat: understanding the challenges and opportunities for addressing wicked problems in HCI

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ABSTRACT
The Urban Heat Island Effect (UHI) is a phenomenon whereby cities tend to be hotter than suburbs. We frame the UHI as a “wicked problem” that poses a range of economic, healthcare, and social challenges. Our paper examines how different stakeholders negotiate complex value systems, collect data, and rely on collaborative platforms to address the problem of urban heat. Using documentary filmmaking as a research method, we conducted ethnographically-oriented interviews with participants including vulnerable communities, urban architects, microclimate researchers, and grassroots activists. Our findings reveal that unlike problems that can be solved using traditional HCI paradigms of distributed work, the UHI presents an entanglement of challenges that do not necessarily converge on a single solution. We conclude by discussing two opportunities for addressing wicked problems through social computing: knowledge systems for sharing hybrid data across domains and interactive forums for discourse among diverse actors.

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Urban heat, wicked problems

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
The Urban Heat Island Effect (UHI) is a phenomenon whereby urban areas tend to be hotter than suburbs. With urban populations projected to grow, and the overall temperatures trending upwards around the world, heat is beginning to present itself as a critical and timely issue for HCI. Indeed, heat poses many challenges, both in terms of its causes, which range from urban infrastructure and human activity to broader trends in climate change, as well as its impacts on human lives, including health, economy, and environmental justice. How can HCI contribute to this

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entangled space? What existing and new mitigation and adaptation approaches might be supported through design?

To explore these questions, we frame heat and UHI as a “wicked problem”—a societal problem that cannot be solved using reductionist scientific methodology because of conflicting stakeholder perspectives and our ever-changing understanding of the problem itself [38]. Leveraging documentary filmmaking [22] as an ethnographically-oriented research method, we present an analysis of the practices of stakeholders who work on mitigation and adaptation strategies, the people most affected by extreme heat, and the general public at large. Our site visits and interviews with 9 participants including vulnerable communities, urban architects, microclimate researchers, and grassroots activists in Sydney, Australia, reveal an entanglement of goals, approaches, and challenges around the UHI. Our findings do not converge on a singular solution for the problem of urban heat. Instead, our analysis of the interview data and footage reveals a complex system of actors, information flow, hybrid (often conflicting) approaches of structural nature and entanglements with other issues and wicked problems.

Research contribution
HCI research on collaborative work has a long history of tackling complex problems by distributing tasks across communities who seek a common goal [e.g., 25, 27, 31, 33]. The domain of extreme heat presents an interesting space for comparison, because, as a wicked problem, its solution and preferred course of action are not well-defined. The main contribution of our work is to present how diverse actors pursue different and sometimes opposing approaches to issues of human health, economy, and social justice within the context of heat. Drawing on our findings, we reflect on two future trajectories for HCI: social computing platforms for sharing hybrid knowledge across domains and interactive tools for discourse amongst diverse actors. These serve as opportunity areas for HCI to engage with UHI and other wicked problems that pose structural challenges that are similar to the issue of urban heat.

WICKED PROBLEMS AND HCI
A “wicked problem” is a systemic problem that concerns policy, planning, science, and society at large and cannot be solved by the classical paradigms of science and engineering [38]. Rittel and Webber discuss these problems as being hard to define, let alone solve, due to gaps in our

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knowledge, challenges of forecasting dynamic sets of variables, and conflicting social agendas. Wicked problems are difficult to conceptualize in part because they involve complex networks of actors who do not always share the same goals. Problems that are thus hard to define do not converge on a “perfect” singular solution.

**Urban heat as a subdomain within sustainable HCI**

Sustainability is increasingly seen as a space without a singular HCI solution. The past few years have brought a shift from developing interventions that encourage specific behavior change (e.g., reducing energy consumption [26]) to exploring systemic perspectives [e.g., 7, 24, 42]. A recent analysis presents sustainable HCI as a field that covers many “genres” of work [9], aimed at understanding issues in a range of subdomains, from environmental pollution to mass consumption and food systems [1, 8, 34]. Silberman, et al. reflect on the intellectual differences between these ways of examining and contributing to sustainable HCI and discuss sustainability as a complex, evolving, and indeed wicked problem space [41]. The authors also suggest that the “processes that give rise to the issues indexed by the term sustainability are larger in time, space, organizational scale, ontological diversity, and complexity than the scales and scopes addressed by traditional HCI design, evaluation, and fieldwork methods” [41]. Our study of urban heat is aligned with this view by inviting stakeholders to participate in video interviews on non-convergent issues, ranging from individual energy use and personal health, to broader trends in social justice and climate change.

In HCI, and particularly in Computer-Supported Cooperative Work and Social Computing (CSCW) research, complex problems are often examined in terms of smaller sub-tasks, with theories and interventions that improve the efficiency or quality of distributed work. Examples include systems such as IdeaGens, which manages expertise in crowd-based creativity tasks [10], frameworks such as the Model of Coordinated Action, which describes complex modes of participation [31], or studies of factors such as the role of feedback in improving the quality of the work [17], as well as numerous approaches for managing the coordination of the work itself [e.g., 27]. Most recently, Malone et al. examine Climate CoLab as a “contest web” that helps large groups address the issue of climate change “by simultaneously exploring many possible combinations of reusable subparts developed by themselves and others” [33]. Likewise, we focus on entangled values and practices in a wicked problem space, albeit through an ethnographically-informed study of actors affected by urban heat in Sydney, Australia.

**Documentary as a research method**

Rajmakers, et al. proposed “design documentary” as a new method to capture the nuances of everyday life and support a dialectic between the filmmakers, the subject(s) of the film, and the audience [37]. Indeed, a range of projects are exploring interactive content co-creation to involve stakeholders in constructing a narrative [12, 13, 15, 35]. Within HCI, documentary filmmaking has been applied to explore plurality of expertise [4], engage people with social issues [22], understand situated technology use [43], study collaborations in industrial design [44], and support dramatic storytelling [23]. Building on this work, we approached our interviews as contributing to a documentary about urban heat. This approach allowed us to capture site-specific factors and to engage with our interviewees not as study “subjects” but as experts who offer nuanced perspectives on the domain of urban heat.

**METHODS**

To develop a narrative that engages with urban heat and the various actors, resources, and values involved, we reached out to 39 diverse stakeholders, including government officials, vulnerable groups, activists, researchers, architects, and infrastructure developers, to name a few. In our initial email, we described the aim of the project “to communicate the causes, effects, and adaptation/mitigation strategies for urban heat islanding to a broader audience” and invited people to participate in a short interview about their work and daily lives in regards to heat. Of the 39 people we contacted, 20 people responded to learn more and 9 agreed to participate (3 female, ages 20’s-50’s). The main reasons for not participating were feeling unqualified to speak on the subject (e.g., a marine biologist’s work not focusing specifically on heat; or a homeless shelter coordinator not being involved in efforts that target heat in particular), as well as not feeling comfortable or not having work clearance to speak on the subject publically.

For each interview, we traveled to the participant’s place of work and spent a significant portion of the visit chatting informally to build trust, empathy, and rapport. Setting up the video/audio equipment presented a delicate moment when the participants recognized that their audience was no longer just us (the filmmakers), but the general public at large. We found several techniques to be particularly effective to overcome this shift: we often shared some personal information about ourselves when turning on the camera, and we tried to maintain continuity between the initial chat and the filmed interviews, which took on the format of conversations rather than Q/A sessions. This required much preparation behind the scenes, as we extensively researched each participant’s work prior to the site visit, developed questions that were specific to that area, and in some cases, discussed links between the participant’s work and themes from our other interviews.

Discussions with participants lasted 1.5-2 hours, with several longer tours (3-4 hours) of participants’ work areas (e.g., a construction site visit or sitting in on a community workshop). 30-60 minutes of each visit was filmed, with the remainder of the time used to build rapport. Upon reviewing the footage to construct the documentary, we discovered interesting implications for HCI, which we present in this paper. In order to publish our findings, we
acquired IRB (internal review board) approval to analyze our field notes and anonymized interview audio. Out of courtesy, we contacted all participants informing them of the post-analysis and offered them the option to have their work and name cited in this paper, which was preferred by one person. All of the interviews were transcribed and coded using an open coding scheme. Once a first draft of the film is completed we intend to show it to the participants, gather feedback and re-edit as needed. The final cut will be made freely available online (e.g., on Vimeo), and based on discussions with participants, we expect it to be widely shared amongst the stakeholder communities.

Our method is similar to other observation-based studies in sustainability domains [e.g., 9, 30, 40, 45, 46, 48]. Our questions were generative and often touched on themes from previous interviews, and we felt a sense of accountability to stakeholder groups. At the same time, participation in our study was not anonymous, which led to a selection bias.

**About the participants**

Our participants’ work ranges from academic research to on-the-ground heat relief efforts and sustainable design and development. Here, we present an overview of each area and refer to data from participants based on their domain.

**Microclimate research.** MR1 and MR2 both have backgrounds in architecture and engineering, and have conducted extensive PhD-level research on urban microclimates, albeit at different scales. MR1 relies on remote sensing to examine thermal properties on a scale of city blocks to assess urban developments based on their thermal signatures. MR2 uses ground-based surveys to examine façades, thermal comfort, and “the role of individual buildings in their contribution to urban heat”.

**Sustainability research.** Complimentary to understanding patterns in urban microclimates, our sustainability research participants investigate how heat impacts various stakeholder groups. Working with government service providers and local communities, SR1 examines information flow in regards to adaptive strategies. SR2 works with stakeholders to develop custom adaptation strategies. Their focus is to shift from a “blanket, state wide regulation of things, [and] give regions the ability and the capacity to make decisions for themselves, and figure out direction they need to go to get to a desirable future” (SR2).

**Sustainable architecture.** Bridging the gap between research and implementation, our sustainable architecture participants are involved in a range of development projects throughout Sydney. SA1 and SA3 are directors of a local architecture firm that designs green roofs, home insulation, or rainwater harvesting systems, while SA2, their collaborator, is a sustainability-focused builder. All three share the goal of engaging clients in sustainable development and “creating better quality space, improving quality of buildings in Australia” (SA2).

**Local grassroots initiatives.** While the SA projects tend to be commissioned by clients, participants LI1 and LI2 implement grassroots initiatives within their communities through local activism. LI1, who preferred to be credited by his name, Michael Mobbs, is the designer and inhabitant of “Sustainable House”1, a house in the heart of Sydney that is completely off the grid. He is also the founder of Street Coolers2, a non-profit research and action initiative managed by LI2, aimed at cooling Australian cities through initiatives such as drain gardens, pale pavement, and solar power. Both participants want to enact impactful, powerful change such as cooling the city by 2 degrees by 2020 and empowering the public “that an ordinary person like me, no special skills, can live like this [off the grid]” (LI1).

**Vulnerable communities.** Finally, two of our participants give voice to the stakeholders who are most affected by extreme heat. VC1 is a Homeless Health Service Manager, who implements heat relief initiatives to reduce the impact of heat on the homeless. His efforts include outreach and awareness, as well as coordinating various on-the-ground efforts between clinicians, case managers, and emergency response teams. VC2 is the health and safety coordinator for Australia’s Construction, Forestry, Mining and Energy Union. His main role is “responding to incidents or developing policy for workers”, such as, for instance, a policy that protects union members from working when certain temperature and humidity thresholds are reached.

**PARTICIPANTS’ UNDERSTANDING OF HEAT AND UHI**

Despite the participants’ different areas of work, they all shared an understanding of the urban heat island effect as a phenomenon whereby urban areas tend to be hotter than their surroundings. All participants also cited studies that suggested the number and intensity of heat waves would rise over the next 50 years. However, differences in perspectives arose when participants contextualized the UHI within their own areas of work, which led them to discuss different contributing factors and different impacts of heat on human lives and society at large.

**Emphasis on different contributing factors**

While all participants agreed that the UHI is influenced by a multitude of factors, each person contextualized the problem within their particular area of work and therefore examined a specific subset of causes. The microclimate and sustainability research participants (MR1-2, SR1-2) tended to focus on the material properties of the city, including thermal mass—the ability to capture and store heat energy; albedo—the amount of light and heat that is reflected by building materials, and perviousness—the degree to which materials comprising roads and buildings retain water. MR1

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and MR2 also discussed skyview as a factor, whereby building arrangement and street orientation also impacted an area’s ability to retain heat and cool off at night.

While the above factors were noted by the other interviewees, the local grassroots initiatives and sustainable architecture participants (LI1-2, SA1-3) tended to place much more emphasis on human activity within the urban infrastructure as a cause of UHI. For example, all 5 noted that the UHI was exacerbated by individual-level behaviors such as over-reliance on cars that increase heat transfer from traffic; the heat generated from AC, especially in uninsulated homes; and over-consumption of resources, such as relying on municipal water instead of using rainwater, or not transitioning to solar power. Moreover, while all 9 participants identified lack of shade as a leading cause of extreme heat in cities, LI1 and LI2 noted that residents were not implementing enough cooling initiatives such as planting trees to shade their neighborhoods.

**Emphasis on different impacts of heat**

All participants were concerned with thermal comfort—a person’s experience of heat due to surrounding conditions (temperature, humidity, sun exposure) and the individual’s coping capacity (e.g., age, activity level, clothing). As noted by MR1, “what most of us don’t realize is that the information that comes from a weather station is often in a context that’s very different from the urban environment.”

Heat’s impact on individuals was of particular concern to those working with vulnerable populations (VC1-2 and SR1). For the homeless who do not have access to AC, “the nighttime minimum [which is often higher due to the UHI] is really important because people can’t thermo-regulate properly” (VC1). Likewise, VC2 emphasized that “heat pays a major role in the industry. Every summer we have numerous workers that collapse due to heat stress. This summer alone we had two elder workers pass away on sites due to heat.” As noted by VC1-2 and SR1, heat’s impact on vulnerable communities is exacerbated by the fact that they often remain unaware of heat exposure due to high levels of activity, mental illness, or lack of information.

Participants who did not directly work with vulnerable groups tended to contextualize the impacts of heat within broader economic, political, and environmental processes, such as: increased load on emergency service and the healthcare system (SR1, MR1); an economic loss of $6 billion a year due to lost productivity (VC2, SR1, MR1-2); increased air pollution (MR1 and LI1); increased crime rates and human aggression (SR1); and larger death toll than any other natural disaster in Australia (“heat kills more people than storms and cyclones, bush fires and floods combined”, SR1). Thus, while participants shared a general understanding of the causes and effects of the UHI, they placed different levels of emphasis on these factors, especially as contextualized by their own lines of work.

**TECHNOLOGY USE AND INFORMATION FLOW**

We now report on participants’ use of technology to address the problem of heat. First and foremost, we found that technology plays a key role in connecting collaborators across domains: VC2 consults doctors, researchers, and ambulance services via phone or email to develop worker policies for extreme heat and humidity; SR1 uses digital datasets from the city council and local communities to examine the impacts of extreme heat; MR2 collaborates with government, industry and university partners to develop computational models of how heat interacts with urban development; SR2 works with the state government to develop regional adaptation plans and disseminate this information via social media; VC1 uses online communication to consult doctors, nurses, drug and alcohol clinicians, and mental health clinicians and develop heat relief efforts on the ground; and LI2 shares locally-collected data with city council to implement projects such as pale-pavement and off-grid housing. Communication tools were particularly valuable for the SA group, who typically worked with up to 10 other people, including builders, plumbers, electricians, designers, etc.:

“We often get the builders on really early in the process so that they can contribute too—their expertise and knowledge to the design as it develops.” SA2

This excerpt is not unique to SA, and reflects sentiments expressed by most interviewees, whereby participants emphasize working across domains to achieve their goals.

**Collecting hybrid data**

Alongside technology-mediated collaborations, participants rely on a range of digital tools to collect hybrid data, ranging from online datasets, analytical software, and handheld sensing, to social media and audio/video recordings of local knowledge shared by stakeholders.

**Online datasets**

Most participants relied on weather data (e.g., the Bureau of

![Figure 1. A green roof in a sustainable architecture project, a heat awareness pamphlet for construction workers; a community workshop to envision heat-tolerant bus shelters; and pale pavement (aspect ratio of documentary stills edited to fit paper format).](image-url)
Meteorology) to inform their practice, whether to assess work safety at construction sites (VC2), determine if an extreme heat protocol should be enacted (VC1), calibrate the energy efficiency of buildings against current conditions (LI1, SA1-3), or to examine trends in urban microclimates (MR1-2). Other widely-used datasets included census and income data (SR1), remote satellite imagery (MR1-2), building codes (SA1-3), and urban traffic data (SR2).

**Measurements and sensor data**

In addition to online sources, nearly all participants rely on digital tools to collect their own data (Fig. 2). For example, LI1 and LI2 installed sensors at various heights on streets where they were implementing green initiatives to understand variations in surface temperature, while VC2 discussed temperature monitoring at construction sites to alert workers when it was too hot to work. To assess microclimate patterns on a larger scale, MR1 chartered a flyover to capture airborne remote sensing data of the city and collected his own in-situ temperature and humidity readings. These measurements enabled him to divide the city in corridors and study how urban form (e.g. vegetation and high/low rise buildings) correlates with temperature. Similarly, MR2 conducted a ground-based survey using a custom-built weather station to “derive thermal comfort indices for outdoor thermal comfort”.

Despite having access to a broad range of technologies, there were no infrastructures in place for data sharing or comparison across sources. This structural gap was particularly salient when participants noted that their measurements were radically different from the reported weather information. For example, VC2 noted that construction sites tend to be hotter, especially when the work involves concrete pours or roofing, while MR2 noted that in urban canyons “air temperature locally was a lot hotter than those predicted temperatures”. Conversely, the grassroots initiative participants showed that the “street [with their projects] is 10 degrees cooler because of the abundance of vegetation out there” (LI1).

**Records of local knowledge**

All participants also relied on traditional recording tools (audio/video recordings, notes, photographs or social media feedback) to gather information from stakeholder communities or “end users” of their services or products. For instance, the SA group records building requirements, co-develops a design plan, and then later, gathers feedback to evaluate their work. VC1 likewise conducts online client surveys to understand heat-related challenges and assess relief efforts amongst marginalized populations. Similarly, SR2’s current project on heat-tolerant bus shelters includes recordings and social media coverage of “lots of user-centered workshops, so that people understand what the community wants from these shelters”.

However, while participants had many local efforts to reach out to other stakeholders to gather information, there were no infrastructures in place for collecting or analyzing this data at scale. The need for such systems was especially emphasized by MR1 and MR2, who stressed that input from stakeholders should be taken into account along with their microclimate analysis: “First of all, you try and understand how is that building going to be used by people inside and outside the building?” (MR2).

**Sharing information: approaches and challenges**

Technology was also used to disseminate the collected data: first, via various sharing tools between collaborators, and second, through platforms for broadcasting information more widely to other stakeholder groups.

**Tools for sharing data between collaborators**

Several forms of data sharing workflows leverage centralized information hubs: MR1 and MR2 share sensor data using online repositories at their universities; VC1 and his collaborators rely on the State Health Emergency Management system to stay aware of current conditions; while for LI1 and LI2, it is the physical co-location of projects in the city that leads to “co-location of knowledge”. More often than not, however, information is spread in ad-hoc and sporadic ways. All participants use unstructured email, phone calls, and texts to track progress and communicate with their collaborators, who range from co-workers, to city officials, external researchers, and representatives from local stakeholder groups.

There were many instances where unstructured information flow broke down. For instance, a major challenge for the SA group is determining whether different components are compatible within the system they are designing:

“We troll through manufacturers’ data, and I end up speaking to the trade guys. We stand and look at it and go, ‘Will this work? How will we make this work?’ …probably a more intelligent approach from suppliers of products in building a building like this is to— [have] a bit more communication across suppliers.” SA2

SA2’s quote illustrates how breakdowns in communication with suppliers make it difficult to know whether certain components can be integrated. Similarly, VC2 noted that there is no standardized database to track worker health related to heat: “there was no data on heat specific incidents, so I had to go to UCF Wales Health and get what we could off them about treatment for heat” (VC2).

![Figure 2. Hybrid data collection: thermal analysis of city blocks and monitoring temperature at various heights on a city street (aspect ratio of images edited for this paper).](image)
Breakdowns in communication between collaborators were also studied by SR2, who discussed instances where stakeholders wanted better knowledge systems—repositories of information that can be accessed by community members and the government. Our interviews thus show that information was shared most effectively through centralized repositories. In cases where these were not available, participants leveraged ad-hoc sharing mechanisms, which sometimes led to challenges and breakdowns in information flow.

Platforms for broadcasting to wider audiences
In addition to sharing data with collaborators, participants also used various mechanisms to broadcast information to a wider audience. VC1 and VC2 alert vulnerable groups about extreme heat events, sometimes using social media and messaging (“if forecast days are going to be in excess of probably 30, we start to send out alerts through social media or email”, VC1). More often, however, information is disseminated through education and outreach efforts on the ground: “we put out a lot of advice especially leading up to predicted hot days and try and educate through safety reps and delegates on sites. Talk to safety committees and site managers and things like that” (VC2). SR1 likewise noted that among vulnerable groups such as the elderly, an advert from the health department is often shared with key community members who serve as “information hubs” to propagate the knowledge throughout the group.

All participants also have ways of sharing their work with the general public. For researchers (MR1-2, SR1-2), this takes on the form of publications and presentations at academic venues. The activist participants LI1-2 use social media and community events to present their work and gain support (resources, funding) for their initiatives. VC1-2 likewise rely on social media and various public outreach efforts to engage a broader audience with issues around workers’ rights and initiatives for the homeless.

To summarize, our interviews show that information was shared most effectively through centralized repositories. However, in cases where such infrastructures were available, participants leveraged ad-hoc sharing mechanisms, which sometimes led to breakdowns in information flow.

ADAPTATION AND MITIGATION INITIATIVES
On a high level, the participants’ work falls into one of two categories: supporting adaptation and implementing hybrid adaptation/mitigation initiatives. Below, we discuss these strategies in detail and present tensions between “overly-narrow” solutions as noted by the participants. These findings provide a foundation for the design opportunities we discuss at the end of the paper.

Supporting adaptation to extreme heat
SR1 defined coping capacity as “people’s ability to deal with extreme heat”. Most participants understood coping to be influenced by a range of factors such as one’s access to cooling appliances, water, or sunscreen, as well as the person’s health, age, and mental state. The participants who focused on adaptation to extreme heat (VC1-2, SR1) discussed several strategies to enhance coping capacity:

“We give out bottles of water, sunscreen. We do try and move them [the homeless] into cooler spaces.” VC1

“Where it’s inevitable and the work has to go ahead, obviously, you want high rotation of workers, additional breaks, plenty of water, and shady areas.” VC2

“Some people might have the financial means to run an AC to keep their house cool. A lot of people that don’t have those financial resources available to them have to go to shopping centers, or the movies, or cooler areas.” SR1

Approaches like distributing water, finding shelter, or reducing activity demonstrate practical ways that vulnerable communities—construction workers, homeless, or low-income groups—can be supported in adapting to heat.

Hybrid adaptation/mitigation initiatives
While the above strategies offer immediate heat relief for affected communities, all participants agree that, as SR2 best put it, “mitigation and adaptation are not quite as separate as perhaps they once were thought of”. Participants implement a range of initiatives that take on this hybrid approach. For instance, planting trees was discussed by nearly everyone as a way of shading the street and cooling the environment through evapotranspiration, as well as mitigating climate change by absorbing storm water and increasing local biodiversity. Green roofs were likewise discussed as a hybrid approach: the SA group, for instance, implemented green roofs for adaptation—i.e. to insulate homes against heat, as well mitigation—to cool the area through evapotranspiration, grow food locally, and increase local wildlife. Many other participants (MR1, SR1, LI2) noted that green roofs also present additional benefits by filtering air pollution and retaining storm water. Pervious surfaces were seen as yet another example of a hybrid adaptation/mitigation approach:

“Pervious areas that are not sealed, on the one-hand side because we want to reduce the thermal mass in cities but also... for flood mitigation. Also, to get evapotranspiration and even the temperature difference”, MR1

In the above quote, MR1 explains how pervious areas provide a means of cooling the city by reducing thermal mass as well as mitigating floodwater.

Tensions between “overly-narrow” solutions
While all participants shared the high-level goal of supporting adaptation and mitigation, our interviews revealed tensions between the applied approaches, especially in cases where initiatives were deemed too “narrow”. For example, reflective or pale surfaces, which lower the thermal mass of buildings may negatively impact outdoor thermal comfort “because the surfaces themselves will not get hot, as hot, but the reflected energy goes
somewhere, and it goes into pedestrians” (MR2). Similarly, SR2 discussed the drawbacks of a new light rail project, which aims to reduce vehicular traffic, albeit at the cost of cutting trees for the development and therefore having a “social and environmental cost to the community”.

Other tensions arose when solutions were perceived to ignore certain stakeholders altogether:

“A lot of the green buildings and the ratings as you know are self-regulated, self-reporting and all that. The processes and the workers themselves don’t need to be looked at in their eyes, so yeah, they get forgotten.” VC2

“From an architecture point of view across the city, I can’t see that there would be anything from my perspective that would improve someone’s outcome if they were hypothermic or if they’re sleeping rough.” VC1

Here, VC1 and VC2 illustrate how many of the “green” developments fail to help those who are most vulnerable to heat. Tensions between “overly-narrow” approaches also emerged from the SA group, with SA2 discussing how “everything is a disparate collection” of components that are hard to integrate into working systems, and SA1 noting:

“One of the major problems is that there’s a lot of good systems and good equipment, but there’s no broad overview of, how do these things all work together?” SA1

COLLABORATIVE AND SYSTEMIC APPROACHES

While discussing the tensions between “narrow” solutions, participants tended to emphasize the value of holistic approaches beyond one particular intervention or group of stakeholders. Here, we present two emergent themes—supporting new value systems and engaging diverse stakeholders—as systemic solutions, and review challenges for these approaches as discussed by the interviewees.

Supporting new value systems

All participants noted that real impactful change would have to stem from shifts in value systems. On one hand, participants suggested aligning public perceptions of what is “sustainable” with what is “high quality” and easily achievable. For instance, using various social media campaigns, LI1 worked to demonstrate that his off-the-grid house was just as comfortable and easy to operate as a regular home that relies on municipal resources. Likewise, the SA group emphasized that “part of building a high-quality building is it’s got to be sustainable” (SA2). In the excerpts below, participants suggest that sustainability should be perceived as a popular social norm:

“Ideally, I’d really love to see the phrase ‘green design’ just disappear, that green would disappear, and it just becomes design, and this is the norm”. SA3

This quote reflects comments from other participants (LI2, MR1-2, SR1-2) who suggested that sustainable living could be integrated into everyday, habitual behavior rather than being seen as a special kind of activity. On a higher level, participants also wanted to see a shift towards embracing humanitarian values such as justice, equity, and empathy between different stakeholders.

“The main challenge around sustainability is not the technology, ‘cause we have that. It’s more around the social equity. It’s around can we make it a more fairer society and a society that’s more inclusive and a politically more tolerant society.” MR2

MR2’s comment suggests that a “fairer” society would be more equipped to address complex sustainability problems such as the UHI, which cannot be solved with technology alone. Similarly, the VC participants discussed how a “stigma to homelessness and to homeless people” (VC1) or an attitude of “I’m glad I don’t do [construction work]” (VC2) prevents society from empathizing and addressing UHI’s systemic impact on vulnerable groups.

Engaging diverse stakeholders in the process

In addition to embracing different value systems, participants also suggested involving diverse stakeholders in developing heat adaptation and mitigation strategies. For the SA group, this meant involving clients in co-design and engaging them with sustainable buildings as ecosystems:

“What we’re working in is an ecosystem, and every part of it’s really important… but it’s all about empowering people to say they are important in this.” SA1

This idea of involving different perspectives in system design was embraced by most participants. For VC2, this meant designing buildings or infrastructures with construction workers in mind, i.e. “to be built in a safe way so that the end product has safer means for the guys doing the work”. For VC1, this also meant conceptualizing heat as a problem that impacts a broad range of people and “not only looking at our most marginalized population, but for everyone really”. For SR2, this meant involving community members, social scientists, designers, and engineers in the development of public infrastructure. Finally, for MR2, this meant collaboration across domains including the “commercial side, in the design-based industries and the developing industries, but also on the minister, government, regulatory environments” (MR2).
Participants discussed several challenges that hindered systemic approaches from being enacted to address heat.

Gaps in policy and public awareness
Participants discussed gaps in public awareness and shortcomings in sustainable policy as the biggest hurdles for changing existing value systems.

“If government regulations were even comparable to Europe where they do ask of everybody to hit a certain level with energy efficiency in certain things.” SA3

“All the technology we need already exists, we just need people to import it. People to change policy. Just more projects to get people excited about change”. LI2

According to the participants, the gaps in policy regulations and incentives were re-enforced by a lack of public awareness. Some participants noted that heat was less covered in media and its “effects aren’t always immediate and can’t be seen” (VC2). Others pointed to a disconnect between people and the outdoor environment:

“Particularly in cities, that environmental signal was lost because everybody lives and works in an air conditioned environment most of the time. Then, it’s only when you go outside that you realize, that yes, it is incredibly hot.” SR2

Participants thus suggested that the public was often removed from the problem of heat—whether by physical barriers of air conditioned buildings, or insufficient social attention and media coverage. These gaps in policy and awareness were seen as fundamental challenges for adopting new values to embrace sustainability as a “norm”.

Diverse goals and agendas
As we discussed earlier, a lack of centralized “knowledge systems” presents a practical challenge for collaborations between diverse stakeholders. In addition, our participants also highlighted divergent stakeholder goals as a key barrier for involving more people in the process. The tension between construction workers and people in charge of development projects was perhaps the most clear-cut. As VC2 explained, “for them, [project leaders], the best possible thing is to keep the project going. A lot of the time workers’ safety gets put to the side because of that.” Similar tensions arose in different domains. For instance, SR2 noted that there is often a mismatch between council engineers, who must build infrastructure “on a very tight budget, the transport providers, who must operate within the infrastructure, and the community members, who’s quality of life depends on the infrastructures. Other participants discussed differences in agendas more broadly, reflecting a sentiment that opposing goals often hinder collaborations and involvement from diverse actors:

“You’re trying to communicate with people from a very different discipline from you, you’re talking across purposes. Sometimes it can be really difficult to get those collaborations.” SR1

DISCUSSION
Thus far, we have presented themes from our interviews with stakeholders who work in the domain of the urban heat island effect in Sydney, Australia. These themes reveal that while the various stakeholders share a general understanding on the UHI, they conceptualize the problem differently depending on their particular area of work. Below, we review key insights into heat as a wicked problem as revealed by our study.

The wicked problem of heat
Our findings show that urban heat is a complex issue that is difficult to conceptualize, let alone solve. Indeed, our findings show that while all participants shared a general understanding of UHI, there were key differences in the way the problem was scoped. For instance, participants from academic disciplines (microclimate and sustainability researchers) tended to focus on urban infrastructure as the main contributing factor, while stakeholders who implemented initiatives on the ground (architects and activists) placed greater emphasis on human activity as the leading cause of urban heat. The impacts of heat were likewise perceived differently, with stakeholders representing vulnerable populations placing greater emphasis on individual challenges (e.g. heatstroke), and others contextualizing heat within broader economic, political, and environmental factors.

Wicked problems, by definition, cannot be solved within a single field of study, and it is therefore not surprising that all of our participants’ work is highly collaborative. Our interviews reveal that the initiatives for addressing the UHI
draw on hybrid expertise: participants deliberately involve academic researchers, medical professionals, policy makers, builders, and stakeholder communities in developing solutions across domains. The diversity of the initiatives, as well as the emergent tensions between them, further highlight the complexity of the problem space. The projects range from data collection and analysis, to efforts for improving local coping capacity, as well as large-scale green developments and awareness campaigns. Interestingly, while all projects aim to address the UHI, our findings reveal that narrow solutions aimed at alleviating one factor may have negative consequences (e.g., green development may reduce heat but does not consider thermal comfort of construction workers; pale surfaces lower thermal mass but reflect the heat onto pedestrians). In discussing the drawbacks of narrower approaches, participants emphasized systemic solutions that produce shifts in value systems and involve many types of stakeholders in the process.

To summarize, our interviews reveal that urban heat is interlinked with issues beyond individual thermal comfort, and this suggests that the problem must be addressed through structural interventions rather than solutions for individual stakeholders. From a broader perspective, a structural approach resonates with longstanding social/historical analyses of dynamic information flow and conflicting interests between actors and networks [28, 29]. Our findings are also aligned with STS scholarship on the fluidity and instability in people’s understanding of “nature” [18, 47]. For HCI, our insights can generalize to other sustainability domains—air quality, energy consumption, or e-waste—where diverse actors such as end users, policy makers, grassroots activists, and corporations interact.

ADDRESSING WICKED PROBLEMS IN HCI
The dialectic relationships with our participants allowed us to holistically examine urban heat as a wicked problem, rather than focusing on one stakeholder group or solution in isolation. Above all, the initiatives for addressing the UHI are highly collaborative and draw on hybrid technologies and expertise. Participants deliberately involve academic researchers, medical professionals, policy makers, builders, and stakeholder communities in developing solutions across domains. The diversity of the initiatives, as well the emergent tensions between them, further highlight the complexity of the problem space. The projects range from data collection and analysis, to efforts for improving local coping capacity, as well as large-scale green developments and awareness campaigns. Interestingly, our findings reveal that narrow solutions aimed at alleviating a single facet of the UHI may have negative consequences (e.g., green development may reduce heat but does not consider thermal comfort of construction workers; pale surfaces lower thermal mass but reflect the heat onto pedestrians).

Wicked problems, by definition, cannot be solved by one group of people, which makes them particularly relevant to HCI. While our findings do not converge on a singular solution, the challenges discussed by our participants reveal two concrete directions for future HCI research.

Collecting and sharing hybrid data
Similar to stakeholders working in may previously-studied sustainability domains such as environmental monitoring or local farming, our findings show that participants rely on hybrid sources—from scientific datasets to sensor data they collected themselves and local knowledge from stakeholder communities—to inform their work. These diverse channels often present complimentary or opposing perspectives, as in, for example, the temperature differences between weather reports and local monitoring data or people’s thermal comfort on the ground. While sharing this data is crucial for participants, gaps in infrastructures result in breakdowns in information flow. This suggests a need for computing infrastructures that support collecting and sharing hybrid data.

On one hand, new sociotechnical systems can aggregate different types of information: data from low-cost temperature sensors deployed on vehicles or drones might be combined with qualitative community knowledge and/or thermal images gathered via a phone app. These on-the-ground sources might in turn be integrated with information from other sources such as satellite imagery, healthcare statistics, weather reports, or policy findings. The resulting “knowledge systems” could be made accessible across diverse collaborator groups such as construction workers, activists, policy makers, builders, engineers, and architects. Computational analysis, coupled with new visualization techniques might reveal discrepancies and conflicting data-points, and represent these tensions to support collective engagement with pluralistic perspectives [as in 16].

In addition, new interactive tools can support broader information dissemination. Currently, our participants try to overcome gaps in public awareness by sharing knowledge through various social media channels as well as in-person outreach efforts. Interactive systems can enable engagement with data beyond viewing traditional numerical or graphic representations. For example, co-design might be applied to develop place-based installations and physical knowledge systems to take on the form of public displays, projections, or kiosks at specific locations (e.g. particularly hot streets or construction work sites). These installations could engage the public with hybrid knowledge by visualizing local sensor data along with thermal satellite imagery, community narratives, and current adaptation/mitigation efforts. Such systems can be applied to other domains such as environmental sustainability to bridge gaps in information flow and help stakeholders align their goal.

Supporting dialectic between diverse stakeholders
Our research uncovered tensions within the complex UHI system of actors, values, and initiatives. Examples range
from the logistical mismatches between components of architecture projects, to diverging aims between project management and construction safety coordination, or friction between community interests and budget and engineering constraints in infrastructure development. While participants try to involve diverse perspectives, this is often done on a very small scale—e.g., through workshops. The need to support discourse across larger groups presents new and exciting opportunities for HCI, not only within the problem of heat, but across other domains.

There are many different formats for supporting discourse, such as, for instance, the idea of a “city commons”—an infrastructure for shared resources that bring together stakeholders around an environmental issue [2]. Given the stakeholders’ widespread use of technology, our findings suggest that much of the technology is already place, but cohesive interventions hinge on changing values, which speaks to the limitations of technology-centered approaches in HCI.

Here, we give special attention to documentary filmmaking because it offers a rich way of sharing first-hand experiences, and because lower-cost recording tools (e.g., cameras on mobile phones) are democratizing content production. Indeed, the documentary format has a long history of being used to initiate dialectic. Earlier in this paper, we noted the works of Cizek, Rose, and Davenport as examples of generative content production that engages participants with each other’s work, as well as the output format that speaks to a broader public [13, 15, 35].

For HCI, documentary filmmaking presents an exciting avenue for crowdsourcing, sharing, and co-producing media content. Recent HCI projects have already been contributing a range of tools to democratize video production and editing, as well as to crowdsourcing content acquisition [4, 5, 39]. These tools, coupled with existing paradigms of distributed work [e.g., 10, 25, 27] could enable stakeholders to create short documentaries around a wicked problem (e.g., heat) as parallel tasks. Using distributed worker platforms such as Mechanical Turk, this media content could be classified by content and shared across social platforms. Annotated media would enable actors to collectively examine practices, challenges, and dependencies around issues such as thermal comfort, public infrastructure development, social equity, and environmental justice. This would result in discourse between stakeholders working in a wicked problem space and potentially build empathy to overcome barriers such as stigma attached to homelessness or construction work. More broadly, platforms for bottom-up film production could help invert values re-enforced by mainstream media. Documentaries produced by the stakeholders themselves can serve to shift value systems around “green design” and what is “sustainable”.

CONCLUSION AND FUTURE WORK

In this paper, we used site-specific interviews that followed a documentary filmmaking approach to investigate the UHI effect in Sydney, Australia. In a forthcoming manuscript, in-depth consideration will be given to filmmaking as a cinematic genre to understand how cinematic techniques can be used to capture nuanced aspects of participants’ lives. While methodology is not the primary contribution of this paper, we nevertheless reflected on how: filmmaking requires preparation and care to effectively elicit in-depth responses; delivers deep insights into people’s first-person perspectives; supports generative dialectic between participants; and entails new forms of accountability between stakeholders.

The focus of this paper has been primarily to examine the practices, challenges, and approaches of different stakeholders working in the domain of urban heat. Our study reveals heat as a complex problem that is interlinked with issues beyond individual thermal comfort, and involves economic, climate change, social justice, and public healthcare concerns. The technologically-mediated entanglements between stakeholders, information flow, and actions do not converge on a singular solution to UHI. However, our findings suggest that CHI research can engage with wicked problems by developing: 1) knowledge systems for sharing hybrid data from personal sensors, scientific datasets, and first-hand observations; and 2) tools for supporting dialectic through larger-scale video collection, annotation, and sharing between stakeholders. Above all, we hope our work has contributed to HCI paradigms for holistically addressing the big challenges of our time.

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