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Designing technology for smart and sustainable cities of tomorrow – What can we learn from IPCC's sixth assessment report?

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ABSTRACT

Since their emergence, technologies have been applied to sustainable development in urban contexts. However, as the pace of climate change is still rapidly increasing, the question remains: what are the most urgent actions that designers of urban technology should focus on during the next ten years? In the HCI community, we need to consider the arguments of climate change experts more extensively. This paper reviews the latest recommendations by the Intergovernmental Panel on Climate Change related to technology development in an urban context, aiming to respond to these sustainable urban technology design requests. Based on the principles of social sustainability and mixed methods approach and analysis of the IPCC's sixth assessment report, this review offers insights into the most urgent challenges that technology design should focus on. The findings suggest priorities and directions for future work when the aim is to halve greenhouse gas emissions by 2030.

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Climate change, urban environments, urban technology

Introduction

Climate change as a global phenomenon is an indisputable fact, and the pace of warming is at a level where more immediate actions than before are needed. One way to tackle the challenge of global warming that is presented is to have technology help us to reduce the pace of warming and warn about the impacts of warming. For example, technology could forecast rapid and unexpected changes or monitor the environment and extremes that happen, or at least technology might support us in slowing down the pace of global warming

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(Feng et al. 2021). In urban environments and particularly in smart city contexts, many attempts are presented to solve the global climate challenge, for example, as roadmaps to the smart and sustainable city on applying digital technology to serve citizens and provide sustainable socioeconomic development and public governance in the digital world (Pereira et al. 2019) or flood risk calculators (Richards and Knowles Ball 2020). In addition, in recent HCI-related research, it is argued that design processes of smart and sustainable cities should also involve citizens from marginalised and diverse communities (Heitlinger, Bryan-Kinns, and Comber 2019), or how civic tech initiatives should dedicate to environmental issues (Hamm et al. 2021). Quite recently, one of the research domains in HCI has turned the attention towards more-than human-centred approaches or planetary-centric approaches instead of user-centric or human-centred approaches to design (see, e.g. Clarke et al. 2019; Heitlinger et al. 2021; Wolff et al. 2021). Regarding these posthuman design practices, Oogjes and Wakkary (2022) present the repertoires, i.e. 'actions the human designer can take to increase participation of nonhumans in design research practice'. In addition, during the past ten years, HCI conferences have dedicated sessions for submissions related to sustainability issues in HCI and environmental issues and particularly, the themes and topics related to sustainability have been acknowledged among HCI researchers as Sustainable HCI (SHCI).

Sustainable HCI research has attempted to address sustainability challenges by focusing mainly on environmental and economic sustainability. Hansson, Cerratto Pargman, and Sapiens Pargman (2021) reviewed SHCI research during the years 2010–2019. According to the review, most of the SHCI research tends to discuss topics of SDG 12, i.e. Responsible Consumption and Production (ibid). Thus, the focus has been on economic sustainability. However, the Brundtland's commission (World Commission on Environment and Development 1987) initially presented three 'pillars' of environmental, social, and economic sustainability defined in 2002. Furthermore, later the fourth pillar, cultural sustainability, was added to discussions (Hawkes 2001). It is argued here that the clear emphasis on economic and environmental sustainability is evident, as is the need for more research on social (and cultural) sustainability in HCI research.

In addition to Hansson, Cerratto Pargman, and Sapiens Pargman (2021) study, also Bremer, Knowles, and Friday (2022) reviewed the critique that sustainable HCI has faced in previous HCI-related research and concluded that HCI researchers should do 1) multidisciplinary expertise and collaboration, 2) shared understanding of sustainability with agreed goals and metrics, 3) systems thinking: simplified solutions will not solve structural problems, 4) system change and activism, and 5) re-imagine the economy and consider limits to growth. All these stated critiques indicate that the way we think in the HCI community of sustainability must change if the aims of a sustainable

future are to be accomplished by the given deadline for reducing greenhouse gas emissions.

In addition, and despite the ambitious attempts to support the UN's Sustainable Development Goals, the emphasis of current SHCI research on environmental and economic sustainability may not be in line and do not respond to the recommendations that the latest the Intergovernmental Panel on Climate Change (IPCC) reports suggest. In particular, the impact of sustainable HCI studies and assessment methods is unclear, as Silberman et al. (2014) have stated earlier. The reasoning for dominant anthropocentric approaches in the HCI community should be reflected and reconsidered, and also the directions of sustainable HCI should be re-evaluated, as Bremer, Knowles, and Friday (2022) have earlier suggested.

The main reason for the reconsideration is that despite the ambitious projects and excellent initiatives of smart and sustainable development in an urban context, the pace of climate warming is still increasing. According to climate change scientists, the pace is alarming, and the target based on The Paris Agreement is to decrease global warming below 2.0 °C above pre-industrial levels and to limit the global temperature rise to 1.5 °C. IPCC (2018, p. 6) identified 'cities and urban areas as one of the four critical global systems that can accelerate and upscale climate action'. Undoubtedly, there are several reasons for this climate warming development, and there is a common agreement that multiple approaches and techniques must tackle the global challenge. What is also a common agreement is that this is an urgent matter to solve (IPCC 2018). Most recently, at Glasgow Climate Change Conference, 141 countries joined the Glasgow Leaders' Declaration on Forests and Land Use urging the actions for finding solutions. (COP26 2021) One way to take part in finding solutions is to design and develop technology that supports climate actions in an urban context.

This study tackles the climate change challenge by reviewing the experts' recommendations on climate change in an urban context. These recommendations are here to be reviewed to show the directions for future HCI research and outline the most urgent domains to focus on for those researchers aiming to develop sustainable and smart urban environments. In addition, this review provides insights into design approaches and guidelines that could support designers throughout the design and development processes.

Thus, this paper reviews the recommendation of the Intergovernmental Panel on Climate Change related to technology development in an urban context. The motivation of the paper is to seek a better understanding of the priorities of future technology design and HCI research in a smart urban environment. The reasoning behind this aim is that 70% of the pollution originates from urban environments. In addition, climate change is related to

health issues of living beings, not only human beings. Air conditions, heat waves are urban floods are obviously causing health problems and social issues, not to mention biodiversity loss. So, the challenge is not only environmental but also social challenge. Therefore, this paper discusses the outcomes based on the social sustainability approach, which is one of the three pillars of sustainability, and which clearly lacks in the current sustainable HCI research in an urban context. In this paper, social sustainability, i.e. a good accessibility to all city functions for all ensuring a safe and accessible urban mobility (Candia, Pirlone and Spadaro 2019), also provides a framework for analysing the data with distributional, recognitional, and procedural equity.

Hence, this paper reviews the recommendations of the experts on climate change that are related to human-computer interaction design in an urban context. This paper aims to seek answers to the following questions:

RQ1: What are the key characteristics and recommendations for urban technology design derived from the IPCC's sixth assessment report?

RQ2: How could these characteristics and recommendations could be applied in urban technology, particularly HCI design?

RQ3: What are the application domains of design indicated as with high priorities and with possible technological solutions?

The main contribution of this paper is to look at the most urgent priorities and recommendations that the HCI research community should focus on in the near future if the aim of HCI researchers on their part is to reduce the impacts of climate change in society. It is admitted here that the climate change phenomenon is complex, and one approach or solution can't solve the challenges of future climate conditions. However, that is particularly why this study relays the arguments and recommendations of the experts on the field of climate change. IPCC is a globally recognised organisation that regularly gathers information from the latest scientific research related to climate change and publishes both technical reports and summaries for policymakers on a regular basis. By systematically reviewing what kind of recommendations and focus areas the IPCC reports and experts on climate change are providing, we could ensure that choices of the directions of research and areas of applications covering those domains, through which we could gain the most effective impact on climate change development.

Background

Urban context

At first, we need to define what we mean by 'urban' context. Based on the report 'A new perspective on urbanisation' (OECD and European Commission

2020), (Murali et al. 2019; Ward and Shackleton 2016) the degree of urbanisation is a continuum of

1. cities
2. towns
3. semi-dense areas
4. rural areas

Of the world's population, almost half (48%) live in cities, 28% live in towns & semi-dense areas and the rest 24% live in rural areas. In addition, metropolitan areas are defined as functional urban areas together with their commuting zones (OECD and European Commission 2020). It is argued here that it is important to acknowledge the continuum of urbanisation because urban centres and rural areas are connected and create together infrastructures (Steele and Legacy 2017) and mechanisms (Dijst et al. 2018) for enabling flows, for example, for energy, water, transports, and communication. In addition, characteristics of environmental hazards are that they don't recognize or respect governmental boundaries between countries, cities, and rural areas.

In cities, the connection between smartness and sustainability is critical and has been discussed in recent years in the context of urban technology (see Bibri et al. 2023). The work done at the EU level has given a strong imperative highlighting the role of smart cities as an engine for sustainable development and urban transformation (Martin et al. 2019). Smart systems that monitor resource use and environmental conditions, such as air, water quality, energy consumption, heating and cooling, have been useful in optimising operations. However, the strong technological orientation has been criticised for becoming more of a goal rather than a tool for greater purposes, such as sustainability (Martin et al. 2019) and smart city initiatives usually have a very technocentric approach that fails to incorporate the needs of the natural environment (Yigitcanlar et al. 2019). Quite recently, the focus has turned to assess if and how smart cities have changed behaviours and quality of life as current research highlights connections between environmental and social sustainability in smart cities (Heitlinger et al. 2021; Trivellato 2017; Beretta 2018). The impact of social sustainability is emphasized.

The previous responses from the HCI community

During the past ten years, sustainable development has become a part of HCI community research. DiSalvo, Sengers, and Brynjarsdóttir (2010) mapped the landscape of sustainable HCI and identified different genres (persuasive

technology, ambient awareness, sustainable interaction design, formative user studies, and pervasive and participatory sensing). Ferreira, Nisi, and Nunes (2022) investigated HCI and design on climate change and engagement with general public.

One major HCI community's response to environmental issues is the domain of Sustainable HCI (SHCI). According to Hansson, Cerratto Pargman, and Sapiens Pargman (2021), SHCI research during the years 2010-2019 tends to empathise with research topics related to mainly the UN's Sustainable Development Goal SG Responsible Consumption and Production. Furthermore, Arambepola and Munasinghe (2021) categorised Sustainable Interaction Design (SID) into 1) sustainability in design and 2) sustainability through design. They also highlighted that sustainable energy had been a dominant research area in SHCI. (ibid)

However, despite the honest and ambitious attempts of the HCI community, the significant and impactful results of sustainability in the field of HCI are yet to come. Or as Knowles, Bates, and Håkansson (2018.) later put it, 'We have spent so long debating definitions of sustainability and SHCI and being indecisive on a direction to pursue that to have any reasonable chance of affecting change, we must make a bold and radical decision on a future course of action'. This notion is confirmed with the findings of Bremer, Knowles, and Friday (2022) who stated that even though there are shifts in 'the SHCI landscape, toward research that is diverse and holistic, but also away from efforts to address the urgent climate crisis'.

Social sustainability

As noted earlier, social sustainability is defined one of the sustainability pillars by Brundtland's commission. Social sustainability is defined by Candia, Pirlone and Spadaro (2019, p. 192) 'as the ability to guarantee, in the most impartial and widespread way possible, even to the weakest subjects, a good accessibility to all city functions; therefore, social sustainability implies a safe and accessible urban mobility'. Accessibility to city functions and safe environments are a couple of the many aims that technology should provide for citizens, for example, by providing public digital services and smart lighting in the streets. Boström (2012) pointed out that in social sustainability, we should divide substantive aspects (what to achieve) and procedural aspects (how to achieve). Thus, the connections between social sustainability and technology in an urban context can be related to customs and channels of sharing information, for example, about the possible risks and supporting the well-being of citizens with technology.

Social sustainability holds the aim of social equity, i.e. justice and fairness for all people. One way to investigate social sustainability and technology in

urban contexts is to apply the different aspects of social equity. These aspects are distributional, recognitional, and procedural equity. Distributional equity means the fair allocation of outcomes of material goods to all members of society (see Schlosberg 2007; Meerow, Pajouhesh, and Miller 2019). In the context of urban development, this may refer to 'equitable access to goods and infrastructure, environmental amenities, services, and economic opportunities' (Meerow, Pajouhesh, and Miller 2019, p. 797). Recognitional justice refers to the equal acknowledgement and respect of different identities and associated social statuses (Schlosberg 2007). Procedural equity is closely connected to both recognitional and distributional equity. An individual or group's membership and participation in decision-making is integral to the equitable distribution of material goods. Without recognition procedures, an individual or group cannot participate in the community; and without such participation, their needs cannot be recognised either. (Meerow, Pajouhesh, and Miller 2019) By focusing on these three aspects in the context of urban environments, we could analyse, in more detail, how technology in the urban context could support sustainability. Therefore, distributional, recognitional, and procedural equity outline the framework for the analysed data.

Data and methods

The main data source for the study presented in this paper is the sixth assessment report published by IPCC. The first part of the report, The Working Group I contribution to the Sixth Assessment Report, Climate Change 2021: The Physical Science Basis, was released on 9 August 2021. IPCC finalised the second part of the Sixth Assessment Report, Climate Change 2022: Impacts, Adaptation and Vulnerability, the Working Group II contribution on 27 February 2022. The chapters in part II, describing the state-of-art in different continents, were excluded from this study. The third part, IPCC's Sixth Assessment Report, Climate Change 2022: Mitigation of Climate Change, the Working Group III contribution, was finalised on 4 April 2022.

These reports can be assumed to present the latest scientific knowledge from a global perspective. In addition, the authors and the reviewers of these reports are recognised as a top scientist in their own research field. The primary source of the study is the three parts of IPCC's Sixth Assessment Report reports. The accepted versions of the technical reports are available for downloading on IPCC's website at https://www.ipcc.ch/. The technical reports were chosen as a primary resource because the summaries of the technical reports to policymakers are processed through policymaking decision processes and are considered here as the secondary data source.

The analysis was conducted with the mixed method approach, including quantitative and qualitative analysis methods. Qualitative content analysis with thematic categories, here distributional, recognitional, and procedural equity, was adapted from Kuckartz (2019). The content analysis with the inductive approach was conducted with the following phases:

1. searching the recommendations and actions related to an urban context
2. coding the urban-related data
3. analysing the frequencies of search terms with descriptive statistics
4. reviewing the context (distributional, recognitional, and procedural equity) where the recommendations are indicated
5. reviewing the reasoning context (distributional, recognitional, and procedural equity) behind the recommendations

The analysis was conducted, and data were coded with Atlas.ti-software between March and April 2022 and during November 2023. The search terms for finding the urban context were urban, urbanisation, and urbanism. In addition, the words city and its extension were included in the search. The total number of resulting words was 8489. After the titles of the references, names, and not related words, like disturbance, were removed, the total number of resulting words was 4290.

The criteria for reviewing the context were defined as follows:

- Distributional equity: Equitable access and allocation of technology
- Recognitional equity: Equal acknowledgement and identification of technology users
- Procedural equity: Participation in decision-making in the design processes

Findings

The findings cover the general recommendation for actions to respond to changing climate in urban contexts. In addition to that, more detailed results are presented related to the design and development of technology.

The first part of the IPCC's report, The Working Group I contribution to the Sixth Assessment Report, Climate Change 2021: The Physical Science Basis, was released on 9 August 2021. This report presents the understanding of the current state of the climate, including how it is changing and the role of human influence, the state of knowledge about possible climate futures, climate information relevant to regions and sectors, and limiting human-induced climate change.

When focusing on urban context and technology design-related issues, in the first part of the Sixth Assessment Report, neither design nor

development is in a big role. However, both the regional and local approaches are emphasised in addition global one. The emphasis on the regional approach can also be found in part two of the Sixth Assessment Report. In addition, the anthropogenic phenomenon is mentioned together with warming, urbanisation, water, and heat.

The second part of the IPCC's report, The Working Group I contribution to the Sixth Assessment Report, is clearly emphasising the adaptation and adaptation management to climate change. This recommendation for adaptation is seen as part of actions to be proactive and reactive to changing climate conditions. In addition, adaptation management is tied together with technology development and technology design with the recommendations of the target groups, design approaches and application domains. The emphasis is on ensuring that technology is developed and designed in such a way that most of the people can use it, for example, in the case of extremes.

The third part of the IPCC's report, The working group III contribution calls policies, infrastructure and technologies needed to reduce global greenhouse gas emissions as recommended. This part of the report addresses the connection between climate mitigation and sustainable development. The third part of the report highlights the social aspects of climate change and describes the available mitigation pathways. The third part of the report covers highly relevant issues for urban technology design domains.

The frequencies of the selected search terms show what is empathised in the IPCC's reports in the urban context (Table 1). Not surprisingly, as focusing on the impacts of climate change, Part II and Part III of the report discuss more design, development, and technology-related issues than Part I of the report. Still, by looking at the relative frequencies of different terms within the reports, it can be argued that technology or technology-related terms as

Table 1. The appearance of the search terms in the urban context in the IPCC's Sixth assessment reports.

Key term	Part I	Part II	Part III	Total
technology, technologies, technical	7	102	174	283
application, applications	2	9	34	45
ICT	0	17	6	23
net, network, networks	18	133	187	338
automation	0	10	5	15
development, developments	26	385	296	707
design	3	78	109	190
robot	0	0	0	0
hardware	0	0	0	0
software	0	0	0	0
urban, urbanisation, urbanisation	240	1552	1518	3310
city, cities	53	509	1229	1791
rural	12	152	64	228

understood as related to computers and information technology or ICT, in general, have rather small proportions compared with, for example, transport or transportation (338), or fish/fisheries (43), or road, roads, roadways (52). The same thing is with the ICT related concepts like artificial intelligence, robots, blockchain, VR, AR, and mixed realities. It can be argued that the authors of the IPCC reports don't see these technologies as the most prominent solutions to the challenges of rapid climate change.

Actions to respond to changing climate in urban contexts: Adaptation and mitigation

Emphasis on procedural and recognitional equity

At a general level, based on the analysis, adaption is one of the most important aims of human actions in the future. The reports describe adaptation pathways, adaptation management and the importance of learning adaptation. Adaptation is seen as a strategy in urban transition, and the planning of that should be inclusive and long-term planning at several scales, i.e. local, municipal, sub-national and national scales. Part of this planning is to provide the technical resources and capabilities in urban systems and such infrastructure and services that enhance the adaptive capacity of vulnerable people. Moreover, as an example, a community-based adaptation is mentioned as one of the strategies for enhancing the lives of particularly low-income and marginalised groups.

The other clearly important aim is mitigation, which is concurrently taking place with adaptation. Based on the data, adaptation and mitigation are part of climate-resilient development. Currently, urban environments in more developed countries are prepared for adaptation and mitigation (Olazabal et al. 2019). According to IPCC (2018) and related to technology design, it is argued that the demand-side mitigation can reached with changes in socio-cultural factors, infrastructure use and end-use technology adoption.

Design and development of technology

First, it is noted at the general level that the current design standards, for example ISO Standards, do not consider the changing climate conditions. This means that even though climate change impacts the design and planning in urban (and rural) areas, this has not affected the technology design approaches, processes, and methods enough. As Besanko (1987) earlier pointed out, technology standards tend to score lower in terms of economics efficiency than carbon pricing and performance. Based on the data of this study, the reconsideration of design criteria and standards should be done due to the changing climate conditions.

Procedural and recognitional equity

As previously mentioned in this paper, one of the important aims of future human activities is adaptation. For the design processes, the role of design in the processes of local adaptation is highlighted in the IPCC's reports. This design should be done, in addition to a local level, at the regional level as well, because the changing conditions of climate usually have an impact in a wider geographical area than in one local community. Regional adaptation means that several local communities need to learn to communicate together and collaborate.

The role of urban design is seen as important in the processes of local adoption. Design should also include citizens through design and deliberate engagement with the cultural artefacts. With inclusive design, contributions to climate resilience can be enhanced. It is also argued that creative design approaches could extend and complement regulatory planning.

The recommendations of the IPCC's reports discuss the aims and the lifespans of design at a general level. Based on the analysis, there are several ways to see the aims of the design: either the aim could be fail-safe or safe-to-fail. The former, a fail-safe approach to design, aims at strengthening the infrastructure against more intense conditions, whereas the latter, a safe-to-fail approach, allows the infrastructure to fail at carrying out its primary function but aims at controlling the consequences of the failure. Whatever the aim of the design is, the lifespan should be longer than it is usually today; the designs should be considered the designed life of 50 years and not five years. This notion answers directly to the challenge that Bremer, Knowles, and Friday (2022) raised about the need for a shared understanding of sustainability with agreed goals and metrics in the HCI community.

Regarding technology design, IPCC's reports highlight the importance of technology maturity and technology readiness in addition to scalability. Technology transfer is also addressed as an essential issue at general level and is related to procedural equity.

What to design

Emphasis on distributional equity

Based on the data, coordination of adaptation is important, but increased difficulties are with the coordination during climate extremes. According to Coughlan de Perez et al. (2015); Fakhruddin and Schick (2019), when investing in hydro-meteorological information systems and early warning systems, we gain a cost-effective way to prevent some of the most adverse effects of extreme events. Therefore, the design of information sharing during the climate and weather extremes and early warning systems before these extremes is a clear design domain.

Particularly, Part III of the IPCC's reports addresses technology-related issues in the energy and emissions domains, and the impact of transportation within these domains is highlighted. Another obvious domain that is discussed as a major challenge in the reports is water-related issues. Floods and the need for drinking water are outlined as a challenge in the data, and it means, for example, systems that predict the floods, manage and monitor the water systems during the floods, and systems that inform the impacts of the floods. A clear design area is related to water management. Based on the IPCC's reports, water-related systems are crucial systems in changing climate conditions. Water-related systems could focus, for example, on water scarcity, water quality, or water availability. In addition to human-centred water-related systems, flooding and the sea level rise, as well as urban stormwater management, have been emphasised.

In addition to water-related issues, air-related issues are mentioned, particularly in the context of air pollution events, air temperature (both outdoor and indoor), and air-conditioning. Considering the urban context, heat weaves and particularly the heat island effect, i.e. urbanised areas having higher temperatures than outlying areas, are mentioned areas for improvement. Typical for urban environments, in these heat islands, buildings, roads, and other infrastructure absorb and re-emit the sun's heat more than natural landscapes.

Furthermore, clear areas of technology where technology design can improve resilience are new technologies and design innovations in cars, trains, and other vehicles, i.e. technology in transportation.

Discussion

Bremer, Knowles, and Friday (2022) analysed the critique sustainable HCI has received during the past years based on the research in the past few years in the HCI community. This study takes another kind of approach by analysing activities and plans that the expert on climate change who are outside the HCI community suggest in an urban context. This approach is in line with the critique towards the HCI community, which suggests that the HCI community should reach outside their own knowledge bubble to develop sustainable HCI (Silberman et al. 2014) and aim at multidisciplinary expertise and collaboration.

The main argument for reconsideration based on the issues raised by the IPCC reports is sustainable development, particularly social sustainability. Technology has been utilised to achieve sustainable development in cities. Quite often, sustainability in the city context has been focused on technology that aims to promote the environmental dimension of sustainable development. For example, measuring air quality (Georgiadis et al. 2022) or

energy consumption or waste management (Blasi, Ganzaroli, and De Noni 2022). Likewise, economic sustainability has been supported by technological development, for example, developing blockchain (Schiavo et al. 2021). The clear emphasis on economic and environmental sustainability is evident, as is the lack of research on social and cultural sustainability in urban contexts. This is the case even though the impact of using technology in everyday life has been recognised. Part III of the report clearly highlights the importance of social sustainability. Regarding technology design, only quite recently, the emphasis on social sustainability has become the focus of research in technology development in an urban context as the connection to environmental sustainability has been recognised (Beretta 2018; Trivellato 2017).

The presented priorities and recommendations based on IPCC's Sixth Assessment Report Part I, Part II and Part III can be assessed in the HCI community as guidelines or future directions for the researchers and interaction designers. Even though the recommendations and priorities of IPCC's reports are not directed particularly to design and research on human-computer interaction, the recommendations describe many important issues that should be considered in the HCI community and in technology design in general. This paper focuses on reflecting the design considerations in an urban context.

One of the main priorities related to the urban context, adaptation, is not a novel design principle for the HCI community. For several years, systems that are either adapted or adopted have been designed and investigated, for example, in adaptive user interfaces or adaptive systems (Benyon and Murray 1993). However, in the context of environmental hazards, understanding and recognising the context that is changing is vital.

Regarding the priority of mitigation, quite recent HCI research has focused on, for example, sustainable ICT (Saha et al. 2022), sustainable participatory design (Cerna et al. 2022), the energy consumption of technology and servers and green HCI. Mitigation may happen for a longer period of time, and therefore the design of technology should consider different time frames for technology use.

One of the recommendations that is presented in the IPCC's reports is the need to reconsider design standards to ensure that they are taking into account the changing climate conditions. When looking at the most recent HCI-related ISO standards, such as ISO 9241-220:2019 Ergonomics of human-system interaction, should we reconsider new terms and definitions, for example, for the term 'context of use' and requirements for human-centred quality?

Conclusions

This paper reviews the three parts of the IPCC's Sixth Assessment Report to provide future directions to the HCI research community and for interaction

designers. The key characteristics and recommendations of the IPCC's sixth report point to adaptation management, mitigation management, and the need for resilience (RQ1). For urban technology and HCI design, this means reconsidering the lifespan of urban technology and standards (RQ2). In addition, understanding the context of climate events at a regional level and designing technology with target groups beyond the administrative boundaries are essential. (RQ2) Regarding urban technology, particularly in the energy and emissions domains, and the impact of transportation within these domains are highlighted in IPCC's report (RQ3). In addition, significant challenges addressed in the reports are water resource management, water-related disaster issues, and heat waves. For urban technology design, developing warning systems and sensors for various users is crucial (RQ3).

Based on the analysis with social sustainability aspects, our suggestion for future work is the following:

1. To support procedural and recognitional equity, the clear direction is to focus on adaptation pathways and adaptation management in addition to mitigation. For technology design, this could mean ensuring resilience in technology usage and designing technology that copes with climate extremes.
2. Highlighting procedural equity in design processes and approaches, it is recommended that design standards be reconsidered to take into account changing climate conditions.
3. The lifespan of the design cycle should be 50 years instead of the current five years. Even though these recommendations are for generic levels of design, the HCI community could apply them as attitudes in research and interaction design.
4. Recognitional equity can be supported by co-design and collaboration methods. Local communities have been the target groups of smart and sustainable urban design, but attention should be paid to target groups at the regional level, too. For example, extremes like floods and heat fires usually happen in a wider area than in the area of one local community. Therefore, censoring and warning systems for these should work beyond the administrative boundaries.
5. Regarding distributional equity, those who have no appropriate technology available, should be included in the design when designing technology. In addition. ensuring that technology is developed and designed in such a way that most of the people can use it, for example, in the case of extremes.

Disclosure statement

No potential conflict of interest was reported by the author.

Notes on contributor

Teija Vainio (PhD) received her doctoral degree in information technology from Tampere University of Technology. Her research addresses two broad topics: human-technology interaction and urban technology design. She has a long-standing interest in the technological development of urban environments and studies architecture and regional science. Her current research interests focus on the technology design methods and design of smart, safe and sustainable urban environments. Currently, she works as a Postdoctoral Researcher at Tampere University, Faculty of Management and Business.

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