Ecological HCI: Reflection and Future

Qiuyu Lu
University of California, Berkeley
Berkeley, CA, USA
Carnegie Mellon University
Pittsburgh, PA, USA
qiuyulu@berkeley.edu

Andreea Danielescu
Accenture Labs
San Francisco, CA, USA
andreea.danielescu@accenture.com

Vikram Iyer
University of Washington
Seattle, WA, USA
vsiyer@uw.edu

Pedro Lopes
University of Chicago
Chicago, IL, USA
pedrolopes@uchicago.edu

Lining Yao
University of California, Berkeley
Berkeley, CA, USA
Carnegie Mellon University
Pittsburgh, PA, USA
liningy@berkeley.edu

ABSTRACT

In light of the HCI community's growing alignment with Sustainable HCI (SHCI) and the awareness of its currently narrow focus. We propose Ecological HCI (EHCI). EHCI highlights emerging, nature-centric research efforts and aims to expand SHCI's scope to encompass a broader range of Sustainable Development Goals set by the United Nations [16]. It focuses on understanding the complex interplay between technology, human activities, and the natural environment, and redefining HCI's role in promoting ecological well-being. This special interest group will gather researchers to discuss key questions in EHCI's development, focusing on refining its vision, positioning within HCI, technical approaches, design strategies, evaluation methods and long-term impact.

CCS CONCEPTS

• **Human-centered computing** → **HCI theory, concepts and models**; • **Social and professional topics** → *Sustainability*.

KEYWORDS

Ecology, Sustainability, More-than-human

ACM Reference Format:
Qiuyu Lu, Andreea Danielescu, Vikram Iyer, Pedro Lopes, and Lining Yao. 2024. Ecological HCI: Reflection and Future. In *Extended Abstracts of the CHI Conference on Human Factors in Computing Systems (CHI EA '24), May 11–16, 2024, Honolulu, HI, USA*. ACM, New York, NY, USA, 4 pages. https://doi.org/10.1145/3613905.3643985

1 MOTIVATION

In recent years, the human-computer interaction (HCI) community has been increasingly aligning its focus towards Sustainable HCI (SHCI) [3, 6]. Although the United Nations' Sustainable Development Goals (SDGs) [16] encompass 17 goals, mainstream SHCI research has mostly concentrated on the goal of Responsible Consumption and Production [8], with a focus on improving recyclability [12], reusability [9], and degradability [2, 17] in interactive technologies. This "indicates that the research focus that has characterised Sustainable HCI for the last 10 years is very narrow" [8].

However, there has been a notable expansion in the development of technologies aimed at harnessing environmental energy [14], enhancing the monitoring of environmental conditions [10], promoting adaptation to environmental changes [18], facilitating the conservation of environmental statuses [4], and catalyzing the restoration of environmental damage [15]. These advancements represent a significant broadening of the SHCI field, embracing a comprehensive ecological perspective and reflecting a deep integration of technological innovation with environmental consciousness. Additionally, these efforts facilitate the fulfillment of other SDGs such as Affordable and Clean Energy, Climate Action, Life Below Water/On Land, etc.

To broaden the current major scope of SHCI, we propose "Ecological" HCI (EHCI), which incorporates the aforementioned emerging approaches of SHCI with a more nature-centric design perspective. EHCI focuses on studying, designing, and evaluating interactive technologies that are aware of and integrated with ecological systems and principles. It extends beyond the traditional boundaries of human-centered sustainable interfaces and product designs in HCI to consider broader ecological perspectives, and the complex interrelations between human activities, technology, and the natural environment. This transition involves adopting more-than-human and environment-centric research theories, methods, and practices, broadening HCI research to include a diverse array of actors and stakeholders [7].

The broad, interdisciplinary nature of this emerging field raises several critical questions, necessitating reflection to effectively nurture EHCI's growth. These include the clarifying EHCI's vision and goals, positioning more-than-human-centric approaches within the HCI landscape, potential technical solutions, design strategies, and the development of novel evaluation methods that adequately

CHI EA '24, May 11–16, 2024, Honolulu, HI, USA

ACM ISBN 979-8-4007-0331-7/24/05.
https://doi.org/10.1145/3613905.3643985

address ecological dimensions. Addressing these questions is essential to advance EHCI and bring new researchers into this domain while ensuring it effectively contributes to both human progress and ecological well-being.

2 CHALLENGES IN EHCI

2.1 Refining EHCI's Broad Goals: Towards Specificity and Actionability

The overarching goal of EHCI is to synergize human technological advancement with ecological well-being. While this goal is ambitious, it covers a broad range of interdisciplinary topics ranging from use of natural materials and bioinspired design, to reducing the carbon costs of computing, measuring the impacts of climate change, and using technology to preserve biodiversity. This wide breadth of topics presents a challenge in aligning community efforts and gauging progress. To address this, we propose engaging the community in a dialogue to refine and add specificity to EHCI's goals. This discussion could focus on developing clearly defined community sub-goals and identifying relevant use cases, fostering more targeted collaboration within the community. Identifying goals and use cases will help define clear problems for researchers in the broader HCI community to begin working in this domain. Such an approach not only encourages interdisciplinary thinking but also holds the potential for new partnerships, leading to tangible outcomes in EHCI technology development. By refining EHCI's vision, the community can establish a more targeted and actionable framework, paving the way for effective collaborations and meaningful ecological advancements.

2.2 Challenges of Positioning EHCI

HCI traditionally centers around human experiences, presenting a unique challenge for EHCI to gain acceptance in a domain that has historically prioritized human-centered research. Understanding how EHCI fits within the broader HCI field is essential, especially considering its shift towards more-than-human-centric approaches. This may involve understanding its relationship with, and distinction from, existing HCI paradigms. While some EHCI technologies primarily serve non-human entities, their ultimate contribution to enhancing the ecological environment also yields significant benefits for humans. Beyond creating sustainable interaction devices, HCI technologies like novel visualizations and gamification strategies could help promote environmentally friendly choices, and new interfaces could be used to coordinate climate disaster responses and advance conservation education. This duality, along with innovative design thinking, fabrication processes and computational tools presented in EHCI work, may be emphasized to advocate for its relevance in HCI.

While integrating EHCI within HCI presents challenges, it simultaneously offers an opportunity to widen the scope and societal impact of HCI. Adopting more-than-human-centric perspectives can foster innovative and meaningful designs and technologies. In this SIG, we aim to encourage discussions on how EHCI both complements and introduces new perspectives within existing HCI paradigms. Such discourse can lead to insights on EHCI's integration and potential expansion within the HCI field, promoting a wider appreciation for its unique focus. Additionally, a better understanding of EHCI's role could enhance interdisciplinary collaborations, optimize resource allocation, and strengthen EHCI's identity in the research community.

2.3 Lack of Systematic Summarization and Comparison of Approaches

The field of EHCI is vast, with various technical and design approaches being implemented from multiple angles. A gap exists in the systematic summarization of these approaches to guide future research effectively. Categorizing them based on EHCI goals might offer clarity. E.g., For waste management, the focus might be on life cycle analysis, creating degradable materials, and simplifying product assembly and disassembly [17]; In environmental sensing, there is an emphasis on self-sustained techniques and/or transient electronics [5]; For ecological restoration, the approach could involve augmenting traditional methods with innovative technologies [1, 15]. Each of these focus areas represents a specific aspect of EHCI, requiring different strategies and considerations. Moreover, each approach can have its strengths and weaknesses, such as electronics offering precise sensing and control but potentially being less sustainable than non-electronic [13], fully degradable alternatives. Understanding these nuances is crucial for advancing EHCI. By promoting discussion on this topic, we hope to initiate an effort to bridge the existing gaps and enhance our collective understanding of the diverse approaches within EHCI.

2.4 Specifying Evaluation Methods and Metrics

EHCI projects often have dual objectives – developing both technological innovations and solutions to ecological challenges. However, existing HCI evaluation methods may not adequately address the ecological dimensions, challenging our ability to fully assess EHCI's impact. There's a pressing need for new, interdisciplinary evaluation methods that can better assess research outcomes, considering both technological and ecological aspects. Developing such metrics can be complex. For instance, evaluating material sustainability raises questions about what constitutes true sustainability. Biodegradable materials might have a higher production cost and embodied energy, which may lead to increased carbon emissions over their lifecycle than traditional material [11]. It's essential to balance advancing research without being hindered by every potential metric, while also acknowledging both the positive and negative impacts of the technologies developed. This nuanced understanding is crucial for meaningful progress in EHCI.

2.5 Field Testing and Long-term Impact

While the intentions behind EHCI are positive, the act of adjusting natural ecosystems carries inherent risks, which can be underestimated by HCI researchers and designers who may not have a profound background knowledge in ecology. This underlines the necessity of effective collaborations with ecologists and field practitioners, rigorous and long-term field testing, and the cautious dissemination of EHCI ideas and designs to avoid unintended ecological consequences. Furthermore, it is vital to impress upon the HCI community the importance of responsible and informed implementation of EHCI solutions. Additionally, the role of academic research in real-world testing, especially on a potentially large scale, is crucial in validating the practical effectiveness and safety of EHCI technologies. This approach will ensure that EHCI innovations are not only technologically advanced but also ecologically responsible and sustainable.

3 SIG'S GOALS AND EXPECTED OUTCOMES

The SIG on Ecological HCI aims to: 1) gather researchers who are actively engaged or interested in this emerging field, 2) engage in discussion about the challenges, 3) create a compendium of resources and insights gathered during discussions, 4) promote future community-driven events and collaborations, and 5) extend EHCI research outreach to broader audiences.

4 ORGANIZERS

Qiuyu Lu is a postdoctoral researcher at UC Berkeley with a background in Mechanical Engineering and Human-Computer Interaction. Focusing on enhancing the sustainability of interactive devices and systems, his research delves into integrating mechanical computation, energy harnessing, and functional degradation to create environmentally conscious technology.

Andreea Danielescu is the Director of the Future Technologies R&D group at Accenture Labs. Her research group focused on new emerging technologies that blend the physical and digital. These technologies include biotechnology, smart materials, energy harvesting and storage and neuromorphic computing. Her specific areas of expertise also include conversational and gestural interfaces, wearable technologies, and AI and tech ethics.

Vikram Iyer is an assistant professor in the Paul G. Allen School of Computer Science and Engineering, with an adjunct appointment in Mechanical Engineering. He co-directs the UW Computing for the Environment initiative. His work takes an interdisciplinary approach to connect ideas across science and engineering to develop full stack solutions for ecological and sustainable computing. This includes first making computing devices more sustainable by developing novel materials for fully recyclable and biodegradable circuitboards, battery-free sensors and robots, and computational design tools for estimating embodied carbon and environmental impacts. Second, his group is developing a broad array of environmental sensing technologies including microrobotic sensors, wildlife trackers, air quality sensors, and sensing solutions to reduce food waste.

Pedro Lopes is is an Associate Professor in Computer Science at the University of Chicago. Pedro focuses on integrating interfaces with the human body—exploring the interface paradigm that supersedes wearables. These include: muscle stimulation wearables that allow users to manipulate tools they have never seen before or that accelerate reaction time, or a device that leverages the smell to create an illusion of temperature. Additionally, his group investigates sustainable future interactive technologies, with recent work focusing on creative reuse of waste and human kinetic energy harnessing.

Lining Yao is an assistant professor at the Mechanical Engineering department at UC Berkeley, where she directs the Morphing Matter Lab (https://morphingmatter.org). Her research explores the positive impact of active and morphing materials on sustainable and ecological design across different scales and contexts. Her work focuses on discovering and studying morphing material mechanisms, as well as algorithms for computational design and fabrication pipelines.

REFERENCES

[1] Rachel Ann Arredondo, Ofri Dar, Kylon Chiang, Arielle Blonder, and Lining Yao. 2022. Blue Ceramics: Co-Designing Morphing Ceramics for Seagrass Meadow Restoration. In *Proceedings of the 14th Conference on Creativity and Cognition* (Venice, Italy) *(C&C '22)*. Association for Computing Machinery, New York, NY, USA, 392–405. https://doi.org/10.1145/3527927.3531453

[2] Vicente Arroyos, Maria LK Viitaniemi, Nicholas Keehn, Vaidehi Oruganti, Winston Saunders, Karin Strauss, Vikram Iyer, and Bichlien H Nguyen. 2022. A tale of two mice: Sustainable electronics design and prototyping. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts*. 1–10.

[3] Eli Blevis. 2007. Sustainable Interaction Design: Invention & Disposal, Renewal & Reuse. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (San Jose, California, USA) *(CHI '07)*. Association for Computing Machinery, New York, NY, USA, 503–512. https://doi.org/10.1145/1240624.1240705

[4] Mrudul Chellapurath, Pranav C. Khandelwal, and Andrew K. Schulz. 2023. Bioinspired robots can foster nature conservation. *Frontiers in Robotics and AI* 10 (2023). https://doi.org/10.3389/frobt.2023.1145798

[5] Tingyu Cheng, Taylor Tabb, Jung Wook Park, Eric M Gallo, Aditi Maheshwari, Gregory D. Abowd, Hyunjoo Oh, and Andreea Danielescu. 2023. Functional Destruction: Utilizing Sustainable Materials' Physical Transiency for Electronics Applications. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems* (Hamburg, Germany) *(CHI '23)*. Association for Computing Machinery, New York, NY, USA, Article 366, 16 pages. https://doi.org/10.1145/3544548.3580811

[6] Vânia Paula de Almeida Neris, Kamila Rios da Hora Rodrigues, and Renata Firmino Lima. 2014. A Systematic Review of Sustainability and Aspects of Human-Computer Interaction. In *Human-Computer Interaction. Applications and Services*, Masaaki Kurosu (Ed.). Springer International Publishing, Cham, 742–753.

[7] Christopher Frauenberger. 2019. Entanglement HCI The Next Wave? *ACM Trans. Comput.-Hum. Interact.* 27, 1, Article 2 (nov 2019), 27 pages. https://doi.org/10.1145/3364998

[8] Lon Åke Erni Johannes Hansson, Teresa Cerratto Pargman, and Daniel Sapiens Pargman. 2021. A Decade of Sustainable HCI: Connecting SHCI to the Sustainable Development Goals. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan,) *(CHI '21)*. Association for Computing Machinery, New York, NY, USA, Article 300, 19 pages. https://doi.org/10.1145/3411764.3445069

[9] Ollie Hanton, Zichao Shen, Mike Fraser, and Anne Roudaut. 2022. FabricatINK: Personal Fabrication of Bespoke Displays Using Electronic Ink from Upcycled E Readers. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 173, 15 pages. https://doi.org/10.1145/3491102.3501844

[10] Vikram Iyer, Hans Gaensbauer, Thomas L Daniel, and Shyamnath Gollakota. 2022. Wind dispersal of battery-free wireless devices. *Nature* 603, 7901 (2022), 427–433.

[11] Eldy S. Lazaro Vasquez, Hao-Chuan Wang, and Katia Vega. 2020. Introducing the Sustainable Prototyping Life Cycle for Digital Fabrication to Designers. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference* (Eindhoven, Netherlands) *(DIS '20)*. Association for Computing Machinery, New York, NY, USA, 1301–1312. https://doi.org/10.1145/3357236.3395510

[12] Jasmine Lu, Beza Desta, K. D. Wu, Romain Nith, Joyce E Passananti, and Pedro Lopes. 2023. EcoEDA: Recycling E-Waste During Electronics Design. In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology* (San Francisco, CA, USA) *(UIST '23)*. Association for Computing Machinery, New York, NY, USA, Article 30, 14 pages. https://doi.org/10.1145/3586183.3606745

[13] Qiuyu Lu, Haiqing Xu, Yijie Guo, Joey Yu Wang, and Lining Yao. 2023. Fluidic Computation Kit: Towards Electronic-free Shape-changing Interfaces. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23)*. Association for Computing Machinery, New York, NY, USA, 1–21. https://doi.org/10.1145/3544548.3580783

[14] Qiuyu Lu, Tianyu Yu, Semina Yi, Yuran Ding, Haipeng Mi, and Lining Yao. 2023. Sustainflatable: Harvesting, Storing and Utilizing Ambient Energy for Pneumatic Morphing Interfaces. In *Proceedings of the 36th Annual ACM Symposium on User Interface Software and Technology* (San Francisco, CA, USA) *(UIST '23)*. Association for Computing Machinery, New York, NY, USA, Article 32, 20 pages. https://doi.org/10.1145/3586183.3606721

[15] Danli Luo, Aditi Maheshwari, Andreea Danielescu, Jiaji Li, Yue Yang, Ye Tao, Lingyun Sun, Dinesh K Patel, Guanyun Wang, Shu Yang, et al. 2023. Autonomous

self-burying seed carriers for aerial seeding. *Nature* 614, 7948 (2023), 463–470.

[16] United Nations. 2. *Take Action for the Sustainable Development Goals.* Retrieved Dec 10, 2023 from https://www.un.org/sustainabledevelopment/sustainable-development-goals/

[17] Katherine W Song, Aditi Maheshwari, Eric M Gallo, Andreea Danielescu, and Eric Paulos. 2022. Towards Decomposable Interactive Systems: Design of a Backyard-Degradable Wireless Heating Interface. In *Proceedings of the 2022 CHI Conference on Human Factors in Computing Systems* (New Orleans, LA, USA) *(CHI '22)*. Association for Computing Machinery, New York, NY, USA, Article 100, 12 pages. https://doi.org/10.1145/3491102.3502007

[18] Lining Yao, Jifei Ou, Chin-Yi Cheng, Helene Steiner, Wen Wang, Guanyun Wang, and Hiroshi Ishii. 2015. BioLogic: Natto Cells as Nanoactuators for Shape Changing Interfaces. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems* (Seoul, Republic of Korea) *(CHI '15)*. Association for Computing Machinery, New York, NY, USA, 1–10. https://doi.org/10.1145/2702123.2702611