Sustainable Unmaking: Designing for Biodegradation, Decay, and Disassembly

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Unmaking is a counterpart to making and creating new things that has emerged as a concept of interest in diverse parts of the HCI community. Unmaking has been posed as an ally to sustainability, encouraging designers to foreground issues relating to reuse, repair, obsolescence, degradation, and decay early in their design process. As a follow-up to the 2022 Unmaking@CHI workshop, this workshop will bring together researchers and practitioners interested in unmaking as it relates to sustainability and will focus primarily on exploring the role of unmaking in material practices, drawing upon the growing body of unmaking theory to explore future research opportunities for designing physical things with sustainable materials that are transient, degradable, and intentionally unmake-able. In addition to considering the pragmatics of what and how to unmake, we seek to articulate the relationships among unmaking and other related emerging themes and sustainable material practices – including biodegradation, designing with more-than-human agencies, reuse, and repair – and propose guidelines for designing for the unmaking of physical artifacts that are sustainable, equitable, and respectful of all entities involved.

CCS Concepts: • **Human-centered computing → Interaction design**; **Human computer interaction (HCI)**; **Ubiquitous and mobile computing**.

Additional Key Words and Phrases: HCI, unmaking, design, digital fabrication, critical design, making, design methods, sustainability

1 BACKGROUND

As the demand and ease of fabrication for electronics and physical goods continues to grow, trash is accumulating on our planet at a dire rate. In response, researchers across disciplines are becoming increasingly interested in developing more sustainable materials and design strategies. Unmaking – a concept referring to the destruction, degradation, decay, and/or disassembly of existing things – has emerged in different HCI sub-communities and has been posed as an ally to sustainability, encouraging more sustainable design practices and more reflection around the materiality of our designs. The term "unmaking" can refer to the literal disassembly of an object or structure, as well as to the dissolution of values, ranks, habits, beliefs, affiliations, and/or knowledge. Unmaking and destruction have been leveraged in art [73], photography [41], education [25], game design [19], textiles [5, 74], 3D physical scanning [45], fabrication [67], repair [32], the handling of e-waste [54], and artful activism [57]. Unmaking has also been used by researchers and philosophers to describe a myriad of phenomena that extend beyond the physical processes of disassembly or destruction, such as degrowth as a challenge to "modern capitalist socioecological configurations" [20], physical bodily pain [62], stigma around intimate touch [12, 13], anthropocentric temporalities [4, 50] and the loss of home [15]. As Sabie et al. describes [59], unmaking in HCI can be categorized as an inevitable occurrence [11, 21, 27, 29–31, 44, 64], a sustainment agent [22, 32, 54, 63, 75], elimination for good [9, 16, 17, 23, 39, 53, 61, 69], resistance [18, 37, 43, 57, 73], and/or material innovation [6, 46, 67, 74], with many embodiments of unmaking embracing two or more of these approaches at the same time. Against this rich backdrop of literature, unmaking has been positioned as a resource for interaction design, linking the processes of invention and disposal and transforming the concept of "end-of-life" from a singular destination into a rich design space with multiple potential embodiments, actors, and timescales [8, 67]. As one approach, a designer might choose to "build in" pre-determined unmaking effects that manifest as an object ages or is handled in certain ways [67], imbuing meaning in the use of natural and sustainable materials that are dynamic and transient.

Meanwhile, there are several other unmaking-adjacent approaches that the fabrication and design communities have embraced to make the design of physical artifacts more sustainable, and there is great potential for the cross-pollination of materials, methods, and theories among some of these approaches and unmaking. For example, a designer interested in operationalizing unmaking requires materials that are readily able to be unmade; fortunately, researchers have been actively discovering and designing with novel materials that are biodegradable, compostable, fermentable, edible, or otherwise transient. Biodesign is an approach that focuses on developing and designing with biological matter, living organisms, and bio-derivatives that readily degrade in the environment. HCI researchers have created interactive designs and electronic components with bioplastics [2, 36, 38, 65], mycelium [24, 70, 72], compostable clay-like materials [6, 10, 55], microbial cellulose [1, 3, 47, 48], slime mold [40], leaf skeletons [66], and microbes [7, 26, 34], among many others [42, 49, 76]. More generally, readily degradable materials have been used to craft electronics that are temporary [68] or functionally destructive [14]. "Designing with" and more-than-human design approaches [51] also become relevant here, as the unmaking and degradation of living matter becomes not just a process that a human designer may pre-determine but also one that more-than-human agents can play a role in and in fact may rely on for their own sustenance.

Similarly, when it comes to commercial electronics and gadgets, researchers have also become increasingly interested in how to disassemble, repair, and reuse electronics to prolong device lifetimes and minimize waste. HCI researchers have studied how communities salvage and creatively reuse electronic waste (e-waste) [33, 35]. Vyas et al. proposed actionable "folk strategies" for handling e-waste and repurposing materials to further goals of sustainable making

and unmaking [71]. Literature focusing on the disassembly, breakdown, and repair of technology has many thematic parallels to unmaking and even biodesign. As appears to be the case with many destructive practices and processes, practices of breakdown and repair surface processes of valuation [28] and are tightly intertwined with political and socioeconomic factors [56]. Additionally, just as is the case with the degradation of biomaterials, the processes of breakdown and repair of electronics are not necessarily ones that humans can "effectively script ahead of time" [56], and as such, parallel tensions and questions arise when considering how to design for the "unmaking" of electronics.

The CHI2022 workshop on unmaking brought together researchers from diverse sub-communities of HCI, with the goals of discussing the scope, ontology, and pragmatics of unmaking in particular [60]. After the 2022 workshop, a subset of the participants organized a Transactions on Computer-Human Interaction (TOCHI) Special Issue on Unmaking – publication expected in spring 2024 – to showcase the many facets and flavors of unmaking. In this year's workshop, we focus on how to apply principles, theories, and practices from the growing body of work in not only unmaking but also biodesign, e-waste management, and others to make material practices and the design of physical artifacts more sustainable. This workshop seeks to bring together a group of multi-disciplinary HCI researchers to better understand and articulate how our growing understanding of unmaking can inform future directions for sustainable design in terms of material selection, fabrication strategies, and ethical considerations. How can materials that are inherently transient be made to look or perform a certain way during their natural decomposition processes? How might we design electronics for disassembly in ways that go beyond simply the detachment of each individual functional part? What are the relationships – both pragmatically and thematically – among unmaking and other emerging sustainable practices where decomposition plays an integral role, such as biodesign and designing for disassembly? What kind of role might the human designer, human user, and more-than-human agents play in the unmaking of physical artifacts? This workshop is open to any researchers interested in exploring such questions and more.

2 WORKSHOP GOALS AND THEMES

Building upon the 2022 CHI workshop and TOCHI Special Issue on Unmaking, this year's workshop will focus on generating research directions for how unmaking can be built into or considered during the making process for more sustainable material designs. Workshop themes and goals include (1) situating unmaking when it comes to designing material things in relation to other un-practices and biological processes like biodegradation, fermentation, and decay, (2) assembling a collection of materials and methods that allow us to build desired unmaking effects into our designs that support sustainability goals and foster respectful relationships with more-than-human agencies involved, and (3) exploring ethical tensions and concerns and setting guidelines for designing with living organisms and/or other materials and assemblies that are inherently temporary. These themes and goals are detailed below.

2.1 Terminology: Unmaking, Biodegradation, Disassembly, etc.

One of the persisting growing pains of unmaking in HCI that the 2022 CHI workshop started to explore is its ontology and related vocabulary. In this year's workshop, we continue to probe what unmaking means to different researchers and how it matters. As previously described, along with the term "unmaking," HCI researchers and practitioners use a variety of terms to describe the potential fate of natural materials as they return to the earth, including biodegradation, fermentation, decay, and destruction. Unmaking has also emerged alongside sustainable practices for handling electronics waste, such as disassembly, unfabrication, reuse, recycling, and repair. Regardless of context, these terms are laden with meaning and often intertwined with processes, states, and design approaches such as obsolescence, ruin, deletion, cancellation, letting go, and designing with more-than-human communities. For this workshop theme, participants will

discuss parallels and tensions among such terms, seek to uncover situations where theory from one concept might apply to another and situations where principles from two concepts might be in direct contradiction, and tease out if, why, and when distinguishing among different terms matters at all.

The target outcome from activities and discussions around this workshop theme is a dictionary or word net of unmaking and related terms.

2.2 Materials, Processes, and Design Tools

The second workshop theme will focus on how unmaking can be operationalized in the design, use, and end-of-life handling of physical goods. We conceptualize this in terms of materials, design strategies, and design tools. Example questions that we will pose in the spirit of these categories during the workshop are below.

(1) **Materials and Assemblies:** This thread will focus on the classes of materials and assemblies that are conducive to unmaking. What materials (including living organisms) might we draw on, and what properties and opportunities throughout their lifetime do they afford? How do we source and work with them? How might we assemble disparate materials together in a coherent, functional design?

(2) **Design Strategies:** This thread will explore strategies and methods for fabricating and designing artifacts that have unmaking capabilities – inherently due to the nature of the materials themselves and/or due to being "built-in" by the designer. How might we as designers shape function and aesthetics during the design, use, and post-use life phases? What aesthetics do we expect and what meaning might they imbue in a design? What kinds of evolving functionality can we build in? Conversely, depending on the material, it may not be appropriate to intentionally shape how an artifact unmakes at all, instead letting biological processes beyond our control take the lead. In either case, how might unmaking effects be linked to specific meanings, and how can such linkages be leveraged to support sustainability?

(3) **Design Tools:** What kinds of design tools might we create to help us unmake? Participants will discuss different tools – potentially to be used at different life stages of a design – that could allow designers to envision and operationalize the unmaking of their artifacts during the initial design process, help users understand the unmaking possibilities in a design, and guide the unfolding of the unmaking process itself.

The target outcome from activities and discussions around this workshop theme is the creation of a library of materials and methods that researchers can search and contribute to as they discover new resources.

2.3 Ethics

The final theme of the workshop deals with the ethical issues that arise when designing for unmaking. Multiple scholars have warned that unmaking can have "an unexpected and unwanted aftermath" [39], is potentially fractious [52], and may be "deemed to be de-motivating, bad news, politically unpopular, negative etc." [22]. In the context of designing for the unmaking of physical objects and electronics, such potential outcomes must be taken into consideration. Another possibility that may raise ethical contradictions is that unmaking can become so popular that it further encourages the over-fabrication of things. In that case, how can we balance the importance of minimizing the creation of things in the first place with the growth of opportunities for creativity with unmaking?

Other questions to discuss revolve around a design's ownership and agency. Whether it be a biological material or an inorganic electronic gadget, there are multiple agents involved in the initial design, "conventional" use phase, and ultimate unmaking of an artifact. How and when should a human designer intervene – if the designer should intervene

at all – in the unmaking of a design? How can and should designers communicate built-in unmaking possibilities to users? Who owns the design, and who owns its unmaking? Who can influence the course of built-in unmaking? Such questions become especially complex when more-than-human agents are involved in unmaking. What expectations should we have for the care and upkeep of living organisms involved? How do we balance the roles of humans and more-than-humans in a way that promotes sustainability and mutual respect?

The target outcome from activities and discussions around this workshop theme is to generate ethical, material, and emotional guardrails needed for unmaking to be leveraged responsibly.

3   ORGANIZERS

The organizers of this workshop come from different backgrounds, practice in various design contexts, and are at different academic career stages. They are engaged in research around design, critical theory, and fabrication, and their publications in HCI explore concepts in unmaking, biodegradation, disassembly, and repair.

Katherine W. Song (primary contact) is a PhD candidate in Computer Science at UC Berkeley specializing in Human-Computer Interaction (HCI). Her research interests include the making, unmaking, and democratization of backyard-degradable interactive systems.

Fiona Bell is a postdoctoral researcher in Computer Science at the University of New Mexico, working at the intersection of HCI, biodesign, and material science. Her research is focused on the development of novel biomaterials that foster more reciprocal and caring interactions between humans, nonhumans, technology, and the environment.

Himani Deshpande is a PhD student in Computer Science at Texas A&M University specializing in Human Computer Interaction. She investigates fabrication tools and techniques to leverage materials' computational properties for function and expressivity.

Ilan Mandel is a PhD student in the department of Information Science at Cornell Tech in New York City. His research focuses on the disassembly and reuse of consumer electronics at scale.

Tiffany Wun is a PhD candidate in Interactive Arts and Technology at Simon Fraser University in British Columbia, Canada. Her work explores a posthuman approach towards designing with materials and their afterlives through vermicomposting.

Mirela Alistar is a bioartist, HCI researcher, and an Assistant Professor in Soft Materials at ATLAS Institute, University of Colorado Boulder, USA. Intersecting microbiology and HCI, her work extends the human to include interactions with their own microbiome and other living organisms, for which she has developed tangible living-media interfaces and biochip-based systems for personalized healthcare.

Leah Buechley is an Associate Professor in the Department of Computer Science at the University of New Mexico, and the founder and director of the Hand and Machine research group. Her work explores the intersection of computer science, art, design, and education. She has done foundational work in paper- and fabric-based electronics.

Wendy Ju is an Associate Professor of Information Science at Cornell Tech in New York City. Her research focuses on interaction with automation, particularly human-robot interactions and automated vehicle interfaces, and novel research methods to understand interaction with autonomy.

Jeeeun Kim is an Assistant Professor at Texas A&M University, leading the HCIed lab. She investigates methods and systems to sustain increasing computing devices and distributed sensors around the world by self-powering mechanisms, as well as to upgrade passive legacy interfaces into responsive interactive interfaces with only minimal changes, through 3D printed augmentations.

Eric Paulos is a Professor in the Electrical Engineering and Computer Science Department at UC Berkeley, and the founder and director of the Hybrid Ecologies Lab. His areas of expertise span unmaking, critical making, urban computing, citizen science, collaborative consumption, robotics, and persuasive technologies.

Samar Sabie is an Assistant Professor at the Institute of Communication, Culture, Information and Technology at the University of Toronto, working at the intersection of HCI, critical participatory design (CPD), and STS. Her work investigates the role design as a social and material practice plays in the spatial politics of difference in urban contexts. She has also conducted research on shelter customization and permanence in war zones and their constant states of making and unmaking.

Ron Wakkary is a Professor in Interactive Arts and Technology at Simon Fraser University and Industrial Design at Eindhoven University of Technology. His research investigates the changing nature of design in response to new understandings of more-than-human relations, multispecies worlds, and posthumanism.

4 LINK TO WEBSITE

The workshop website is here: https://kwsong.github.io/unmaking-at-chi/. The website will be updated with the call for participation, information about attendance, the workshop agenda, and organizers.

5 PRE-WORKSHOP PLANS

Our goal is to reach a broad range of audiences who might be interested in unmaking for sustainability, from junior to established scholars and practitioners. We will publicize the workshop and distribute the call for participation via relevant professional mailing lists, social media outlets, as well as personal connections with various research communities (e.g. critical design, fabrication, STS). Participants will be asked to submit contributions (position papers, case studies, design fictions, etc.) relevant to the workshop themes. The organizing team will review all submissions in relation to the workshop goals and anticipated discussions. Accepted contributions will be posted on the workshop website as open access before the workshop date. We aim to recruit 25-35 participants.

6 WORKSHOP STRUCTURE

6.1 Program and Activities

See Table 1 for the proposed workshop program. In this one-day workshop, participants will engage in interactive activities focused on the current status and future of unmaking in HCI. The workshop will start with an invited keynote speech. The first group of participant presentations will follow the keynote speeches. We will then move to our first activity, during which we will as a group brainstorm a list of terms related to unmaking and craft a visual map to better understand how the concepts relate to one another. After a long break for lunch, we will commence with the second round of participant presentations. Next, after a short break, we will do a second group activity, during which we will discuss and compile desirable unmaking effects and associated materials and methods to achieve them. Another short break will follow. In the third and final activity, we will discuss issues around ethics and how to handle . Results from the three activities will be tracked and documented to develop a summary report.

6.2 Format and Asynchronous Engagement

This workshop will be held using a hybrid format – we expect that most participants will attend in person, but we will support remote participation as well. We will use our institutional Zoom link for remote participants. Digital

Table 1. Workshop Program

Time	Activity
10:00 - 10:20	Welcoming notes
10:20 - 10:50	Keynote speech
10:50 - 11:00	Break and networking
11:00 - 11:40	Participant presentations #1
11:40 - 11:50	Break
11:50 - 12:30	Activity 1: Mapping relationships among unmaking and other related concepts
12:30 - 13:30	Break
13:30 - 14:10	Participant presentations #2
14:10 - 14:50	Activity 2: Concretizing unmaking with materials, methods, and tools
14:50 - 15:00	Break
15:00 - 16:00	Activity 3: Ethics discussion
16:00 - 17:00	Putting it all together and closing remarks

collaboration tools (e.g., Miro and Google Docs) will be the primary method of documenting our activities so that both in-person and remote participants can easily participate and interact with others. Any in-person activities (whiteboarding, paper prototyping, etc.) will be captured with a webcam and streamed to Zoom. Links to shared documents will be provided beforehand so that participants who have difficulties accessing them synchronously can catch up on what they missed on their own time. Pictures of in-person synchronous activities will also be taken and posted on shared documents for participants to review and comment on afterwards as well.

Some of the co-organizers have experience organizing and facilitating workshops in hybrid and online formats (e.g. CHI '21 migration workshop [58] and CHI '22 unmaking workshop [59]) and have attended several virtual conferences and workshops.

7 POST-WORKSHOP PLANS

After the workshop, pictures and digital records from group activities and discussions will be posted to the workshop website. Upon participants' approval, participants' submitted papers will also be published to https://ceur-ws.org/. The discussions and outputs of the workshop will be communicated to the broader HCI community via the publication of a workshop report or an ACM Interactions article. In the Interactions piece, the organizers will include outcomes from the workshops – including the word net of unmaking terminology, the library of materials and methods, and reflections on identified key ethical considerations – and provide a suggested roadmap for the future of sustainable unmaking, along with designing with biodegradation, designing for disassembly, and other identified partner design approaches in HCI.

8 CALL FOR PARTICIPATION: CHI 2024 WORKSHOP ON UNMAKING

As the demand and ease of fabrication for physical goods continues to grow, trash is rapidly accumulating on our planet. Unmaking – a concept describing the destruction, degradation, and/or disassembly of things – has emerged across different CHI communities and has been positioned as an ally to sustainability, encouraging more sustainable design practices and more reflection around the materiality of our designs. Unmaking is also well situated among other approaches for sustainable design, such as biodesign, designing with more-than-human agents, and designing for the disassembly and repair of electronics, which bring their own relevant techniques and theories to the table.

This workshop will bring together a community interested in sustainable unmaking and other material practices related to designing with materials and assemblies that are inherently degradable or temporary. Our goals are to (a)

articulate the relationships between unmaking, biodegradation, disassembly, and other un-practices; (b) build a shared collection of materials, design strategies, and tools needed to operationalize unmaking; and (c) reflect on the ethics and challenges of designing for the unmaking of physical things. We invite participants to submit short papers or pictorials (max 6 pages including references using the single-column ACM template) describing reflections, case studies, design fictions, or novel methods/theories. Submissions will be selected based on quality and the potential to stimulate discussions. Submissions must be sent to unmakingatchi@gmail.com by February 28, 2024. Upon acceptance, at least one author must attend the workshop and register for both the workshop and for at least one day of the conference. Accepted pieces will be published on the workshop's website adn https://ceur-ws.org/. See https://kwsong.github.io/unmaking-at-chi/ for more details.

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