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Computing for the 22nd Century

More-than-human to see the environmental footprints of profound technologies

Mikael Wiberg*
Umeå University
mikael.wiberg@umu.se

Robin Teigland
Chalmers University of Technology
robin.teigland@chalmers.se

ABSTRACT

Over the past 40 years, human-centered design has driven technological development, seamlessly integrating technologies into our everyday lives. However, this "disappearing act" has led to these technologies' environmental footprints becoming invisible. Building on three illustrative examples, we contribute to the current development of the more-than-human design approach by suggesting 1) this approach is a useful analytical lens to foreground the environmental footprint of today's emerging profound technologies starting to "disappear", and 2) instead of upholding a dichotomy between human vs. more-than-human, we can use the more-than-human approach to unify these two in efforts to establish a vision for the 22nd century that explores holistic approaches for more-than-human worlds.

CCS CONCEPTS

• **Human-centered computing** → Human computer interaction (HCI); HCI theory, concepts and models.

KEYWORDS

AI, Disappearing technologies, EVs, Blockchain, Environment, More-than-human

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1 INTRODUCTION

In 1991 Professor Mark Weiser stated in "The Computer for the 21st Century", "The most profound technologies are those that disappear. They weave themselves into the fabric of everyday life until they are indistinguishable from it." [24, p.94]. Since then, this seminal paper has guided technology-based research and development, evident from its more than 20,000 citations. Indeed, over the past few decades, a human-centered approach focusing on technology design, development, and implementation for human needs and comfort has become the dominant design approach. However, the externalities arising from this approach have contributed to significant environmental problems and the climate crisis. For sure, the Anthropocene has revealed the profound negative impact human activities and human-made technologies have had on the planet, as formulated by Hamilton, et al. [10] "with the adoption of the Anthropocene concept we have to come back, superficially at least, to a Buffonian view in which human history and Earth history are commensurable and deeply interconnected".

In response, the more-than-human movement within Human-Computer Interaction (HCI) advocates for a radical shift in our approach to design—one that decentralizes human needs and foregrounds the entire planet's sustainability. Along these lines, we suggest that Weiser's observation of "disappearing technologies" is a human-centered observation and as such, does not follow a more-than-human approach. In other words, the planet is also an actor in the design, development, and implementation of technologies. From a more-than-human perspective, these technologies do anything but disappear as their environmental footprints leave huge scars on the planet. It seems that Weiser's definition of disappearing is rather one of "out of sight, out of mind" for the users but not for the planet as a whole. Thus, we propose the "more-than-human" movement as an analytical lens to foreground the hidden environmental footprints of disappearing technologies. Below we discuss this approach and illustrate how it could be applied to some of today's emerging profound and "disappearing" technologies, e.g., GenAI, blockchains, electrical vehicles (EVs).

*Corresponding author

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2 BACKGROUND ON THE MORE-THAN-HUMAN MOVEMENT WITHIN HCI

The more-than-human movement within HCI represents a significant paradigm shift, challenging the traditional field's anthropocentric focus [23]. Historically, HCI has focused on optimizing the interaction between humans and computers, often prioritizing human needs, activities, and goals. However, this approach has unfortunately neglected the broader ecological and environmental externalities of technological design, production, and use.

Rooted in interdisciplinary environmental philosophy, anthropology, sociology, cultural geography and ecology influences (e.g., [25];[6];[15];[22]), the more-than-human movement advocates for recognizing and incorporating the interests and well-being of non-human entities, e.g., animals, plants, ecosystems, the planet—into the design process. This perspective urges designers and researchers to move beyond human-centered design to more inclusive approaches that consider ecological and environmental externalities. By expanding HCI's scope to include more-than-human considerations, this movement aims to foster a more holistic, ethical, and sustainable technological landscape ([23];[7];[8];[3]).

Several key principles characterize the more-than-human movement. First, researchers propose decentralizing the human by shifting focus from exclusively human users to a broader array of stakeholders, including non-human entities, that are indirectly effected [4]. When decentralizing humans, other things become foregrounded, such as the environmental context in which technologies are implemented. This calls for a design approach that acknowledges the interconnectedness [16];[17] of all life forms and their environments and encourages designers to think about how their designs interact with and impact natural ecosystems. Second, this shift is an ethical shift – from acknowledging human needs to also accounting for the rights and well-being of other non-human entities [8]. This includes minimizing harm and promoting the flourishing of all life forms. Third, the more-than-human approach is fundamentally about sustainability and how to design technologies that not only reduce environmental impact but also actively contribute to ecological regeneration and resilience. In this context, "noticing" has been proposed as a method to foreground more-than-human aspects. As a method and perspective "noticing" has been defined as "a state of mind - an experience that is situated and embodied, while being directed at the more-than-human world" [17].

3 MORE-THAN-HUMAN AS AN ANALYTICAL LENS - THREE EXAMPLES OF "DISAPPEARING" PROFOUND TECHNOLOGIES

We build on this concept of "noticing" [16];[17] and suggest that a more-than-human approach can be an analytical lens to "make visible" the externalities of technology design and use. In so doing, we consider not only the human benefits and the affordances of a technology but also its other-than-human effects, such as its environmental footprint and how it influences a larger ecosystem, thus accounting for the tradeoff between what the technology offers humans and its effect on more-than-human worlds.

We argue that this approach is increasingly relevant as today we are on the brink of the "disappearance" of yet another set of digital technologies. For example, GenAI, blockchains, and EVs are increasingly becoming woven into the fabric of everyday life, thus becoming indistinguishable from it. Further, we see these technologies as "profound" as they are prophesied to be solutions to arrive at the future, e.g., "AI is the future", "EVs are the future". From the more-than-human perspective, we therefore seek to foreground the invisible or "hidden" environmental footprint of each technology.

3.1 GenerativeAI

As formulated by Xu [26], AI is in its third wave of development where AI is increasingly deployed at a societal level and integrated throughout our everyday lives. Indeed, the GenAI hype is leading to corporations, public sector organizations and individuals alike to use these technologies without regard for their more-than-human impact. For example, a well-reputed author on the future of work recently encouraged those at an international conference to always regenerate GenAI answers, claiming "*It doesn't cost anything!*".

This is surprising as GenAI models require considerable processing power and electricity to run complex matrix operations on large datasets over prolonged periods on several high-performance GPUs or TPUs. For example, researchers estimated that creating GPT-3 consumed 1,287 megawatt hours of electricity and generated 552 tons of CO2 - the equivalent of driving 123 gasoline-powered cars for one year, and this was only for preparing the model's launch. Furthermore, while GenAI is lauded to be a "key to the future", the World Economic Forum[1] noted recently that the energy required to run AI tasks is "*already accelerating with an annual growth rate between 26% and 36%, and that by 2028, AI could be using more power than the entire country of Iceland used in 2021*". GenAI also has an expanding water footprint to cool data centers. According to Li, et. al. [13], ChatGPT consumes 500 milliliters of water for every 10 to 50 prompts, depending on when and where it is used. Still, for the average user, these tools are invisibly located "in the cloud" rather than being viewed as an exponentially expanding environmental problem.

3.2 Blockchains and cryptocurrencies

Blockchains and cryptocurrencies provide several societal benefits, such as decentralization, transparency, and security within industries such as financial services and logistics. They are most famous for cryptocurrencies like Bitcoin and Ether. These benefits do, however, come at a major and frequently invisible environmental cost ([5];[20];[2]). The most well-known is the energy-intensive mining process, particularly in Bitcoin's Proof-of-Work (PoW) consensus mechanism. To verify transactions and safeguard the network, mining entails resolving intricate mathematical puzzles, requiring enormous processing resources. As of August 2022, the total global electricity usage for crypto-assets was estimated to be between 120 and 240 billion kilowatt-hours per year or 0.4% to 0.9% of annual global electricity usage[2]. This is greater than the total annual electricity usage of many countries, including Argentina and Australia, and is comparable to the annual electricity usage of all conventional data centers in the world. While increasingly using renewable energy sources, fossil fuels are still primarily the main energy source, which results in significant CO2 emissions. Again, this speaks to the invisible scale of this problem.

3.3 Electric vehicles

Electric vehicles (EVs) are agued to cut greenhouse gas emissions within transportation, halt global warming and provide an alternative to fossil fuel-driven vehicles. Compared to conventional vehicles, EVs are advertised as having a large environmental advantage ([9];[12];[14]), but they also have hidden environmental effects ([11];[21];[19]). For example, 1.9 tonnes of water are required to mine one tonne of lithium, with 15 tonnes of CO2 emissions in the process. To mine lithium, cobalt and nickel, hazardous chemicals and extensive manual labor (sometimes even child labor) are used in areas where water is scarce with runoff contaminating underground water sources[3]. Moreover, China produces 77% of

[1]https://www.weforum.org/agenda/2024/04/how-to-manage-ais-energy-demand-today-tomorrow-and-in-the-future/#:~:text=The%20energy%20required%20to%20run,phase%20and%20the%20inference%20phase.
[2]https://www.whitehouse.gov/ostp/news-updates/2022/09/08/fact-sheet-climate-and-energy-implications-of-crypto-assets-in-the-united-states/
[3]https://www.theguardian.com/environment/2021/jan/03/child-labour-toxic-leaks-the-price-we-could-pay-for-a-greener-future.

all batteries, using coal as its primary energy source. Finally, EVs generally weigh more than their counterparts due to their battery packs. The average EV weighs 1.9 tonnes with the largest SUVs almost 3 tonnes, e.g. Mercedes EQV at 2.96 tonnes, Audi e-tron 55 at 2.72 tonnes[4]. No wonder some label this development as "the green paradox".

4 DISCUSSION

As we are now "halfway to the future" to echo the symposium's theme, it is also time to reflect on our direction. If the 21st century was the century of "disappearing technologies", what will the 22nd century be about? The current movement suggests a radical shift from the human-centered approach to a more-than-human perspective. We appreciate this shift in terms of how it foregrounds non-human entities and how it makes visible the environmental footprints of disappearing technologies (from a human perspective).

However, currently there seems to be a dichotomy between "human-centered" vs. "more-than-human" centered approach, with researchers suggesting that we need to shift to more-than-human perspectives and values [27]. Further, more-than-human scholars suggest that there is no dichotomy between the two, and following that philosophy we should not create new divides but rather look at approaches integrating these two, as we still have many human-related problems to solve (e.g., UN SDGs). In this context, HCI research could drive the agenda for the design and development of systems that not only design along the principles of user-centered design and user testing but that also include at least critical reflections on their environmental footprint (ranging from natural resources used to electricity to power these interactive systems).

Also, we as humans have the resources, capabilities, and responsibilities to design and envision more preferable future states. We should take this responsibility and design both for humans and for more-than-human worlds. To do this requires a holistic understanding of not only what technologies can do for us but also what they do to the planet. We should keep a keen eye on the more-than-human and think about how such efforts in return also solve human-related problems. While technology should "disappear" in the Heideggerian sense of working as effective tools that are "ready-at-hand", we also need to ensure that such profound technologies do not disappear – from a human-centered perspective, while being very present from a more-than-human perspective. To ensure this, we need to ensure that this duality is constantly foregrounded in active discussions on how the technologies we design must benefit the planet and not just serve human needs and comfort. Ultimately, we might realize that once a technology starts to "disappear" (from a human-centered perspective), then we need to urgently look for how it appears from other (more-than-human) perspectives - including how it influences other species, our climate, and our planet in the long run. We suggest that the more-than-human approach is exactly one such fruitful lens to see these things holistically - across humans and more-than-human actors - to constantly keep an eye on the technologies we design and adopt in our everyday lives and how they affect other lifeworlds. With this as a central and unifying perspective, a vision for the 22nd century can be formulated. Here, we should not just look for how "profound technologies disappear" but also ask critical questions about how these technologies at the same time re-appear – for other lifeforms, and for more-than-human worlds.

[4] https://insideevs.com/news/527966/electric-cars-from-heaviest-lightest/

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