Digital Technologies and Environmental Change

Examining the influence of social practices and public policies.

Vanessa Thomas

HighWire Centre for Doctoral Training
Lancaster University

This dissertation is submitted for the degree of
Doctor of Philosophy

Graduate College November 2017

I would like to dedicate this thesis to the family members, friends, mentors, supervisors, digital technologies, animals, ecosystems, lovers and haters who have come in and/or out my life at any point in the last 32 years. I also dedicate this thesis to RoboCop.

Declaration

I hereby declare that except where specific reference is made to the work of others, the contents of this thesis are original and have not been submitted in whole or in part for consideration for any other degree or qualification in this, or any other university. This thesis is my own work and contains nothing which is the outcome of work done in collaboration with others, except as specified in the text and Publications List. This thesis contains fewer than 55,000 words including appendices, bibliography, footnotes, and tables. I also hereby declare that I am a little teapot, short and stout.

Vanessa Thomas
November 2017

Acknowledgements

What you're about to read is the product of years of gruelling reading, walking, cycling, working, writing, talking, reflecting, arguing, crying, laughing, programming, feeling lost, being confused, and occasionally attempting to make sense of incoherent strands of thought amidst that activity. I laid some of the foundations for this dissertation long before I joined HighWire, but my tenure at Lancaster University gave me the time, space, encouragement, and permission I needed to fuse several of my disparate projects, interests, and ideas into this thesis. Lancaster also introduced me to countless new people, perspectives, and research disciplines. From Stuart Walker's lectures on modernity to the social events hosted by and for the Digital Economy Network (DEN), every moment of my HighWire experience has challenged me to grow personally, professionally and academically, just as I had hoped.

Being in the UK during this politically, economically, and environmentally difficult period—during which the city I lived in (Manchester) endured a bombing, the UK voted to leave Europe, the US elected Donald Trump, the effects of climate change became even more evident, and Canada, under Justin Trudeau, somehow emerged from a decade of overt conservatism to be a global leader for liberal ideals—was as much a process of self-discovery as it was a process of 'generating knowledge' for a wider community. I feel incredibly privileged to have spent the past four years getting to know myself, one of my ancestral homelands (the UK), and my colleagues (many of whom I now consider friends). A decade ago, I hardly could have imagined finishing my Bachelor's degree, let alone going on to earn two Masters degrees and a Doctor of Philosophy. The fact that I was privileged enough to spend most of the past four years reading diverse literature, roaming the edges of several established disciplines, and traveling to conferences and events around the world to discuss ideas is still astounding to me. What an incredible privilege and delight!

I'd like to extend my thanks to dozens of people, each of whom helped me in their own way, and many of whom I will have sent a 'thank you' note via snail mail, email or text message. Those people include: my famjam (Mary, Bruce, Jeff, and Angela Thomas, as well as Phil Gibeault), my grandparents (Margaret and Ken Thomas, and Evelyn and Ed Kueber), my loving and supportive aunts and uncles (esp. Liz, Rose, and Randy), my supervisors (Nick Dunn and Mike Hazas), the backbone of HighWire (Tish Brown and Kate Wright), Oliver

Bates, Manu J Brueggemann, Ding Wang, Benjamin Wohl, Andy Darby, Miriam Sturdee, Robert Potts, Dhruv Sharma, Joe Lindley, Liz Edwards, Claire Dean, Emma Young, Sebastian Weise, Stuart Haffenden, Louise Mullagh, Holley Goodban, Justin Larner, Rui Ramos, Ben Shreeve, Elisavet Christou, Barney Craggs, EV-ER-Y-ONE else in HighWire, David and Sarah (and Sol!) Feldman, Chris Chan, Teresa Currie, Katie Sowden, Courtney Burr, Linden Couteret, Micha and Derek Flynn, Kim McCrae, Ali Jones, Erich Welz, Christian Remy, Hayley Alter, Henrik Korsgaard, Daniel Finnegan, Ishraaq Adam, Davin Robertson, Kelsie Tetreau, Six Silberman, Mick Schubert, Giles Crawford, Michael Liegl, Hannah Stewart, Richa Sharma, Andrea Izquierdo, Dr.(!) Dee Hennessy, Ross Prusakowski, Peter Craigon, Judit Varga, Matt Voigts, Hanne Wagner, Delvin Varghese, Johanna Walker, Keisha Taylor, Aluna Everett, Benjamin Neimark, Saskia Vermeylen, Felicia Black, Niall Hayes, Alan Dix, Adrian Friday, Paul Whaley, Aluna Everitt, Stephanie Shantz, Micah Cooper, Lara Salinas, Serena Pollastri, Adrian Gradinar, Zoe Luski, Zoe Todd, Dan Thompson, Adam Millie, Jenn Doucet, Navita Kalra, Mark Rouncefield, Maria Angela Ferrario, Abhijit Karnik, Giovanni Bettini, Chris Boyko, Claire Coulton, Janet Davis, Adam Greenfield, Monika Büscher, Mike Chiasson, Stuart Walker, Sane Gaytan, Theresia Williams, Axel Meisen, and SO MANY OTHER PEOPLE. I'd also like to thank C02K31YADRVG, C02QK6EDG8WN, CB5A24N59J, ZY2243NDTH and the dozens of other digital technologies and services that supported me throughout this doctoral process. Basically, to every person, animal, or object who has indulged me with an interview, an informal conversation, a coffee date, a late-night-beers-and-bitching session, an anonymous or not-so-anonymous critique, a question at a conference, a shoulder to cry on, an absurd joke or comment to laugh at, a thought-provoking piece to scribble notes on at 2am, an inbox to rant to, a keyboard to rant on, a class of undergrads to speak to, or anything in between, really: thank you. Sincerely. From the bottom of my heart. It has meant absolutely everything to me.

I'd like to extend an extra special thanks to Gordon Blair, Paul Coulton, and Patrick Stacey, who interviewed me for HighWire and took a chance on a girl whose "digital hero" was "RoboCop". My thanks also go to the EPSRC for partially funding the HighWire Centre for Doctoral Training (and me!) and to Global Affairs Canada for selecting me as one of their inaugural "International Policy Ideas Challenge" winners. Further thanks go to the RCUK's Digital Economy Network for partially funding some of my other travel and research endeavours. Lastly, my sincerest thanks go to Lisa Nathan and Nicola Spurling for their care-full readings of my thesis, and for their valuable feedback during my viva.

My warmest thoughts and regards also go to anyone who has made the time to open this thesis, even if just to look at this section. Take care of yourself and keep up the good fight(s).

ps. Northside Edmonton, represent!!!! (Steele Heights! M.E. LaZerte!)

Abstract

Digital technologies and services affect the planet. Every line of code, every photo uploaded to 'the cloud', and every smartphone, computer, or 'IoT' device, has an environmental footprint. That footprint often takes the form of carbon dioxide emissions, ecosystem degradation, and resource depletion, each of which occur to varying degrees throughout the production, use, and end-of-life processing of digital technologies. In the past two decades, multidisciplinary researchers and practitioners have examined and responded to many aspects of these processes; the responses have taken diverse forms, including energy efficiency and design standards, restrictions on the use of hazardous materials, and the international adoption of rules and regulations about electronics waste (e-waste). Despite these responses, the global environmental footprint of digital technologies and services has continued to rise due to their growing ubiquity, dwindling lifespans, and 'always on' support infrastructure.

In this thesis, I respond directly to calls for increased analysis and discussion of the social practices and public policies that influence the environmental footprint of digital technologies (e.g. [83, 139, 232]). To narrow the scope of this broad line of enquiry, I focus on the social practices of retrocomputing repairers and human-computer interaction (HCI) academics—two communities whose practices influence the footprint of digital technologies—as well as environmental public policies that influence HCI practitioners. By drawing on secondary data and semi-structured qualitative interviews with 7 retrocomputing repairers and 22 HCI academics, my thesis offers three sets of contributions to complementary and ongoing conversations within the HCI community.

The first two sets of contributions focus on the social practices of distinct but indirectly connected communities: retrocomputing repairers and HCI academics. While many HCI academics work to conceive of new digital products and services, the retro repairers actively work to maintain their ageing digital products in the face of increasingly scarce resources. Each group influences the environmental footprint in unique ways, which have been hitherto unexplored. I discuss some of these influences, and use them to highlight questions about existing and future HCI research.

The third set of contributions focuses on environmental public policies and HCI. By fusing two existing approaches to understanding public policies and their relevance to HCI,

I highlight opportunities for HCI researchers to engage with and influence environmental public policy. This allows me to suggest ways that environmental public policy could influence and be influenced by HCI research.

Two degrees? Three? Four!?!
We must unite our efforts.
Tech might be a hitch.

#ThesisHaiku #haiku

Table of contents

List of figures

PhD journey:
Reflect, research, and repeat.
A three year process.

#IntroductionHaiku #haiku

Chapter 1

Introduction

Digital technologies and services affect the planet. Every line of code, every photo uploaded to 'the cloud', and every smartphone, computer, or 'IoT' device, has an environmental footprint. That footprint often takes the form of ecosystem degradation, resource depletion, and carbon dioxide emissions, each of which occurs to varying degrees throughout the production, use, and end-of-life disposal or recycling of digital technologies. During the past two decades, multidisciplinary researchers and practitioners have examined and responded to many aspects of this environmental footprint; their responses have taken diverse forms, including energy efficiency and design standards, restrictions on the use of hazardous materials, and the adoption of international rules and regulations for e-waste shipping and processing. Despite these responses, the global environmental footprint of digital technologies and services has risen dramatically in the past decade, in part due to their growing ubiquity, dwindling lifespans, and 'always on' support infrastructure.

In this thesis, I analyse and discuss some of the social practices and public policies that influence the environmental footprint of digital technologies[1]. To narrow the scope of my inquiry, I draw from and speak to my own research community: the human-computer interaction (HCI) community. HCI is a multidisciplinary community of researchers and practitioners who often work to design, develop, and deploy highly heterogeneous interactive digital technologies and systems [22, 52, 141]. This multidisciplinary hive of activity has made HCI difficult to succinctly define [193], and many sub-communities have formed to address niche topics of interest, including games, healthcare, international development, privacy, tools and methods, and educational technology, among other topics. My doctoral

[1] Whilst I agree with the notion that "we manage what we measure, and neglect what we don't" [248], I have opted to write about the footprint of digital technologies, as opposed to the 'handprint', because I believe we are still at an early stage of understanding the footprint of digital technologies. Moreover, handprinting itself—a fascinating, timely, emerging approach to understanding sustainability—feels at too early a stage of development for me to competently apply it to digital technologies.

research speaks primarily—though, not exclusively—to the sustainable HCI (SHCI) community, which is populated by people who have become interested in the environmental dimensions of HCI.

The sustainable HCI community has been actively exploring and engaging with some of the complex, multi-faceted dimensions of sustainable computing for nearly a decade [49, 139, 215]. During that time, some SHCI researchers have focused their efforts on rethinking the material composition and lifecycles of our digital technologies (e.g. [21]), while others have examined how systems design and usage are related to the carbon footprint of digital technologies (e.g. [14, 101, 204]). Some have designed or proposed tools and technologies that might inspire sustainable behaviours (e.g. [49, 71]), while others have questioned the effectiveness of those interventions [29]. My thesis directly responds to calls for and from SHCI researchers to examine the complexities of social practices, public policies, and the environmental footprint of digital technologies (e.g.[83, 96, 139, 232]). In response to those calls, I focus specifically on the social practices of HCI academics (Chapter 3) and retrocomputing repairers (Chapter 4), as well as environmental public policies related to digital technology design, use, and end-of-life processing (Chapter 5).

I selected these practices and policies intentionally, and for several reasons. Firstly, they were topics that the SHCI community identified as being of interest, thereby clearly indicating that I would have opportunities to contribute knowledge to SHCI discourses. Secondly, these practices and policies were specific enough that I knew I could thoroughly examine them within the short, three-year time-frame offered by my UK doctoral program. Lastly, they represented a set of practices and policies that were of interest to me. I have been playing with retrocomputing devices since childhood, and engaging with public policy in some capacity for most of the past decade; only academic HCI practices were foreign to me at the outset of my PhD, and even they quickly captured my interest. When I started my PhD, I was unsure if I wanted to remain in academia after I earned my PhD, and I suspected that focusing my doctoral studies on an academic community—one that I might eventually belong to, due to my pre-PhD background in computer science, social science, and design—might help me make sense of my future career trajectories. These reasons influenced the shape and nature of my thesis and research[2]; they also underscore the logic behind my aims and objectives.

1.1 Research aim, questions, and objectives

The primary research question underpinning this thesis is: **"How do social practices and public policies influence the environmental footprint of digital technologies?"**

[2] I do my best to openly address these motivations throughout the text of this thesis.

Such a research question is enormous in scope, and I could spend my entire career addressing it. To contribute to the ongoing discourses within the SHCI community and narrow the scope of my research, I have opted to pursue three research objectives that examine specific dimensions of my research question. My objectives in this thesis will be to:

> 1) use social practice theory and qualitative methods to identify and analyse academic HCI practices, then link those practices to the environmental footprint of digital technologies (chapter three).
> 2) use social practice theory and qualitative methods to identify and analyse the repair practices of retrocomputing enthusiasts and link those practices to the environmental footprint of digital technologies (chapter four).
> 3) conduct a policy survey to identify which environmental public policies affect the environmental footprint of digital technologies, and link those policies to the research conducted by the SHCI community (chapter five).

Each objective speaks to a narrow aspect of my research question and aim. Objectives one and two speak primarily to the "social practices" dimension of my research question and aim. That is, objectives one and two seek to examine and analyse the social practices of two communities that—I believe—influence the environmental footprint of digital technologies: 1) people working to design digital technologies and train the next generation(s) of interaction designers, as well as 2) people working to extend the lives of their ageing technologies. Meanwhile, objective three speaks primarily to the "public policy" dimension of my research question and aim, while linking it directly to the work of my primary audience.

Of course, public policies, social practices, and issues related to the environment are intimately interconnected [230], and it is difficult—arguably inadvisable—to speak directly to either of the "social practice" or "public policy" dimensions of my question without considering the influence of the other. I attempt to grapple with this messy, interconnectedness in chapter six.

At this point, I would also like to note that my research question and objectives have been partially driven by my personal objectives, which were to:

> 1) take a break from my career.
> 2) build my confidence and decide if I wished to continue working in a male-dominated industry.
> 3) learn about the environmental footprint of digital technologies.
> 4) learn how to apply social science methods.

These objectives indirectly influenced how, when, and why I conducted my research. They drove me to expand my knowledge of social science research methods (i.e. social practice theory and qualitative methods). They drove me to consider a topic that I believe I would otherwise never have an opportunity to examine in the workpalce (i.e. the environmental footprint of the digital technologies that I design and deploy). I return to and reflect on all of this—my research aim, research objectives, and personal objectives—in the conclusion of my thesis (Chapter 6).

1.2 Thesis structure

Chapter two describes the background for this thesis. It begins by outlining the environmental footprint of digital technologies, focusing on three stages in the lifecycles of most machines: production, use, and end-of-life. With this foundation in place, the chapter shifts focus to the academic context for my research. It begins by describing what social practices and public policies are, and how to study them. Then the chapter describes how existing research in HCI—my target audience and community—has addressed topics relevant to my research.

The remainder of the thesis is broken into two parts, each of which addresses a different phase and foci of my research.

In Part I, I present, discuss, and analyse two empirical studies focused on the social practices of HCI academics (Chapter 3) and retrocomputing repairers (Chapter 4). HCI academics can influence the design and adoption of new digital technologies through their research, education, and public service outreach activities. As a result, HCI academics have considerable direct and indirect influence on the environmental footprint of digital devices throughout their lifecycle. Meanwhile, retrocomputing repairers work to keep their ageing digital technologies alive—using techniques and tools that are often presented as mechanisms through which to reduce the environmental footprint of digital technologies [21]. To date, no research has explicitly studied how either community of practitioners has influenced the environmental footprint of digital technologies. Chapters 3 and 4 address this gap and identify several opportunities to reconsider research and practices related to HCI and retrocomputing repair.

In Part II, I examine some of the ways that public policy, human-computer interaction (HCI), and environmental sustainability intersect. Chapter 5 offers a direct response to calls for the HCI community to engage with and inform public policy related to environmental sustainability, security, and justice [83, 139, 152, 232]. It draws on research that I conducted for Global Affairs Canada (GAC) and that I used to help inform—or at least attempt to inform—Canadian public policy. The chapter draws on my GAC research, but is targeted at an HCI audience; it examines climate change, “waste electrical and electronic equipment”

(WEEE), and "green public procurement" (GPP) policies and evaluates how they could inform and be informed by the HCI community.

Chapter 6 draws together the seemingly disparate threads from Chapters 3, 4, and 5. It reminds readers that public policy influences social practices, and that social practices can influence public policy—both of which affect the environmental footprint(s) of our digital technologies. The chapter offers an overview of my contributions, and identifies a set of future research opportunities that could build upon the work within this thesis, including opportunities for sociologists, and HCI researchers. It closes with a reflection on my personal and academic aims, and my hopes for my own future endeavours.

A note about Methodology

As you can see, this thesis does not contain a methodology chapter. Rather, in Chapter 2 (the background chapter), I introduce the methodological approaches I use in Parts I and II (i.e. social practice theory and my own variant of public policy analysis, tailored to HCI audiences). Chapters 3, 4, and 5 each contain sections that describe how and why I: recruited participants, conducted interviews, undertook analysis, and wrote up my results. I chose not to fuse these sections into a single methodology chapter because the approaches I use in Parts I and II are so distinct. My initial attempts to weave such distinct approaches into one chapter failed and, after much reflection, I ultimately decided to keep them separate.

1.3 Contribution statement

The contributions offered by this thesis come in several forms. The first two sets of contributions focus on the social practices of distinct but indirectly connected communities: retrocomputing repairers and HCI academics. While many HCI academics work to conceive of new digital products and services, the retro repairers actively work to maintain their ageing digital products in the face of increasingly scarce resources. Each group influences the environmental footprint in unique ways that have yet to be examined by the SHCI community. I discuss some of those unique influences, and use them to highlight questions about existing and future HCI research. This, in and of itself, offers a unique set of analytical contributions to the SHCI community. But those contributions hinge on the rich analytical descriptions I offer of academic HCI practices and retrocomputing repair practices.

The empirical research underpinning my practice-specific descriptions included conducting and analysing semi-structured qualitative interviews with 7 retrocomputing repairers and 22 HCI researchers. It also included considerable secondary data analysis and a phase of unintentional immersion in one of my communities of study, both of which are described in greater detail in Chapters 3 and 4. These analytical descriptions are also unique contributions to the SHCI community; they offer new insights related to how the academic HCI community and retrocomputing repairers contribute to the complex web of personal, social, political, temporal and material factors influencing the environmental footprint of digital technologies.

The final set of analytical contributions focus on environmental public policies and HCI. By fusing two existing approaches methods of understanding public policies and their relevance to HCI, I highlight opportunities for HCI researchers to engage with and influence environmental public policy. I also offer examples of ways that environmental public policy could influence HCI. To make my contributions clearly accessible, I have included summary tables at the end of Chapters 3, 4, and 5.

1.4 Developing my reflexive research practice

Authoring this thesis has been a considerable challenge for me, as I imagine it must have been for millions of other doctoral candidates before me. Perhaps the biggest challenge I faced while writing this thesis was figuring out how to maintain an engaging and functional narrative whilst simultaneously representing and incorporating the abductive, iterative, and reflexive research process I developed throughout my three year PhD journey. That research process mattered a great deal to me; it is why I pursued the research topic, project scope, and supervisory team that I did. It is why this thesis looks and feels the way that it does. It is also why I submitted my thesis when and to whom I have submitted it. In short, my iterative, abductive, and reflexive process was fundamental to what I was able to present within this thesis, and I feel it's necessary to include some evidence of that within my thesis.

The descriptions I've included of my field studies, as well as my use of first person narrative and footnotes, are my attempt to weave my research process into the linear, narrative format of my thesis. I do my best to keep the first person narrative confined to my descriptions of field work and personal reflections on future directions for the work. I use the footnotes throughout this thesis to address some of the issues or concerns I have with specific terms and terminology [3]. In the list of aims and objectives for this thesis, I also included my personal objectives, which I return to and reflect on in Chapter 6. This is an imperfect mechanism for incorporating and addressing my iterative, abductive, and reflexive process. But I've come to

[3] Where appropriate, I have described and addressed those concerns in the body of the thesis. However, some terms and terminology that I have strong opinions about do not play significant roles in this thesis, and therefore do not deserve more than a footnote's worth of commentary.

believe that a thesis is an imperfect mechanism for sharing the results of three years of work, anyway [4].

[4] I'm aware this is an opinion not shared by all; I am also aware that a more gifted or experienced academic writer might have been able to craft a more ideal solution.

Existing research:
How does it frame my thesis?
What more can I add?

#ChapterTwoHaiku #haiku

Chapter 2

Background

Portions of the section on "environmental effects of digital technologies" were previously published [251]. I have rephrased some of that text and added sections 2.2 and 2.3 to this chapter. See Appendix A for more details about publications contributing to this thesis.

Glaciers are melting, oceans are becoming more toxic, species are dying, and soil quality is degrading. For decades, international and interdisciplinary researchers have warned that humans are creating an inhospitable living environment on Earth, and that we need to adjust our actions and behaviours quickly [84, 239, 167]. These warnings have become even more urgent recently as increasingly clear evidence has demonstrated that "we're running up to and beyond the biophysical boundaries that enable human civilization as we know it" [111]. In response to these challenges, some governments, international non-governmental organisations (e.g. the United Nations), businesses, policy makers, and educators have committed to changing what they do and how they operate. In tandem with these developments, some researchers have started exploring how digital technologies are linked to climate change, natural resource extraction, and environmental sustainability.

In this chapter, I describe and introduce: the environmental effects of digital technologies; how social practices and public policies influence the footprint of digital technologies; how and why to study social practices and public policies, and; how the HCI community specifically has examined these issues to date. These issues underpin the focus, methods, and scope of my doctoral research, and indicate where my work can contribute.

2.1 Environmental effects of digital technologies

The environmental footprint of a digital technology is influenced by its hardware and software. Hardware is the tangible part of a digital technology; you can see hardware and hold it.

Examples of hardware include cellular telephones, laptops, tablets, monitors, Internet routers, 'smart' watches, printers, air quality sensors, bluetooth chips, hearing aids, animatronic prosthetic limbs, and heart monitors, along with thousands of other products and pieces. Hardware is often made from a combination of electronic components, such as batteries, capacitors, switches, resistors and semiconductors, as well as additional plastics, chemicals and metals that facilitate information sharing between those components.

Software is less tangible; it is the set of programs and applications ("apps"), libraries and files that allow hardware to share information and function as a complete device. Examples of software include operating systems (e.g. Microsoft Windows, Apple's OS X and iOS, Android, Ubuntu, Linux), word processing or spreadsheet programs and files (e.g. MS Word, Excel, Pages, Google Docs), email clients and services (e.g. Outlook, Gmail, Yahoo), social media websites and mobile apps (e.g. Facebook, Twitter, Vine), social media posts (e.g.. tweets, pictures, shared stories), Internet browsers (e.g. Firefox, Chrome, Internet Explorer), traffic management systems, and digital mapping tools, among others.

Software and hardware are co-dependent; the type of hardware in a device dictates the type of software that the device needs, and the type of software in a device influences how hardware components are used. Hardware and software affect the environment in interconnected ways during their production, use, and at the end of their lifecycle, when they are being recycled or discarded [134, 249].

2.1.1 Production: design, mining, and manufacturing

Consumer demand, advancements in technology, and industry-led design decisions (e.g. planned obsolescence) drive the production of hardware and software. Each production process unfolds distinctly, and has measurable effects on the environment.

Software production occurs in homes, universities, and businesses around the world. Much like software itself, the environmental effects of producing software are often considered less tangible and measurable than those of its counterpart, hardware. But the electricity, transportation, office spaces, and office supplies used while designing and developing software all carry environmental costs that contribute to the overall 'embodied impact'[1] of a digital technology [5, 36]. Moreover, software development teams and their structures, employee turnover, code quality, knowledge sharing practices, and development processes—among other factors—influence the 'sustainability' of a piece of software, in

[1] 'Embodied impact' is a term used to describe the total environmental impact of sourcing, transporting, processing, and manufacturing a material, product or service. Some resource-specific 'embodied impact' estimates and calculations are available online (e.g [180, 272]).

terms of how quickly and effectively it is produced, how it is tested, and how it can be maintained [185, 198, 226, 227].

Hardware production is a more tangible and environmentally demanding process. The environmental footprint of hardware arguably begins with its design (e.g. conceiving of a product, creating product wire frames, deciding what material should be included in the hardware, prototyping the device, etc.); however, very little information is publicly available about proprietary hardware design processes. As a result, attempting to measure and assess the environmental impact of hardware design is difficult and often left to individual companies to report. In contrast, the natural resource extraction and hardware manufacturing processes are highly documented, and have attracted a great deal of attention from academics, journalists, the private sector and governments alike (e.g. [4, 5, 36]).

Every digital device is made of a unique combination of natural resources, including: gold, aluminium, platinum, palladium, tungsten, cobalt, neodymium, terbium, petroleum, and lithium, among others [134, 249]. The embodied impact of extracting and producing these resources varies significantly between mining companies, mining sites, and resources. This is partly due to the diverse legal and policy frameworks in place around the world, but also due to the facilities, techniques, and types of labour used in the mining processes [5, 36, 134, 174, 249]. Many mining operations supply hardware manufacturers with the raw materials they need to make our digital technologies. Some of the most notorious include the cobalt mines in the Democratic Republic of Congo [12, 237] and the lithium mines in Bolivia [213], but many other mines exist in China, Brasil, Mozambique, South Africa, and Canada [36, 158, 174, 272]. Mining operations have caused significant ecosystem degradation around the world when they have collapsed, had chemical spills, or been abandoned [12, 158, 237]. These types of events have led to water pollution, soil contamination, air quality degradation, and, in some cases, the serious harm of locals and workers [12, 174, 237].

Hardware manufacturing carries its own set of environmental costs, which also differ considerably based on the manufacturing company, the location(s) of its facilities, the product(s) it makes, and the policies and regulations affecting its business [5, 36, 175]. Some manufacturing facilities use large amounts of freshwater to create their products, while others dump waste-water from the manufacturing process into rivers [175]. This has been an especially serious issue in China, where FoxConn and UniMicron—two of Apple Inc.'s hardware manufacturers—have been accused of contaminating soil and water with heavy metals from their processes [258]. Similarly, several hardware manufacturing facilities in Japan, Taiwan, and India have been accused of air, water, heat and noise pollution [36, 159]. Whilst the electronics industry has faced some pressure to clean up their supply chains and some progress has been made [5, 36], these global industries have proven to be complex operations for intervention.

2.1.2 In use: what we do, where we go, and how much energy we use

When we use our digital technologies, we affect the environment in several ways. We contribute to the amount of carbon dioxide (CO_2) in the atmosphere through our increased demand for electricity, which we need to power our personal and workplace devices, as well as the support infrastructure we have created for our technologies (e.g. the Internet, data centres, satellites). We change the shape and nature of physical spaces by installing devices and support infrastructure (e.g. Internet cables, wifi routers in parks, water quality sensors in our waterways, satellites in space, etc.) in places that previously had other uses. We also alter how, where, and when we engage with the environment when we follow apps that tell us where to travel, what to see and do, where to eat, etc.

Whilst renewable energy sources are becoming increasingly popular and available, 77% of electricity globally continues to be generated from fossil fuels [120]. Some of that electricity powers our at-home and at-work digital technologies, as well as our internationally distributed data centres. Data centres are the backbone of the Internet; they are the physical places where we store much of our digital information (e.g. our tweets, Facebook posts, online photos, emails, documents in 'the cloud', and our 'digitised' personal data) and many of our digital services (e.g. Netflix, YouTube, Flickr, etc.). Data centres are almost always 'on', which is a large part of why global data centres have an annual carbon footprint that is equal to, if not greater than, that of the airline industry [206].

Industry reports and academic researchers predict that the demand for and from data centres is likely to triple in the coming decade [42, 101, 206]. Some of that increased demand will come from our personal choices; a UK study showed that residents spent an average of 9.9 hours online during a typical week in 2005, and over 20 hours per week online by 2014 [101]. We currently install more apps on our phones than ever before, and we often have more Internet-connected 'smart' devices in our homes, too. Although many of these latter 'smart' devices come with promises of increased home energy efficiency or thermal comfort, recent research from the UK and Australia suggests that these devices actually increase overall energy use and data centre demand [14, 101, 241–243, 273]. This increase stems from the higher overall number of Internet-connected products in the home, as well as from the automated software updates and communications that run in the background of an application. These automated updates are hidden data and energy costs, which highlight how personal choices are not the only influence on increased demand.

The technology industry and its design decisions, currently drive—and will continue to drive—much of the increased demand for data centres. Their continued push for more Internet-connected devices and services in our homes, workplaces, and urban spaces (see: "Internet of Things" [IoT] projects and global 'smart city' projects led by IBM, Siemens and Cisco), as well as 'abundant' access to the Internet (Facebook's Internet.org project; Google's Project Lune), have direct implications for the scale and volume of data centres needed to support such projects. The short-term gains from these projects—which often offer promises of economic growth, improved service delivery, or 'innovation'—might not outweigh their long-term social and environmental consequences. Professor Ian Bitterlin, one of the UK's leading experts on data centres, recently explained that "even if the [data centre] industry were able to shift to 100 per cent renewable electricity, the volume of energy they would need would put intolerable pressure on the world's power systems" [16]. In addition to their energy demands, data centres often require immense volumes of water for their cooling systems [112]. These issues have led some researchers to question if it's time for self-imposed limits on Internet usage and speeds [101].

Our use of digital technologies also affects the environment in other ways. We change the shape and nature of physical spaces by installing devices and support infrastructure around the world. For example, Internet cables, like telephone cables, now traverse our oceans and have attracted the attention of sharks, among other marine wildlife [143, 168]. Traffic monitoring sensors are being installed in our roadways, a process that often requires significant retrofitting of those roadways [110]. Satellites contribute to our growing 'space waste' problem [75]. We also alter how, where, and when we engage with the environment every time we follow the 'most efficient' directions provided by mapping algorithms, or when we eat at the same set of restaurants recommended by Yelp and TripAdvisor, or when we adjust our homes furnishing so that they are more popular on airBnB. These processes have measurable effects on the environment, but few studies have explored those effects. They are 'emerging concerns' that have primarily been discussed by journalists and in a few non-academic books [34, 89].

2.1.3 End-of-life: discarding or recycling

When we throw away or replace our digital technologies, they become electronics waste (e-waste), and they continue to have a demonstrable effect on the environment. E-waste is—and has been for almost a decade—the fastest growing waste stream globally [156]. This is because we, as global consumers, are buying more digital technologies now than ever, and the lifespans of those digital technologies are shrinking. Moreover, many consumers do not know what to do with their old electronics when they buy new ones. In some cases, people store their old electronics in drawers or cupboards at home [77, 182]. In other cases, people simply throw their old electronics in the trash, or donate them to organisations that ship them overseas [79]. Some people recycle their old electronics at formal recycling facilities. But these electronics recycling facilities do not exist in all countries or regions, and some have prohibitive costs associated with their use [57].

Until recently, many discarded and 'recycled' electronics from developed countries (including Canada, the United States of America, and members of the E.U.) ended up in informal e-waste 'dumping grounds' [156], the largest of which developed in India, China, and Agbogbloshie, Ghana [57, 166, 187]. Life in the dumping grounds is perhaps best described in this vignette:

> "In Agbogbloshie, seven- to twenty-five-year-old boys smash stones and simple tools against TVs and PCs to get to the metals, especially copper. They will earn approximately $2.50 per day. Most of them, hoping for a better future, left their families from the poor northern and upper west regions of Ghana for this kind of work. Injuries like burns, untreated wounds, lung problems, eye damage, and back problems go hand in hand with chronic nausea, anorexia, debilitating headaches and respiratory problems. Almost everyone suffers from insomnia. Smoke and invisible toxins (especially cadmium) harm the careless workers because they often don't know about the risks and walk around in flimsy footwear like flip-flops. Most of them die from cancer while in their 20s." [166]

Similar descriptions have been written about dumping grounds in India and China [7, 57, 73, 196, 187, 277, 279]. The processes used to dismantle electronics at these informal sites differ somewhat based on the tools locals have available to them, as well as the minerals or metals they are hoping to collect and sell. But in general, the dismantling processes are harmful to workers and the environment. Most people at these sites have no protective work gear; they openly burn plastics and electronic components, which leads to smoke inhalation as well as soil and water contamination. This contamination extends to regions nearby, jeopardising global ecosystem security [7, 214].

Many developed countries—including Canada and members of the European Union—have implemented stringent waste electrical and electronic equipment (WEEE) legislation, and have developed environmentally sensitive recycling systems in their home territories to help tackle the problem. This has helped to reduce the flow of illegal, non-functioning WEEE from developed countries to developing countries [156]. However, those flows have not been completely eliminated, and there continue to be many lingering issues with global e-waste tracking and processing [187, 156]. As a result, only 30% of global e-waste is tracked and processed in formal recycling systems [187]. The rest ends up in landfills, is illegally exported and “unaccounted" for, or is processed through other means, including those used at informal dumping grounds [187].

2.2 Social practices and public policies

Social practices—the things we do—and public policies—the policies set by governmental and intergovernmental organisations—influence the environmental footprint of digital technologies in various ways. For example, as mentioned in the previous section, public policies can influence what sort of mining operations are legal, what type of components a digital technology might include, and what sort of e-waste recycling facilities and processes exist [7, 134]. And our social practices (i.e. things we do with our electronics) can influence what software is on our devices, how much energy our devices consume, and what happens to our devices at the end of their lives [101, 182, 273]. Multidisciplinary academics are just beginning to examine many of these influences, and many gaps in our knowledge persist. My thesis contribute three new perspectives to this dialogue by focusing on HCI research practices, retrocomputing repair practices, and environmental public policies related to HCI.

There are many established ways of studying the influences of social practices and public policies. My thesis relies on the social practice theory approach outlined by Shove et al. [231] and a fusion of the two-pronged policy analysis approach outlined by Lazar et al. [152, p. 74] with the policy ‘scales’ identified by Nathan and Friedman [178]. These approaches were selected for two reasons: 1) they suit my research questions, and 2) they are already in-use and accepted by the HCI research community[2]. In this section, I introduce each approach and discuss how it will inform my research.

2.2.1 Studying social practices

> "We are living in a very complex and rapidly changing world. Social science does not exist in a vacuum: by its very nature, social scientific study directly considers those things in life which are close to our concerns as human beings—how we produce things, communicate with one another, govern ourselves, understand our varied environments, and how to solve the problems we face in the organisation of social relations and processes. The social sciences offer a way of dealing with all these issues." [234]

[2]Both of which were crucial considerations given the short time-frame of a British PhD, as well as HighWire’s unique, loosely structured doctoral process.

Within the social sciences, there are many theoretical approaches for studying what people do, as well as how and why people undertake certain activities. Practice theory is one such approach; it examines how and why everyday activities (e.g. bathing, cooking, or walking) unfold and change over time. Practice theory focuses on the activities themselves. This sets it apart from many of its theoretical peers, which focus on individuals and their behaviours, choices, or agency [207, 231, pp. 2-8]. Centring practices instead of individuals allows scholars to examine how human "activities are shaped and enabled by structures of rules and meanings, and [how] these structures are, at the same time, reproduced in the flow of human action" [231, p. 3]. Practice theorists often conduct their analysis by acknowledging and examining the interconnectedness of practices-as-entities (i.e. the materials and resources of a practice) and practices-as-performances (i.e. the ways that people enact a practice) [217, 222, 231, pp. 6-8]. But there is a great deal of variation amongst practice theorists in terms of how they analyse practices-as-entities and practices-as-performances [207, 217]. Shove, Pantzer, and Watson have developed a unique approach for examining practices, which they outline in their book "The Dynamics of Social Practice" [231].

Shove et al. centre their analysis of social practices on three types of 'elements': materials, meanings, and competences [231, p. 14]. Materials are the 'things' related to a practice. Meanings are the diverse beliefs, emotions, motivations, and expectations attached to a practice. And competences are the skills or knowledge acquired for and used in a practice [231, p. 14]. Analysing the individual nature of, as well as the linkages between, those three elements is what allows Shove et al. "to describe and analyse change and stability [in a practice] without prioritising either agency or structure" [231, p. 22]. They also examine how 'bundles', or types, of practices influence one another [231, pp. 81-87], as well as how different careers lead to the development, transformation, and abandonment of certain practices [231, pp. 69-74]. For example, they describe the shifting practice of driving a car in the USA by addressing the changing materials within vehicles (e.g. different engines require different skills to drive, maintain, and repair), the growth and development of support infrastructure for driving (e.g. traffic lights, roads, driver training schools), and the various careers that enable and shape driving (e.g. chauffeurs, mechanics, and manufacturers) [231, pp. 6-41]. They also touch on how other modes of transportation—including trains, boats, and planes—relate to the practice of driving cars [231, pp. 45-47]. This complex yet intentionally reductive approach to describing social practices is useful "as a means of conceptualising stability and change" in those practices [231, p. 15].

During Part I of my thesis, I adopt the social practice theory approach outlined by Shove et al. to study how retrocomputing repairers and HCI academics influence the environmental footprint of digital technologies. I made this decision because practice theory has become seen as a suitable framework for sustainability-focused HCI researchers to address one of the criticisms of their field: that their focus of analysis is too centred on individuals and their behaviours [202]. Adopting a practice theory approach has allowed HCI researchers to expand their field of analysis and reconceptualise the dynamic and at times unpredictable roles that digital technologies play in the changing world [202]. As I discuss in Section 2.3, adopting a social practice approach has specifically allowed researchers interested in sustainability and computing to explore new aspects of socio-technical changes [200, 202, 269]. These unique strengths underscore why I selected social practice theory as the theoretical grounding for my research in Chapters 3 and 4. Few—if any—other social theories have gained such widespread adoption and acceptance within the HCI community, especially with regards to digital technologies and sustainable lifestyles.

2.2.2 Studying public policies

Public policies play a unique and iterative role in governmental and intergovernmental organisations; they are often based on existing laws, regulations, strategies, and social norms, yet they also influence future laws, regulations, strategies and social norms [142, pp. 3-6]. As a result, the process of studying policies, or undertaking policy analysis, often relies on going beyond what a policy document states and "necessarily involves [analysing] the complex array of state and societal actors involved in decision-making processes" [117, p. 7]. This can be a complex process because many societal actors are involved with developing, setting and influencing public policy, including member of the public, legal experts, professional societies, interest groups, private companies, non-profit organisations, and academics [152, pp. 71-74]. Policy analysis can also be a complex process due to the wide range of analytical frameworks available [116]. As Howlett et al. explain,

> "Outside of basic criteria such as internal logic and respect for the empirics of policy-making, there is no *a priori* reason why any single framework should be adopted over any other, and, to a certain extent, choices can be made between those which focus on factors such as structure or agency in providing different levels of balance between clarity of explanation and fit with empirical detail." [116]

Howlett et al. go on to explain that "at least four current frameworks developed in the 1970s and 1980s continue to struggle for supremacy in helping understand and explain policy" [116]. Choosing which framework to use depends significantly on the audience with whom you intend to speak [116]. My audience is the HCI community, and the HCI community is at a relatively early stage in its efforts to engage with public policy [152].

There is currently no established, sufficiently complex process for conducting public policy analysis directed at the HCI community. In their recent monograph, Lazar et al. outlined two compelling reasons for the HCI community to engage with public policy: "first, public policies can influence how HCI researchers and practitioners perform their work. Second, the HCI community can inform public policy by providing expertise, taking part in the development of policy, and researching the impact of various policies related to HCI" [152, pp. 74]. In addition to explaining why and how HCI researchers could engage with public policy, I believe these two reasons offer loose guidelines for how to usefully communicate about public policy to HCI audiences. Unfortunately, the reasons noted by Lazar et al. are so broad that they offer little guidance for how to specifically address and explore the complexities of multiple public policy domains.

For this reason, I also draw on the notion of policy 'scales' identified by Nathan and Friedman [178]. In particular, I draw on two of Nathan and Friedman's policy scales: the 'domestic' (e.g. municipal or national) and 'international' (e.g. United Nations [UN] or African Union [AU]) policy scales [178]. These scales help to narrow the scope of analysis into manageable—if still incredibly large and complex—niches.

By fusing Lazar et al. [152] with Nathan and Friedman [178], I turn two separate-yet-related and familiar conceptual frameworks into a mechanism through which to analyse public policies for an HCI audience. I consider this fusion to be an adequate, if nascent, solution for the lack of clear public policy analysis structures in HCI[3].

2.3 Prior research in HCI

Human-computer interaction is a relatively young, multidisciplinary field of research and practice. Its origins lie in a fusion of computer science and psychology methods, and it has evolved considerably by drawing on research and methods from a variety of other disciplines, including sociology, anthropology, engineering, and the environmental sciences [20, 22, 50, 52, 55, 141, 148, 193, 228]. Within the HCI community, debates have raged about the nature of work being completed, the methods being used, and the priorities that researchers should pursue [20, 22, 50, 55, 141, 193]. Is HCI a craft? Is it a science? Is it an extension of engineering? Is ethnography a suitable method to gather insights about design? Is ethnomethodology more ideal? Are 'insights for design' really the point of using such rich methods within HCI? The debates surrounding these questions—among many others—are

[3] I recognise that my approach is merely one of many possible solutions, most of which have not been proposed or adopted yet by the HCI community. As I discuss in the conclusion, I believe that articulating public policy analysis for HCI audiences is one of the future areas of work that I could pursue.

far from settled; I mention them here because they indicate the variety of practices, passions, and areas of focus within the HCI community. With such a flurry of activity taking place under the banner of HCI, many sub-communities have formed. These sub-communities often use their own set of practices, methods, theories, and frameworks. My research primarily draws from and contributes to the sub-communities interested in sustainable HCI (SHCI).

2.3.1 Sustainable HCI

The sustainable HCI community has been actively exploring and engaging with some of the complex, multi-faceted dimensions of sustainable computing for nearly a decade [49, 139, 215]. During that time, some SHCI researchers have focused their efforts on rethinking the material composition and lifecycles of our digital technologies (e.g. [21]), while others have examined how systems design and usage are related to the carbon footprint of digital technologies (e.g. [14, 101, 204, 273]). Some designed or proposed tools and technologies that might inspire sustainable behaviours (e.g. [49, 71]), while others questioned the effectiveness of those interventions [29]. A recent 'practice turn' in the sustainable HCI community has seen some scholars adopt practice theory and its methods to study sustainable practices.

Sustainable practices

SHCI studies have examined a variety of existing and future sustainable social practices [14, 144, 200, 202, 269]. For example, in their exploratory work on future bathing practices, Kuijer, De Jong, and Van Eijk use creative methods to consider how we might reduce the resource consumption associated with bathing [144]. Bathing has become a water- and an energy-intensive routine for many people, especially in North America and Europe. Kuijer et al. attempted to intervene in this resource-intensive practice by designing and testing a bathroom-like space in the Netherlands; this space constrained water consumption by eliminating flowing water and instead offering "a 20-litre basin on an integrated stand, and a seat" [144]. Through their experiment, Kuijer et al. were able to challenge existing ideas about bath- and shower-specific behaviour change technologies, and provoke the HCI community to consider more radical reconfigurations of spaces in homes.

In similarly radical and future-focused work, Tomlinson et al. explore *collapse informatics*, which they describe as "the study, design, and development of sociotechnical systems in the abundant present for use in a future of scarcity" [259]. Rather than focus on a specific practice like bathing, Tomlinson et al. use practice theory and the notion of collapse informatics to imagine how sociotechnical systems might operate in the future. They briefly present and discuss several existing practices that might survive a future of collapse, and then call for interested researchers to embrace reflexivity in their work. This call to reflexivity can also be found in Håkansson and Sengers' discussion of practices performed by *simple living families* and *organic farm families* [96]. My work takes direct inspiration from these sustainable practice studies. In chapter 3, I especially embrace the calls to reflexivity found in Tomlinson et al. [259] and Håkansson and Sengers [96] by focusing on future, sustainable directions for my own research community's practices.

Repair practices and heirloom devices

Diverse repair practices have attracted the attention of SHCI scholars throughout the past decade because they are seen as a method through which to extend the life of digital devices. Moreover, designing digital devices that can be easily repaired is a core tenet of SID [21]. SHCI scholars have examined repair practices in numerous generalist repair communities (e.g. 'hacking' and 'mending' communities [164, 218, 247]), as well as in a variety of countries (e.g. the USA [128], China [247], and Bangladesh [127]). Many of these studies have found that practices of repair are highly unique, creative, and innovative processes, which vary significantly across time and space [115]. Several have called for continued examination of repair practices, as part of an effort to better understand their nuances, values, and implications [115, 247]. In parallel with these studies, HCI researchers have called for investigations into "heirloom quality" digital devices.

Heirloom devices are digital technologies that get, or have been designed to be, "passed down across generations of family members as a way of sustaining social relationships and bolstering ideas of shared heritage, history and values" [181]. They are seen as a potential solution to the growing issue of planned obsolescence [21, 97, 132, 137, 181]. The longer a device lives, the smaller its environmental footprint [5, 21, 212]; if a family or a person is willing to pass down, transfer, or work to extend the lives of their cherished digital technologies, then it could help reduce the environmental footprint of that technology [21, 181]. To date, HCI researchers have studied how to design heirloom quality devices through the use of attachment theory and the concept of ensoulment; researchers also developed several interesting prototypes of heirloom devices [137, 181]. Yet a gap remains in understanding how and why people currently keep and maintain retrocomputing systems. Retrocomputers are living examples of the heirloom devices and cherished digital objects discussed or referenced by a growing body of SHCI literature [14, 21, 37, 137, 181, 211, 261]. In Chapter 4, I set out to address this gap by exploring how and why people repair their retro digital devices, as well as how those repair practices influence the environmental footprint of our digital technologies.

2.3.2 SHCI and public policy

Several SHCI researchers have called for increased engagement with public policies related to the environment [83, 139, 232]. Although members of the HCI community have been directly and indirectly engaging with other types of public policy for decades (e.g. [43, 45, 92, 152, 171, 178, 268]), there is little evidence to suggest that SHCI or HCI researchers have engaged with environmentally focused public policies. My research—presented in Chapter 5—attempts to fill this gap by focusing on a subset of environmental public policies. Environmental public policy (EPP) is a broad group of policies that attempt to address environmental issues, including energy production and consumption, non-renewable resource extraction, biodiversity, water and food security, and 'green' economic growth [62]. My work examines three specific types of EPP: climate change, "waste electrical and electronic equipment" (WEEE), and "green public procurement" (GPP) policies. I analyse how these diverse policies could inform and be informed by the HCI community, using my aforementioned fusion of Lazar et al. [152] and Nathan and Friedman [178].

Part I

Social Practices

Social practices:
What and how we do some things;
There’s a carbon cost.

#PartIHaiku #haiku

Overview of Part I

Introduction

In Part I of my thesis, I present, discuss, and analyse two empirical studies focused on the social practices of HCI academics (Chapter 3) and retrocomputing repairers (Chapter 4). HCI academics can influence the design and adoption of new digital technologies through their research, education, and public service outreach activities. As a result, HCI academics have considerable direct and indirect influence on the environmental footprint of digital devices throughout their lifecycle. Meanwhile, retrocomputing repairers work to keep their aging digital technologies alive—using techniques and tools that are often presented as mechanisms through which to reduce the environmental footprint of digital technologies [21]. To date, no research has explicitly studied how either community of practitioners has influenced the environmental footprint of digital technologies. Chapters 3 and 4 address this gap by describing and analysing the social practices of each community.

Structuring the text on social practices

I have structured the text describing academic HCI and retrocomputing repair practices in close alignment with the structure found in Shove et al. [231]. In their book, Shove et al. explain that "it can be useful to think of elements *as if* they had relatively autonomous trajectories amenable to analysis, interrogation and comparison. At the same time, it is clear that the elements are nothing unless integrated in practice, and that if practices are to persist, they need to recruit people willing and able to keep them alive" [231, p. 62]. I embrace that notion in Chapters 3 and 4. I begin each chapter with a description of the individual elements of the practice (i.e. the competences, materials, and meanings). Then I present examples of the linkages between those elements before discussing the careers of people 'carrying' the practice. I selected this structure so that I felt confident I thoroughly addressed the nuances of each practice. I recognise more gifted and experienced practice scholars use other descriptive structures.

HCI research:
Its influences are broad.
Its impact is, too.

#ChapterThreeHaiku #HCIhaiku #haiku

Chapter 3

HCI research practices

3.1 Introduction

Every year sometime in April or May, thousands of people gather at the SIGCHI Conference on Human Factors in Computing Systems, also known as CHI. CHI is internationally recognised as one of the best venues—if not *the* best venue—for publishing HCI research, and competition for publishing/presenting work at CHI is high. For example, in 2016, researchers and practitioners submitted 2435 papers but only 565 of those papers were published (an acceptance rate of 23%) [8]. CHI also tends to act as a type of moral compass[1] for many HCI researchers. In the words of the CHI 2014 conference organisers,"CHI is more than a conference, it is an international community of researchers and practitioners who want to make a difference. Everything we do is focused on uncovering, critiquing and celebrating radically new ways for people and technology to evolve together" [129]. This description of CHI leaves much to the imagination. What type of work do HCI researchers and practitioners conduct? How does this translate into developing their identity as a "community of researchers and practitioners who want to make a difference"? And what counts as "radically new ways for people and technology to evolve together"? There are, of course, many answers to these questions.

Some of the answers can be found in literature published in and about CHI (e.g. [15, 22, 50, 52, 55, 141, 148, 228]), and some can be found in the late-night, post-conference rumblings and grumblings of CHI attendees[2]. A common theme in some of the late-night grumblings is CHI-publishable work; people hoping to establish their careers in HCI should

[1] I acknowledge that 'guide' might be a better term.

[2] Universities and businesses, such as Microsoft and Google, often host late-night, post-conference happy hours, where conference goers gather and socialise. Many of these parties are invite-only, or have a limited sign-up, so attendees often have to be 'in the know' before showing up at CHI if they wish to attend.

structure their research and projects in such a way that they will be able publish their work annually at CHI. Through this annual publication cycle, researchers establish their reputation and build their network, both of which help to develop their careers. The push to develop CHI-publishable work influences what projects HCI researchers develop and deliver. And those projects influence the environmental footprint of our digital technologies [232].

In this chapter, I discuss and analyse the complex nexus of practices performed by HCI academics, and I link those practices to the environmental footprint of digital technologies. I begin by detailing the field study I conducted for this research. I give considerable attention to the unplanned trajectory my research took, including an acknowledgment of how my immersion in the HCI community may have influenced my work. I then present the findings of my research, in the form of a narrative about the social practices of HCI academics. I begin by describing the complex, global, contemporary academic workplace wherein many academics perform their practices, which comprise a nexus of teaching, research, and 'public service' practices. When I shift my focus to the nexus of HCI academic practices, I focus on elements and linkages that appear to be more specific to HCI academics. These HCI academic-specific practices underscore many of the ways that the HCI community influences the environmental footprint of digital technologies. I address these influences in the discussion, and draw attention to several areas of HCI academic research that contribute to the embodied carbon of our digital technologies, and that appear to be unaccounted for in most calculations.

3.2 Field study: timeline, methods, and immersion

From inception to analysis and write-up, this research project spanned nearly twenty months[3]. It overlapped with both of the other studies contained within this PhD, and it took on a much larger scope than I had initially anticipated. When I started this research project, I had planned and designed my study using the social practice theory approach outlined by Shove et al.[4] [231]. I had expected to study the everyday research practices of HCI academics because I assumed this would complement an existing study of industry-based HCI practitioners [122]. I had planned to conduct between twenty and thirty interviews with researchers from diverse career stages and countries[5], and then complement my findings from those interviews

[3]This research project unfolded between August 2015 and April 2017.

[4]I made this decision so that I could cross-compare my findings with the study on retrocomputing repair presented in Chapter 4.

[5]I wanted to interview researchers from diverse career stages and countries because I was already aware that the duties of and demands on PhD students were considerably different than those faced by postdoctoral researchers and more senior academic staff. I was also aware that funding structures, publication pressures, and

with knowledge or commentary found in HCI publications. However, my broader immersion in and engagement with the HCI community complicated those preliminary, and arguably simplistic ideas, about how I would conduct, analyse, and write up my research for my thesis. In the following paragraphs, I introduce and outline the strand of fieldwork that involved qualitative interviews and secondary data analysis. I then turn my attention to my immersion in the HCI research community, by discussing how that influenced and shaped the research within this chapter.

I submitted my ethics forms to our University Research Ethics Committee in November 2015, and received official approval in January 2016 to begin conducting interviews. By mid-January 2016, I started compiling a list of potential interviewees; this was a process of purposive and convenience sampling. Two main factors influenced my sampling process: my limited (i.e. non-existent) access to data collection-specific travel funds, and my desire to interview a diverse array of HCI researchers. The former factor meant that, if I wanted to interview researchers further afield than Lancaster University's computing department, I would need to do so over Skype, on the phone, or whilst travelling to the researchers' place of work for other purposes (e.g. to attend a conference or workshop for which I did have funding). The latter factor meant I felt pressured to interview people who I thought represented HCI's large, international, multidisciplinary, and multigenerational community. Neither of these factors resulted in "objectively scientific"[6] sampling. However, they did encourage me to be creative within my constraints.

In tandem with my initial sampling process, I accepted an invitation to co-author a CHI2016 workshop paper with three colleagues at Lancaster University[7]. This, I thought, might give me an opportunity to secure funding so that I could attend and conduct interviews at CHI. I began reaching out to researchers in mid-February and secured my first interview in the UK on 1 March 2016. At about the same time, our workshop paper was accepted and I successfully secured funding to attend CHI2016 thanks to HighWire's support. I continued contacting researchers in the UK and EU throughout February, March, and April. I completed ten interviews in-person and via Skype prior to flying to San Jose in early May.

Despite plans to interview nearly a dozen international researchers at CHI, I was only able to conduct six interviews in total. Several interviewees cancelled our pre-scheduled meetings at the last minute, either because they were too busy with other meetings or felt too hung-over

even bodies of knowledge upon which academics were expected to draw varied considerably from country to country and region to region. As such, I wanted to interview a wide range of scholars in an attempt to unpack and represent that diversity; on reflection, thinking that I would be able to do so in the span of twenty-to-thirty interviews was short-sighted.

[6]By "objectively scientific", I mean: clearly and easily replicable by other researchers faced with the task of selecting a sample for a similar research project.

[7]For more on this, see Bates et al. 2016 listing in Appendix 1.

from the previous night's parties. When I returned from CHI, I began transcribing my existing interviews and noticing several clear patterns in the data. First and foremost: many of my interviewees discussed pressures and issues that fell outside of their research duties. They mentioned teaching duties, administrative requirements, and public outreach projects. From this, I could tell it would be useful to continue conducting interviews, so I returned to my search for potential interviewees. By the end of summer 2016, I had completed 22 interviews with international researchers and felt confident that I had conducted enough. My supervisors agreed. I spent the remainder of 2016, through to April 2017, slowly transcribing my interviews, planning the analysis of my work, reflecting on my own research trajectory, and seeking supplementary, secondary data.

Interview structure and content

I used the semi-structured interview guide included in part B.1 of Appendix B for all of the interviews that I conducted, both in-person and via Skype. This is the second interview guide that I designed for a social practice theory study, and I cut down on the content included in the guide as a result of lessons I learned during the retrocomputing repair study[8]. I designed this shorter interview guide and tried to direct the content of the interviews according to the three individual elements of a practice identified by Shove et al. (i.e. the competences, materials, and meanings) [231, p. 14]. I did not wish to directly ask participants to describe their materials, meanings, and competences; rather, I wanted to see which materials, meanings, and competences—and linkages between those elements—emerged when participants described their research and design practices. Thanks to the semi-structured nature of my questionnaire, in the few cases where participants were vague or neglected to mention some dimension of the elements of social practice, I was able to ask direct follow-up questions. In general, though, participants identified a range of materials, meanings, and competences simply by describing their educational backgrounds, typical days at the office, favourite projects, and least favourite and most favourite aspects of being an HCI researcher.

3.2.1 Summary of participants

Overall, I conducted semi-structured interviews with twenty-two HCI researchers from around the world, including: six based at North American institutions, fourteen based at European institutions[9], and two based at Australasian institutions. Throughout this chapter,

[8] This study and the lessons I learned from the lengthy interview guide are described in greater detail in Chapter 4

[9] I am including UK institutions in that total, despite Brexit.

I refer to my participants using randomly assigned, unique identifiers (R1 through R22) and, when quoting the researcher for the first time, I provide some very basic descriptive information about the region where the research is based and their career stage. I have chosen to limit the descriptive information in this way for one reason: by studying the HCI community and writing a thesis chapter targeting an HCI audience, I have created a 'small population problem' for myself [220]. A 'small population problem' arises in studies 'where there is a high risk that individuals may recognise themselves in the talk of others' [220]. The HCI community is relatively small and some of my participants might have met with each other—as well as some of my potential audience—at conferences or other academic events. As such, there is a risk that they might be able to identify certain quotes from participants, especially if I were to provide comprehensive demographic information about my participants. For this reason, I have worked to include only general statements from participants, and I have withheld a considerable amount of demographic information that I collected.

To maintain the anonymity of my participants whilst also acknowledging the diversity of the participants I was able to recruit, the remainder of this paragraph provides some aggregated, generalised demographic information about my participants. Eight of my interviewees were female and fourteen identified as male; they ranged in age from their twenties to fifties. In terms of years of experience with HCI research, eleven had less than ten years, seven had between ten to twenty years, and four had over twenty years. I interviewed one prolific Master's student, five PhD students and candidates (three of whom have since graduated), seven Lecturers (i.e. early career researchers), six Senior Lecturers, Research Fellows, or Readers (mid-to-late stage career researchers), and four full Professors (later stage career researchers). My participants had diverse educational backgrounds, spanning topics such as anthropology, computer science, clinical and applied psychology, human geography, industrial design, educational design, English, urban studies, electrical engineering, and instrumentation engineering.

Participant recruitment

I faced very few challenges recruiting participants for this research. As mentioned, several confirmed and cancelled at CHI. Similarly, one interviewee confirmed and then cancelled (by never responding to follow-up emails) an interview initially scheduled during the DEN HCI summer school. I contacted thirteen people who never responded, but otherwise received few rejections of or objections to this research. I note this here for two reasons: firstly, this indicated to me that the HCI research community was open to the ideas contained within this study. Several researchers even stated that they were excited this work was finally being conducted, and they asked me to share my findings if ever they were published in a journal or conference. Secondly, several of my interviewees described their openness to and interest in my work as a type of reciprocity; they had asked other people to participate in their interviews, and they felt a kind of obligation to participate in other researchers' work when approached. This latter reason, stated on- and off-record by at least seven of my interviewees, has almost certainly influenced my write-up of this research.

Knowing that there is a certain level of reciprocity amongst researchers helped me feel as though I belonged to a community. And I suspect that feeling increasingly like I belonged to a research community made me more sensitive in my interviews, write-up, and analysis. Perhaps that sounds strange to established researchers who have long belonged to a research community, but isolation—not feeling a sense of 'belonging' in any community—is a common thing for PhD students. As a PhD student in a 'radical' and 'postdisciplinary' doctoral training centre in particular, I spent most of the first year and a half of my studies feeling like I did not belong in any research community [10]. Slowly, over time, I grew to feel like I did belong in HCI. And that 'sense of community'[11] has almost certainly influenced my research in ways that I address in the section titled "Immersion in the HCI community", as well as in the limitations section.

3.2.2 Immersion in the HCI community

Prior to submitting my ethics forms for this study, I had taken on a teaching assistant (TA) position with one undergraduate HCI course and another undergraduate ethics in computing course[12]. The HCI course ran during Michaelmas term of 2015 (October to December), and the other course ran during Lent term of 2016 (January to March). Three established HCI researchers (i.e. one early stage researcher, and two senior researchers) led the courses, and I shared my TAing duties with five other HCI-focused postgraduate students. During labs, while students worked on assignments, the established researchers, other TAs and I would occasionally share stories about our experiences thus far in academia. I heard these stories months before I conducted my first interview in March 2016. They gave me glimpses into how the HCI community operated, how careers started and flourished—or floundered—and some of the ways the field had changed over time.

Similarly, as I was searching for potential interviewees in early 2016, I also—largely by accident—found myself involved with the design and development of a daylong workshop

[10] I am aware that feeling isolated is often part of the PhD journey[194].

[11] I am also aware that having "a sense of community" is still a hotly contested issue within psychology [33], and that I am in no position to resolve that debate.

[12] I had done this without making any intentional connection to my PhD research; I had done this for the experience of teaching and merely felt most qualified to assist with these courses.

for HCI graduate students. The workshop itself came out of several in-person and online conversations with friends and colleagues in the UK. I had met these friends and colleagues through the EPSRC's Digital Economy Network (DEN)[13], which happened to be organising an HCI-focused summer school at Newcastle University's OpenLab. The organisers wanted graduate students to gain experience designing and developing workshops with and for their peers from other universities. There was a workshop proposal process, and from the [unknown number of] submissions, the organisers selected seven day-long workshops, including our own [188]. We put together a call for participants, we advertised our workshop online, we met several times in-person and via Skype to plan out the daylong schedule of events, and we ultimately delivered the workshop during the DEN Summer School in mid-July. Although this process was not identical to that of organising a workshop for a major conference (e.g. CHI or DIS), the process offered me a glimpse into the unstated labour involved with planning and organising academic events.

There were, of course, other ways I participated in the HCI community, too. I reviewed papers for DIS 2016 and 2017, CHI 2016 and 2017, and alt.chi 2017. I attended the HCI Across Borders (HCIxB) workshop during CHI2016. I recently sat on the Program Committees for the ISS 2016 Posters Program [245] and the HCIxB Symposium for CHI2017 [146], each of which involved reviewing several papers. I contributed to the first International Fictional Conference on Design Fiction's Futures '16 (FCDFF), a fictional conference with very real activities underpinning its design and planning [138]. I coordinated HCI talks and events for my peers at HighWire. I co-supervised an intern's summer project in 2016. I co-organised a very different reflexivity workshop during Tiree Tech Wave in the fall of 2016. I wrote papers for HCI venues. I had discussions about HCI topics on Twitter[14]. These experiences, and my increasing sense of "belonging" within the HCI community, have made their way into my write-up in this chapter. In some cases, I explicitly reference my experiences in the description of HCI research practices. In other cases, I cite primary interview data and secondary published sources that align with my experiences.

I mention my immersion in the academic HCI community here and now—before presenting my discussion and analysis of HCI research practices—for transparency. As I briefly mentioned above, I believe my immersion in the HCI community has almost certainly influenced my research. By that I mean I suspect it influenced the tone, candour, and content

[13]HighWire CDT belongs to the EPSRC's DEN, "a national network supporting activities of postgraduate research students and Centres for Doctoral Training (CDTs) within the Research Councils UK Digital Economy theme" [48].

[14]This discussion about my distaste for the phrase "in the wild" [253] was a personal favourite; I REALLY. TRULY. appreciated having an established academic explain to me that it's "good to ground [my] problems with 'ITW' in concrete instances", as if I wasn't aware of that.

of several of my interviews[15]. I suspect it has also influenced some aspects of my analysis and write-up[16]. I become aware of this during the transcription and write-up process, and have since found other researchers who identified similar issues in the work of academics writing about their own community practices. For example, Reed-Danaha highlighted that researchers writing about their academic community have to navigate "the issues of insider versus outsider perspectives, and the construction of the [researcher] as both participant and observer" [209]. Although I was not aware of these issues at the outset of my research, I have worked hard to openly address them here, in my write-up.

A keen reader might note that I have not labeled my work as "ethnographic" or "community action" research, despite my immersion in the HCI research community. This is intentional. My work does not—and did not originally—set out to meet the strict criteria of either ethnographic or community action research projects, and it would be inappropriate for me to adopt either label. I kept a reflective research journal throughout my PhD—and this has informed some of my reflections and write-up—but I did not make strict and regular observations or field notes to such a degree that my work could be considered ethnographic. In retrospect, I wish that I had written strict and regular field notes, and I wish that I could have foreseen the depth of my immersion in the HCI community. But that is simply not what happened, nor was it how I planned and intended my research to unfold when I crafted this topic in August 2015.

3.2.3 Secondary data

In the forthcoming description of academic HCI practices, I reference a variety of studies conducted and published by other academics, HCI and otherwise. I sought out these additional and complementary materials based on: 1) recommendations from my interviewees and colleagues, 2) publications shared at the HCI events that I attended (e.g. University College London's "Symposium on HCI Grand Challenges", the DEN Summer School, the HCIxB workshop at CHI2016), 3) keyword search terms in the ACM's digital library, based on some of the publications shared by and recommendations from my interviewees, and 4) my late awareness of academic literature on academic practices.

[15]For example, even though I tried VERY hard to remain calm and attentive during interviews, I openly admitted to "fangirl-ing" to at least one interviewee whose work I admired.

[16]For example, I opted not to include a list of my participants with basic demographic information and generic details about their careers. However, I *did* include that list in the next chapter on retrocomputing repair. I have asked myself several times: would I feel so comfortable including that table with participant information if I were more thoroughly immersed in the retrocomputing community?

3.3 Introducing: the academic workplace

In 2017, academic practitioners tend to be found studying in or employed by postsecondary institutions, such as universities, colleges, institutes of technology, and seminaries[17]. These diverse postsecondary institutions—which can be publicly or privately owned—“serve as a staging ground for conflicting societal demands, ranging from capitalist accumulation and the reproduction of existing class structures on the one hand to upward mobility and social equality on the other” [189]. Such societal demands influence the course offerings, business ethos, and global ambitions of postsecondary institutions and their administrators [1, 72, 205]. Many postsecondary institutions now fiercely and internationally compete for students, researchers, funding, and prestige [1, 72, 189, 205]. Within this complex, dynamic, and highly political domain, universities tend to balance “three basic missions: teaching, research, and public service” [205]. These three basic missions, as well as the aforementioned societal demands, directly influence the everyday practices of academics.

Teaching can be a full-time or part-time, face-to-face or online, and unionised or non-unionised role for many academic practitioners[18] [91, 157, 170]. In their roles as educators, academics can be expected deliver instructional sessions to undergraduate students, post-graduate students, professionals, and public audiences during workshops, classes, seminars, presentations, masterclasses, and intensive short-term ‘residential’ courses [44, 157, 170]. The format, audience, cultural context, and funder of an instructional session can influence the configuration of an academic’s teaching practice [44]. Likewise, an academic’s career stage (e.g. graduate students vs Professors), gender, as well as formal training in or familiarity with pedagogy and andragogy[19], can also influence the configuration of an academic’s teaching practice[91, 157, 170]. For example, a Senior Lecturer in Anthropology in the UK might have never studied pedagogy or andragogy, but could be teaching a mix of undergraduate and postgraduate courses and undergoing evaluation using the UK’s Teaching Excellence Framework (TEF)[109]. Elsewhere, an academic in a similar post might have needed to take a teacher training certificate program to be able to deliver course materials. In many cases, graduate students act as teaching assistants, as opposed to the primary instructor, and they contribute to “complex teams of lecturers, administrators and others [who] collaborate in complex programs which have to be right first time, or not happen at all. Such programs depend on commodification of content, sophisticated timetabling systems and explicitly shared rules and procedures to ensure fair and consistent treatment for students across the modular

[17] Seminaries are theological colleges or divinity schools that educate students on religious issues and topics.

[18] Of course, not all academics are required to teach. Some academics have purely research-oriented roles.

[19] Pedagogy refers to the methods and theories of education. Andragogy deals with the specific methods and theories for teaching adults.

scheme" [44, pp. 42-43]. Beyond all of this, the trend of 'globalising' or 'internationalising' educational offerings has meant that some teachers have mobility—in terms of where they work—and in some cases have had to learn to deliver instructional materials in their second or third (or other) language [44, 170].

Research is, in many cases, a separate component of contemporary academic practice[20]. It is often the primary reason why academics join academia, and researchers "have to love [their] research so much that [they]'re willing to do all of the other stuff that this job requires" [93]. "All of the other stuff" includes teaching and public service activities, which can be incredibly time-consuming [93]; many academics are left to conduct their research in the workday hours, evenings, or semesters when they are not required to teach or perform public service duties. Academic research is heterogeneous; it can be conducted by an individual or a team. It can use qualitative, quantitative, experimental, computational, mixed, or a variety of other methods [87, 233]. It can rely on positivist, interpretivist, postmodernist, or any other number of epistemologies [87, 233]. It can be "publishable" or not [163, 176, 229]. The exact configuration of many of these latter statements depends on which discipline or field of research an academic practitioner hopes to contribute to (or is already contributing to). Academic communities tend to be unique in terms of the theorists they use, the ways they communicate their research results (e.g. at conferences vs in journals vs in books), and the expectations they hold for their fellow researchers [102]. These unique community expectations influence research practices in ways that are compounded by diverse global cultural contexts [104], research funding requirements [51], institutional expectations about types of research and acceptable research outputs[44], as well as an academic's career stage (e.g. graduate students vs Professors), gender[91], and social network [3, 68].

In addition to their teaching and research practices, academics are often expected to—or are voluntold to—perform public service duties [205, 271, pp. 76-78]. These duties can include a variety of public engagement activities, which Hart, Northmore and Gerhardt [98] summarised along the following seven dimensions: 1) public access to facilities; 2) public access to knowledge; 3) student engagement; 4) faculty engagement; 5) widening participation; 6) encouraging economic regeneration and enterprise in social engagement, and; 7) institutional relationship and partnership building [98]. These duties can "be realised in a number of ways, from student volunteering to opening university libraries to the public, to authoring a general interest book" [271, pp. 76-78] or hosting a lecture, seminar, or discussion with a mass media organisation [98]. Much like with teaching and research practices, the institutional and research-community-driven expectations related to public

[20]However, as mentioned, some academics maintain primarily research-focused roles, and some academics purely act as teachers. Moreover, some academics—including a few of my participants—have combined their teaching and research practices.

engagement vary considerably around the world and, as a result, so, too, do the configurations of academic public service practices.

The meanings, materials, and competences that academics draw on while performing these three diverse practices are as varied as the practices themselves. From the physical infrastructure on campuses and in locations where public service activities unfold to the meanings that most academics hold for performing their work in the way(s) that they do, the variation amongst practices and practitioners is extensive. Variation is the empirically backed notion that "the same set of activities can never be enacted in exactly the same way, making even 'routine' practices the site of ongoing reproduction and change" [118]. It is especially relevant in the case of academics because their 'routine' practices can easily be interrupted by unplanned office visits, phone calls, fire alarms, emails, classroom interruptions, or methodological challenges; moreover, their 'routine' practices can vary considerably between term-time, summer breaks, and research or teaching field trips. As Watson explains, "universities have constantly invented and reinvented themselves. Change is, to a large extent, the status quo of university life; only the pace of change may have varied during the long history of universities as institutions and as communities" [270, p. 7]. And that, too, is reflected in the dynamic and changing practices of academics worldwide. Any description of academic practices must therefore endeavour to acknowledge this dynamic and variable ecosystem. In the next section, I discuss the social practices of HCI academics by building on this general introduction to academic practices.

3.4 The social practices of HCI academics

As mentioned at the outset of this thesis, HCI is a relatively young, multidisciplinary field of research and practice. Its origins lie in a fusion of computer science and psychology methods, and it has evolved considerably by drawing on research and methods from a variety of other disciplines, including sociology, anthropology, engineering, and the environmental sciences [20, 22, 50, 52, 55, 141, 148, 193, 228]. Within the HCI community, debates have raged about the nature of work being completed, the methods being used, and the priorities that researchers should pursue [20, 22, 50, 55, 141, 193]. The competences, materials, meanings, career trajectories, and recruitment practices associated with these diverse and contested issues influence the environmental footprint of digital technologies.

3.4.1 Competences: designing, deploying, and evaluating software, hardware, and products

Every day, HCI academics draw on a wide range of competences depending on what they are doing and where they are working [as described by R1-R22]. Much like in the academic practices of other disciplines, some of the competences that HCI academics rely on include: basic and community-specific literacy, communication skills, critical thinking or problem solving skills, creativity, as well as the ability to work in a team. There are generic research-, teaching-, and public-service-specific competences, as well, including knowledge about: appropriate research methods, research ethics, professional ethics, and pedagogy or andragogy. Many of these competences are learned in academic settings during an academic practitioner's career-related training [as described by R1-R22]. For example, learning about pedagogy or andragogy often takes place during formal training sessions offered by universities (e.g. [150]). Although there are discipline-specific ways that those competences are configured[21], they are broad and general competences found in many academic practices.

A considerable amount of HCI research deals with the design, deployment, and evaluation of interactive digital technologies (i.e. software, hardware, and products). The competences needed to deliver this work are diverse, in part because of the broad range of digital technologies that HCI academics are designing, deploying, and analysing [20, 54, 50, 141][and as described by R1-22]. In their popular introductory book to HCI, Dix et al. dedicate several chapters to discussing interaction design basics, software development, design principles, implementation practices, and different models for delivering interactive digital technologies [54]. Examples of the digital technologies designed by HCI academics have included tools related to thumb and pen gestures on tablets [199], software for tracking mobile phone usage [14, 273], a domestic technology that prints random Flickr photos [183, 184], multi-purpose platforms for device or service management [46], and "internet of things" devices and support services [114, 246], among many, many other types of software, hardware, and products.

In the aforementioned examples of HCI projects, the programming languages used included C#, C, Javascript, and Python; my interviewees also noted using objective C, C++, SQL, NoSQL, R, HTML, CSS, and Ruby[22]. The materials—which I discuss in greater detail in the 'materials' section—designed or used in the aforementioned examples included: Arduinos, Android phones [14, 273], a vibrating and sensor-equipped belt [246], a hand-

[21] For example, "creativity" in an anthropological field study might take a different form than in a design-oriented, lab-based HCI project, which might also take a different form than when teaching a class with fifty undergraduates.

[22] There have almost certainly been HCI projects that relied on other languages, as well; there might even be a temporal correlation between the types of languages used by HCI academics. Legacy languages, such as BASIC and PASCAL, likely featured more prominently in HCI development in the 1980s and 90s.

crafted wooden box with a printer inside[183], and hand-held sized cubes “laser-cut from 3mm semi-translucent acrylic” [114]. Where and how HCI academics acquired the skills to work with those diverse languages and materials varied considerably [as described by R1-22]. Some HCI academics learned their software and hardware design and development skills during formal computer science or product design academic programs, whereas some were self-taught and others simply worked on multidisciplinary teams with a relevant expert or intern [as described by R1-22].

Deploying these technologies once they have been designed relies on a different, resource-intensive competence: the ability to establish relationships with partnering communities. In the words of R20[23], relationship building is “not usually the part that gets written about, but it’s the necessary part.” He witnessed public service projects failing or resulting in negative press when relationship building was ignored or went sour. Similarly, few—if any—HCI research projects are completed in isolation, and research projects can fail or go sour if HCI academics do not invest in building relationships within their research teams. Many HCI academics work on multidisciplinary research teams, and some research grants are explicitly structured to require cross-country collaboration (e.g. European Union Horizon 2020 grants). This can bring cross-cultural and cross-linguistic challenges to relationship building processes [according to R6[24]]. Beyond research project-specific research building, some established HCI academics take on informal mentorship roles with junior academics [R2[25], R10[26], R19[27], and R21[28]], and many take on supervisory roles with postgraduate and undergraduate students[29]. Moreover, many HCI academics also build relationships while performing their teaching duties. Being an effective teacher often depends on establishing a rapport with students, as well as with fellow teachers and support staff.

Assessing or evaluating digital technologies once they are deployed also relies on a unique set of heterogeneous competences, which vary depending on what is being evaluated, as well as by and for whom the evaluation is being conducted. Dix et al. explain that “evaluation tests the usability, functionality, and acceptability of an interactive system” [53], and they offer a number of examples of how evaluation can unfold (e.g. heuristic evaluation, model-based evaluation, experimental evaluation). Evaluations can take place in controlled laboratory scenarios or in everyday contexts, which the HCI community often refers to as “in the wild”

[23] R20 is a mid-career male academic based in North America.
[24] R6 is a senior female academic based in Europe
[25] R2 is a senior male academic based in Europe.
[26] R10 is a mid-career male academic based in Europe.
[27] R19 is a senior female academic based in North America.
[28] R21 is a male mid-career academic based in Europe.
[29] The practice of offering supervision or being supervised was mentioned by all of my participants.

contexts[30]. Acquiring the competences to perform evaluations often happens during an HCI academic's postsecondary education, or in the field from colleagues. Four of my own participants mentioned that they learned to conduct evaluations during their pre-HCI career training as Psychologists [R7[31], R10, R12[32], and R22].

3.4.2 Materials: the software, hardware, products and papers used, created, and evaluated by HCI academics

HCI academics rely on, create, assess, interact with, and influence a wide range of materials in their daily lives. Some of the materials that appear to cut across academic HCI practices include: university office spaces, HCI publications and their hosting services (e.g. journals and databases), as well as computers, phones, various software packages (e.g. Microsoft Office, Adobe Creative Suite, Google's G Suite), existing digital services (e.g. Skype, Dropbox, mailing lists, minecraft), and mobile devices (e.g. smart phones, tablets, laptops). There are practice-specific materials, as well, including: course materials and student assignments, event-specific materials (e.g. posters or presentation slides), and project-specific materials (e.g. one-off designs, prototypes, ethics forms).

As mentioned in the previous section, a considerable amount of HCI research deals with the design, deployment, and evaluation of interactive digital technologies (i.e. the software, hardware, and products that comprise digital technologies). To be able to design and deploy software, many—but not all[33]—HCI academics need to be able to write code in at least one of the languages noted in the previous section (i.e. C#, C, Javascript, Python, objective C, C++, SQL, NoSQL, R, HTML, CSS, and Ruby). To write code in those languages, an HCI academic would need to have an appropriate development environment installed on their personal or workplace computer (e.g. RStudio for R) or they would need to have access to a web-based development environment and service (e.g. Node.JS for javascript). The hardware that an HCI academic chooses to work with also influences the requisite language and software development environment. Arduinos, Android phones, iPhones, and Microsoft Kinects all have their own software development environments. As such, the software and hardware materials an HCI academic chooses to work with will influence what a digital device can do and how it performs. The physical shape of a digital device depends on the

[30] There are explanations of why HCI uses this phrase [216], I just find it colonial, distasteful, and dated, so I refuse to use it in my own work [253].

[31] R7 is an early-career female academic based in North America.

[32] R12 is a female early-career researcher based in Europe.

[33] Many HCI academics who work on theory development, evaluation, and analysis do not need to write code.

other not-necessarily-digital materials that an HCI academic chooses to incorporate into a design (e.g. a belt, the wooden box, the semi-translucent acrylic).

How and why HCI academics acquire these materials also varies. In some cases, HCI academics simply use the materials that they have readily available to them. For example, R10 mentioned using what was available around their lab due to their limited budget. Similarly, R3[34] explained that his team consistently used the same hardware because they were the only people on the planet to have it and they wanted to "milk it" until it died. Of course, ease of access isn't the only reason why HCI academics choose to use certain materials. Some HCI academics carefully choose and curate the materials they use because those materials convey a certain aesthetic. One of my participants, R21[35], described a recent attempt to achieve a specific, desired aesthetic:

> I spent, like, eight hours with a few other colleagues sanding. Just sanding. For eight hours. Just sanding down wood, with like, increasingly finer grain. Just. I mean, I wouldn't be doing that every day, but, like, some of my days are consumed with these, like, just very nitty gritty, like, doing tests for staining. Like, using different oils to see if the stain is going to be right. Or if it's kind of achieving that level—or like, trying to laser cut some veneer and... I mean, just these really, really, nitty gritty details that are extremely important [...] just in terms of just, like, getting a kind of prototype or a system to achieve that quality of, like, resolution. Um. That, I think, is important. At least for the kinds of work that I'm doing.

Although this carefully crafted aesthetic mattered to R21, he noted that not all HCI academics shared his interest. In fact, some HCI academics do not even share an interest in designing new products; rather, some HCI academics prefer to study how a participant uses their personal devices. In these projects, HCI academics write a piece of software and install it on a participant's device. R2 ran a project where "people used their own phones. That was a requirement, a recruitment requirement." Similarly, R1's[36] team ran "an observational study, so we didn't want to mess with practice as it had settled in. [We] recruited specifically people with [certain devices] who were happy to install the app and let it run for [a period of time], and then happy to give us the logs, which showed application foreground time, and all that kind of stuff. So kind of a bit invasive, but we couldn't see, you know, what pages and stuff [people visited]." In these types of projects, HCI academics let their participants' existing devices dictate the design and deployment of software or hardware.

[34] R3 is a mid-career academic male based in Europe.
[35] R21 is a mid-career male academic based in North America.
[36] R1 is a mid-career male academic based in Europe.

3.4.3 Meanings: making a difference, being a renowned expert, having fun, feeling exhausted

HCI academics associate a variety of meanings with their workplace practices. Some of the most frequently mentioned meanings amongst my participants included: doing good or making a difference, becoming a renowned expert, and having fun with what they do. For example, R6 explained that "I have my personal mission, which is that my work should change—a bit—something in the world, somewhere. I will probably—I used to say that I'm seeding, probably I won't see the flowers. But I hope that someone will." Similarly, R8[37] explained that

> "I really enjoy it. It's as straight-forward as that. I mean, we've been able to set up a spinoff company, uhm, off the back of the software, which we market to pharmaceutical companies, uhm, I enjoy the teaching, I get a buzz from seeing an idea that excites me light up in somebody else's head, that's, that's a great feeling. And yea, I guess, just the buzz of something working out. And I guess it's still an environment where you can try things and if they don't... go wrong, that's not a career ending kind of thing."

These aforementioned meanings are all positive, and align with some of the HCI community-wide interests in doing good [195]. But not all meanings associated with HCI academic practices are positive. Some of the HCI academics I interviewed used neutral or negative framings to describe aspects of their work. For example, one of the most frequently maligned duties was "administrative" work, in terms of grading assignments and exams (R8, R10, R15[38]), or dealing with project finances, coordination, and forms (R3, R4[39], R6, R10, R13[40], R15, R17[41]). Others mentioned being frustrated by the arrogance of some of their peers (R2, R4), and the pressures of having to publish or communicate their work in specific venues, using specific language (R7, R9[42], and R16[43]).

Many of the less positive meanings mentioned by my interviewees highlight how HCI academics are not the only people who get to determine the meaning or value of their work. For example, R10 recently relocated from the UK to a comparatively small country and noticed that, in his new working environment, "if there's something in the news, often, the

[37] R8 is a senior male academic based in Europe.
[38] R15 is an early-career male academic based in Europe.
[39] R4 is an early-career male academic based in Europe.
[40] R13 is an early-career male academic based in Europe.
[41] R17 is a mid-career female academic based in Europe.
[42] R9 is a mid-career female academic based in Europe.
[43] R16 is an early-career male academic based in Europe.

newspapers, the TV channels and all that, they go to the academics for comment on it. So people will constantly be, like, people are constantly on TV and in the papers and they actually respect your opinion. I don't think that was ever the case over in the UK." This anectdote indicates how academic representation or involvement in media systems can lead some academics to feel like their work is, or opinions are, valuable and worthy of respect.

Metrics set by funding bodies and/or associated with privately owned publishing outlets (e.g. journals owned by Elsevier, Taylor and Francis, or MDPI) can also influence the external meanings associated with academic practices. A few of my participants mentioned this type of external valuation of work, too, including R6, R13, and R22. In R13's case, he explained,

> "I see this becoming very very competitive around very few metrics. [...] There're people who create a research environment where they get other people to work very focused on papers and deadlines and collaborations that, I mean, pick collaborations towards who will get me published and get me cited. Um. I think it's very competitive, and my criticism is that I see that being influenced... it's an influence I see stemming mostly from the US climate."

Similarly, Alan Dix recently conducted an analysis of the UK's Research Excellence Framework (REF)[44] and found that the results related to computing departments "are misleading, [which] may also have affected textual feedback to departments, funding to institutions and possibly gender neutrality" [51]. These externally set metrics influence the complex meanings that HCI academics develop, carry, and share amongst each other, directly and indirectly. They can also directly influence the types of project HCI academics deem "valuable" to their careers, and therefore the types of products they develop and materials they might use. In short, these metrics, again, link to and influence HCI's novelty bias [20, 141].

3.4.4 Linking the elements of academic HCI practices: a focus on conferences

As implied by Section 3.3, HCI academic practices tend to unfold in postsecondary institutions, such as universities, colleges, and institutes of technology. Many of the linkages between academic HCI practices' elements align with the three basic missions of postsecondary institutions: teaching,research, and public service [205]. In fact, early in the interview process for this study, I asked R3 to describe a typical day in his life. He laughed at first, before explaining that:

[44]The REF is a formalised, UK government-run "system for assessing the quality of research in UK higher education institutions."[108]

> "Yeaaa, there is no such a thing [as a typical day for me]. My duties as an academic kind of split between three areas, so: teaching, research, and kind of service or admin duties. And so, uh, I guess a typical day probably has all of those things? So. You know, for instance, today, I've been in meeting most of the day, so I guess a lot of my time is spent in meetings. A lot of it is student meetings, so, meeting my PhD students, or postdocs, or I had a meeting today with one of my final year project students, so the undergraduate students. [...] Uhm, and then, teaching, so I had no lectures today. I guess, typically, you know, I teach a couple of hours a week. And some weeks I have to do a couple of hours in the labs as well. Um, and then we also have sort of a service component, so [for example], yesterday, I ran this day with school children. So that's an outreach sort of thing we do where we had 40 school children come in for the day and build cool holographic display things. But that's sort of counted as part of my administrative duties, as kind of a, uhm, *'yea, you're good at talking to students, so, go and organise that'* kind of thing. "

R3's comments were echoed by almost all of my interviewees. From PhD-level candidates to established Professors, HCI academics rarely felt they had 'typical' days. Their projects and job requirements were ever-shifting, depending on what career stage they were in or what funding bid they had or had not been awarded. Their research teams changed as academics came and went, thereby shifting the nature of teaching, research, and public service practices being performed by the research team (due to availability of certain competences). Their teaching course-load shifted with semesters, leading them to seek out new opportunities for public service or research activities during certain months. Sometimes the materials (i.e. assignments or prototypes) submitted by students introduced established HCI academics to new research topics and collaborators. Amidst this large, dynamic, and varying set of practices, what appears to clearly link together the elements of HCI academic practices are academic conferences.

Academic conferences tend to be the physical places where academic work is shared amongst, and occasionally conducted by, a research community[45]. This includes sharing work about teaching, research, and public service practices. As mentioned at the outset of this chapter, CHI is one of the most important conferences for HCI academics, and thousands of researchers and practitioners flock to it annually, regardless of where it takes place. It is not the only HCI-targeted conference, though; numerous other topic-specific and region-specific computing conferences act as gathering places for HCI academics (e.g. Designing Interactive

[45] However, research is also shared in other physical places, both formally and informally, and is digitally shared via journal publications.

Systems [DIS] [172], NordiCHI [69], CSCW [153]), and many HCI academics publish in or attend non-HCI-specific multidisciplinary conferences (e.g. conferences related to Geography, Urban Studies, Anthropology, and International Development). Conferences often offer a variety of sessions dedicated to paper presentations, keynote speeches, workshops, panels, and public service activities during conferences; the specific focus and quantity of those sessions changes every year depending on conference themes, submissions from academics and attendees, availability of speakers, and funding available or raised to run the conference. Some academic conferences have faced criticism recently, due to their size and exclusivity (e.g. a recent blog post by an HCI academic launched an online discussion about reforming CHI [192]), as have the materials generated at academic conferences. For example, R13 lamented that "the ten page CHI format is a very very poor knowledge product." But in general, evidence of the diverse linkages and configurations of the nexus of academic HCI practices are found in the papers, presentations, and panels run at conferences (e.g. [14, 46, 114, 181, 184, 199, 202, 219, 246, 273]).

3.4.5 Careers of carriers: recruitment and multidisciplinarity

As Shove et al. explain, "the contours of *any one* practice—where it is reproduced, how consistently, for how long, and on what scale—depend on changing populations of more or less faithful carriers or practitioners"[231, p. 63]. HCI is a relatively young academic community, which has evolved considerably in the past four decades by drawing on research and methods from a variety of other disciplines, including sociology, anthropology, engineering, and the environmental sciences [22, 50, 52, 55, 141, 148, 228]. The 'carriers' of HCI research practices have led that evolution, and they have done so by coming from multidisciplinary backgrounds themselves.

The routes to becoming an HCI academic are diverse. Not all universities offer undergraduate or postgraduate courses specifically in HCI. But universities often have formal recruitment events and online materials targeting prospective students in some of HCI's contributing disciplines (e.g. computer science, computer engineering, psychology, and sociology). My participants came from diverse educational backgrounds spanning topics such as anthropology, computer science, clinical and applied psychology, ergonomics, mathematics, human geography, industrial design, educational design, English, urban studies, electrical engineering, and instrumentation engineering. For example, in R10's case, he explained that:

> "My PhD was sort of about games, but not from an HCI perspective at all. I didn't even really know what HCI was to be honest, at that point. [Mine] was very much a Psychology PhD. Then, there was just a job advertised about games,

> and just through doing that, I realised, oh, what's that? Design is a discipline, and then, oh, there's this whole HCI thing exists in between design and psychology and the kind of people who are making the software that I was designing, and so yea, I just kind of got into it that way, I suppose. Just kind of naturally."

What ultimately drew R10 to HCI, and kept him involved with it, was its inter- or multi-disciplinarity; that was also true for most of my participants [R3, R5[46], R6, R9, and R18[47]], several of whom were proud to call themselves HCI academics. However, not *everyone* shared in that pride. Some of my participants did not see themselves as HCI academics. For example, R18, who has many HCI publications and whom I interviewed after she delivered a keynote presentation at an event, openly reflected, "I wonder what would count as HCI research? I would say [I identify as] an anthropologist and an educator, [not an HCI academic]." This makes the careers of many HCI academics interesting; Shove et al. mention that, "the moment when someone sees him or herself as a doctor or drug-taker may prove to be a moment of no return: from that point on, their career is set" [231, p. 71]. According to my participant R1, "academics who've been at it for a while do tend to move around"; unfortunately, few of my participants went into detail about those moving processes.

3.5 Discussion

In their research practices, HCI academics often work to conceive of new digital products and services. In their teaching practices, they educate a portion of industry-based digital technology designers and producers, who contribute to the design, development, and deployment of our consumer electronics. Through these practices alone—in addition to the diverse activities they perform as part of their public service practices—HCI academics can have a considerable direct and indirect influence on the environmental footprint of digital technologies. What materials they choose to use in their own designs can influence a digital technology's recyclability, longevity, and its owner's attachment to that technology [21]. What HCI academics teach in classrooms can have long-term effects on how students view design decisions and evaluation metrics. How HCI academics communicate their design decisions—as well as the relevance of those decisions to the environmental footprint of digital technologies—to a general audience during public service outreach activities can influence how popular culture presents, and how public perception responds to, the environmental footprint of digital technologies. What does this mean in terms of understanding the environmental footprint of digital technologies? And what does this mean for HCI?

[46] R10 is an early career male academic based in Europe.
[47] R18 is a senior female academic based in North America.

3.5.1 Connecting HCI academic practices to the environmental footprint of digital technologies

The materials that comprise HCI academic practices indirectly and directly influence the environmental footprint of digital technologies. This happens through several dimensions. First and foremost, as Blevis [21] noted in 2007, the materials that HCI academics choose to use in their own designs can influence a digital technology's recyclability, longevity, and its owner's attachment to that technology. My research suggests that there is an additional set of unknown environmental costs associated with the materials that HCI academics choose to use in their designs: the costs associated with acquiring, creating, and sharing hardware, software, educational materials, and academic publications. Few, if any, of my interviewees tracked where or how they acquired these materials, and many do not bother to conduct lifecycle analysis on their designs and projects[48]. Another material dimension missing from most discussions about the environmental footprint of digital technologies is the infrastructure that allows HCI academics to design, develop, and deploy digital technologies. While universities might individually track the embodied carbon of their on-campus infrastructure, that information and its influence on digital technology design is seemingly rarely communicated to academics. Although Hazas et al. [101] and Preist et al. [204] have demonstrated that our reliance on the Internet and its digital services carries considerable and possibly growing environmental cost, no studies have appeared to examine on-campus infrastructure specifically.

In many ways, this latter material dimension links with an oft-ignored, competence-related factor that influences the environmental footprint of digital technology: how we share, acquire, and store our knowledge. Knowledge sharing, acquisition, and storage in HCI—we well as in many other academic disciplines—is increasingly dependent on digital infrastructures. As Hazas et al. [101] and Preist et al. [204] have demonstrated, that infrastructure has an environmental footprint. My interviews have suggested that HCI academics remain unaware of that footprint, and so are not considering it in their decisions about how to share, acquire, and store academic HCI knowledge. This suggests that there are opportunities to develop academic practice-specific metrics related to carbon emissions and material use. For example, publishing academic work is an oft-overlooked part of the environmental footprint of digital technologies (i.e. lifecycle assessments do not consider if patents or academic papers have been created during the production of digital technologies). Publishing choices can shift academic culture [162], and developing metrics that allow

[48] In fairness, most universities do not require academics to conduct lifecycle analysis on their projects.

academics to understand the carbon footprint of certain publishing outlets or practices could be of value.

Similarly, academic and non-academic conferences carry an unknown environmental footprint. There is a footprint related to hosting and running large-scale events like conferences, and there are also carbon emissions related to co-locating thousands of people in a city for a large-scale conference event. My research suggests that HCI academics have an opportunity to start studying the environmental footprint of their conferences, as no information appears to be publicly or communitarily available. Of course, much like the practices of sharing, acquiring, and storing academic knowledge, the practice of attending conferences is critical to academic career development. Attending conferences like CHI helps HCI academics learn about new research in their field, and to connect with other relevant researchers working elsewhere in the world. These connections can help fuel another untracked dimension of HCI academic practice, which indirectly influences the environmental footprint of digital technologies: academic mobility.

Many careers of HCI academics depend on global mobility. My research has highlighted how important this mobility is to the careers of HCI academics. HCI academics frequently establish collaborative partnerships with out-of-country researchers, and they also—often, but not always—move from academic institution to academic institution as they progress in their careers. These moves will each carry a highly variable environmental footprint, which indirectly contributes to the environmental footprint of digital technologies because the moves are often an important aspect of the development of the materials, meanings, or competences associated with HCI academic practice. When an HCI academic moves to a new institution, they are often introduced to new modes of thinking, doing, and making. This, in turn, influences the kinds of tools that are conceived of, designed, tested, and incorporated into educational materials or public service activities. Measuring that influence seems a difficult task, but ignoring it seems misguided if we hope to develop a more nuanced understanding of how our practices influence the environmental footprint of digital technologies.

These findings should mostly be of interest to HCI and SHCI academics who are interested in the environmental footprint of digital technologies, especially those interested in evaluation [210]. In a forthcoming paper, Remy et al. discuss challenges related to evaluating the "sustainability" of interactive digital technologies [210], but they do not include a discussion about the role of our own, HCI academic practices. Researchers who have been calling for greater reflexivity and awareness about our own practices, and who are interested in sustainability (e.g. [96, 177]) might also find value in my research. My interviews suggest that few researchers think about what happens to their hardware, software, and other data after a project ends, and that HCI's well-documented focus on "novelty" arguably encourages this [20, 141].

3.5.2 Limitations

Despite believing in the findings of my research and being firmly committed to the content in the discussion, the data I gathered during this study is (necessarily) incomplete. Within the nexus of teaching, research, and public service practices performed by most academics, HCI academics specifically perform a highly varied set of duties. Each of those sets of duties could influence the environmental footprint of digital technologies in ways that I have not yet uncovered, due to the incomplete nature of my study. To produce a more thorough and satisfactory study of how HCI academic practices influence the environmental footprint of digital technologies, I would have needed to undertake targeted studies that explicitly focused on unique HCI teaching, research, and public service practices. I came to realise this far too late in my doctoral process; as in, I realised this in mid-2017 while writing up my research results and immersing myself in the multidisciplinary body of literature on general academic practices[49].

Existing literature on academic practices addresses many of the issues that came up during my interviews and had I been aware that these issues were so commonplace (e.g. teaching frustrations, cross-cultural and cross-linguistic collaboration, the three main practices involved with academia!), I would have shifted my questions slightly and spent more time discussing issues directly related to the environmental footprint of digital technologies. What I've just highlighted is, of course, not merely a limitation of my study; it is a limitation that is frequently associated with novices studying new fields. Learning about and reflecting on this limitation has been helpful for me, and I believe it will change how I conduct future research projects. I will endeavour to more thoroughly examine literature outside of the HCI/SHCI domain, using seemingly unrelated search terms. I will do so at the outset, not at the end, of my research project.

As my PhD examiners (Lisa Nathan and Nicola Spurling) rightly pointed out, these process-related limitations are not the only limitations of my work. My work is limited by the fact that I merely conducted an interview-based study of academic practices. At no point did I undertake a formal observational study, nor did I ask any HCI academics to participate in a journal-based study (wherein they would write in their journals and share their daily routines, thoughts, and reflections with me). I also failed to recruit any non-"Western" (i.e. from the Global South) scholars to participate in my study. These choices—along with my

[49] I was not aware of this body of literature until I accidentally combined a unique set of search terms in Google Scholar; I wish I had found it much earlier or that one of my colleagues had been aware of it.

failure to share this chapter with my interviewees and solicit their feedback in advance of submitting my thesis—have directly affected the depth of my study, and the content of what I have been able to include in this chapter. As such, my findings cannot claim to speak to the full set of practices performed by HCI academics, nor the impact of those practices on the environmental footprint of digital technologies.

Lastly, and perhaps most glaringly, I failed to explicitly link this phase of my research to my study on public policy and digital technologies, despite the considerable overlap in both research pursuits. Although policy spontaneously came up in one interview, I failed to directly ask any of my interviewees about public policy and what role it did or did not play in their practices. This means that my research can only speculate on the linkages between these domains. Future research could address these limitations, to expand on and enrich the practice-focused, public policy, and sustainability dialogues taking place within HCI.

3.6 Summary

HCI academics can influence the design and adoption of new digital technologies through their research, teaching, and public service outreach activities. As a result, HCI academics have considerable direct and indirect influence on the environmental footprint of digital devices throughout their lifecycle. In this chapter, I discussed and analysed the complex nexus of practices performed by HCI academics, and I linked those practices to the environmental footprint of digital technologies. I described the novel field study I conducted for this research, as well as the unplanned trajectory my research took. Using a narrative foused on the social practices of HCI academics, I presented the findings of my research. I then analysed how those HCI academic-specific practices can influence the environmental footprint of digital technologies. The unique contributions from this research are summarised below, in Table 3.1:

Table 3.1 Summary of contributions

Contribution	From which findings or observations	Relevant to...	Intended outcome
Materials: the global creation and sharing of hardware, software, educational materials, and academic publications carries an unknown environmental footprint; no HCI academics appear to track that.	Participants' description of academic HCI practices and my examination of other HCI and 'acaemic practices' literature.	SHCI and HCI researchers	Consider mechanisms for measuring this unknown environmental footprint; work (as a community) to identify ways to reduce this unknown footprint.
Materials: the infrastructure to support HCI academics often carries an unknown environmental footprint; universities might have data, but it not necessarily clearly communicated to academics.			
Competences: knowledge-sharing using digital services carries an unknown environmental footprint.			
Careers: academic and non-academic conferences carry an unknown environmental footprint, which professionals and organisers do not appear to calculate or share.			
Careers: the global movement of HCI academics throughout their careers carries an unknown environmental footprint.			

Retrocomputing:
How ageing machines live on,
Through caring repair.

#ChapterFourHaiku #retrohaiku #haiku

Chapter 4

Retrocomputing repair practices

Portions of this chapter are included in a publication that I submitted to TOCHI in March 2017. The description of the field study and the discussion in this chapter are considerably different than my TOCHI submission. See Appendix A for more details about publications contributing to this thesis.

4.1 Introduction

In a heated 1700 sq. ft. storage unit in Edmonton, Alberta, Canada, there are enough IBM-startup-era computers (from the 1980s) to create a high-functioning Beowulf cluster[1]. The owner of these machines, Gerrard, is a retired school teacher; he spends $1564.50 per month to rent his storage unit and he is very aware that his wife and children do not approve of the expense. But Gerrard takes pride in his vast collection of computer systems. Many of his machines are over thirty years old, and he has poured years of work into them just to keep them running. For him, the machines represent his connection to a bygone era. Every time Gerrard needs to repair or maintain one of his machines, he has to draw on the hardware and software repair skills he learned during his involvement with 'hacker' communities in the 1980s and 90s. His eyes light up when he talks about that era. His hands get more animated. He tells vivid stories of machines he modified, and students he mentored. Gerrard worries about what will happen in the next decade, as he faces his mortality and that of his machines.

[1]A Beowulf cluster is a high-performance parallel computing cluster that uses components from consumer-grade computing devices. They can be used for "traditional technical applications such as simulations, biotechnology, and petro-clusters; financial market modeling, data mining and stream processing; and Internet servers for audio and games" [197].

Computers, much like humans, age. Their software and hardware decay. Their components become obsolete[2]. They experience breakdown. When this happens, owners are presented with a series of questions: do they repair their machine? Do they throw it away? Do they give it to a friend or an organisation who wants to deal with it? Or do they recycle it using local recycling facilities?[3] Each question carries its own implications for the environmental footprint of a device, and every response reflects—to some degree—a person's values, attachment to their machines, and the skills or facilities that they feel they can access [57, 182].

In this chapter, I respond to and explore those questions by presenting, analysing, and discussing an empirical study of retrocomputing repair practices. I begin by defining retrocomputing and specifying what I mean with the phrase 'retrocomputing device'. I then describe my field study, including how my participant recruitment process led me to narrow the scope of my research analysis, and how that led me to gather and analyse secondary data. Then I introduce the Commodore 64 and its parent company, Commodore Inc. This lays the groundwork for my narrative description of the niche practice of C64 repair. This description includes an overview of the individual elements of C64 repair, as well as the linkages between those elements. I complement these sections with a discussion of the careers of the people carrying C64 repair, as well as the potential ways that this practice could persist in the coming decades. I close the chapter by teasing out what retrocomputing repair practices could mean for HCI and the environmental footprint of digital technologies.

4.1.1 Defining retrocomputing

What *is* a retrogaming or retrocomputing device? Who decides what 'counts' as a retro device? For better or for worse, there is no strict classification system; what 'counts' as a piece of retrogaming or retrocomputing hardware is a difficult task because many pieces of hardware achieve 'retro' or 'vintage' status at different speeds. For example, a four year old smartphone might already be considered 'vintage' by some people, whereas a four year old desktop computer would likely not be. The four year old desktop might be considered out-of-date, slow, or obsolete, but even those terms are highly contested. In many cases, what counts as retro, vintage, or obsolete is in the eye of the beholder. Digital technology companies also get a say. Some publish their own definitions of vintage and obsolete hardware, while others provide lists of 'retired' products. Apple Inc. publishes strict age limits that define

[2]Sometimes, components become obsolete at a specific time or on a specific date, due to decisions made by designers (i.e. planned obsolescence).

[3]Rapid consumer electronics replacement cycles mean that people occasionally *choose* to encounter some of these questions long before their technologies breakdown; I explored and examined such a scenario in [255].

its vintage vs. obsolete hardware [6]. A piece of hardware becomes vintage if it is between five-to-seven years of age, and it becomes obsolete after seven years [6]. As their website explains, Apple 'discontinue[s] all hardware service for obsolete products with no exceptions' [6]. Sony similarly states that it has a 'long-standing support policy of manufacturing and providing replacement parts for equipment for seven years after model discontinuation' [235], and Microsoft provides a list of 'obsolete' products and their 'support lifecycles' [169]. However, many digital devices continue to function long after their parent companies label them obsolete, stop producing replacement parts, and halt product support services. These long-functioning devices are retrocomputing devices.

4.2 Field study: timeline, methods, and narrowing the scope

This research project unfolded over the span of approximately twenty one months (May 2015 - February 2017), overlapping with both of the other studies contained within this PhD. However, I completed the majority of the work for this project between June 2015 and January 2016. During that period, I conceived of the research project, conducted all of the interviews, and undertook the first major phase of transcript analysis. My idea for this project first emerged while preparing my e-waste focused design fiction paper for ICT4S [255][4]; while reading about how HCI researchers conceived of and studied e-waste, I noticed—what I perceived as—a considerable gap in the literature with respect to existing "retro" devices. I grew up in a house full of computers made in the 1980s, and my father belonged to a Commodore 64 enthusiast community. As I read the e-waste literature, I became increasingly convinced that the Commodore 64 community's unique repair practices could offer some novel insights to the HCI community. I crafted this research project and proposal with Mike Hazas' guidance; it was the first phase of my PhD and he suggested I should try to have the first interviews completed before handing in my end-of-first-year "confirmation panel" document in September [5].

I submitted my research ethics forms for approval on 1 June 2015. After two revisions of my documents, I received ethical approval to begin conducting my research in early August. This recruitment process spanned three months (August to October 2015), during which I was able to recruit a retired electronics technician, a household goods sales representative, a

[4]My interest in e-waste emerged during my immersion in the smart cities domain [257].

[5]At Lancaster University, the confirmation panel is a formal assessment of a student's work; it typically takes place within the first six months of the second year of a PhD. The task of the panel is to"confirm that the student's work is of appropriate quality and standard, and the project is viable within the registration period, on the basis of draft chapters and/or evidence of data gathered" [149, p. 79], which is why Mike was pushing to have the first interviews done before submitting the requisite documentation.

long haul truck driver turned computer lab manager, one joiner-turned-computer-engineer, a retired teacher, and two computer engineers. The interviews took place between September and November 2015, lasted between twelve minutes and two hours, and were held in locations that the participants deemed ‘convenient’, including in the homes of the participants, in a Korean restaurant, via email, and via Skype. I transcribed the interviews in late November 2015. In December 2015, I coded the interviews using the three elements of Shove et al.’s social practice approach (i.e. materials, meanings and skills), searching for the linkages between elements [231]. In the fall of 2016, I reviewed the coded interviews and re-coded them while seeking additional insights from the data.

Interview structure and content

I used the semi-structured interview guide included in part B.2 of Appendix B for all of the interviews that I conducted, both in-person and via Skype. This is the first interview guide that I designed for a social practice theory study. As with the previously described HCI researcher study, I designed this interview guide and tried to direct the content of the interviews according to the three individual elements of a practice identified by Shove et al. (i.e. the competences, materials, and meanings) [231, p. 14]. I began this set of interviews by trying to learn more about the ecosystem of retrocomputing devices that the repairers kept, in part because I thought that might help me understand their attachment to devices [182] and the meanings they attached to the practice of repair. This ended up being an unnecessary line of questioning, which I removed from the HCI researcher study interview guide; the more avid repairers ended up reiterating these meanings and describing their ecosystem of devices elsewhere during the interviews.

The majority of my interview guide and discussions centred on describing a specific instance of personal or service-shop-based repair. I wanted to see which materials, meanings, and competences—and linkages between those elements—emerged when participants described their repair practices or the repair practices they interfaced with when using a repair service. In general, participants identified a range of materials, meanings, and competences simply by describing their experiences conducting repairs, and I had to merely prompt them for minor additional details about how and where they acquired materials. In the interview guide, I included a substantial number of questions about my participants’ motivations for conducting repairs. During most interviews, I asked very few of those questions because the participants described their motivations throughout our discussion. As such, I learned that this number of motivation-centred questions were likely unnecessary for future semi-structured interview guides, which i why they are absent from the HCI researcher guide.

4.2.1 Summary of participants

Overall, I recruited and conducted semi-structured interviews with seven participants for my study. Six participants lived in North America, and one lived in Europe. Much like in the preceding chapter, I will henceforth refer to my participants using randomly assigned, unique identifiers (P1 through P7). When quoting the repairer for the first time, I provide some very basic descriptive information about the region where they are based and the length of time they have been repairing retrocomputing technologies. I have chosen to limit the descriptive information in this way because the retrocomputing community is a small, niche community and I have once again created a 'small population problem' for myself [220]. Although the retrocomputing repair community is not my primary audience, there is a risk that one or more members of the community might read this chapter (or any subsequent publications) and be able to identify certain quotes from participants. For this reason, I have worked to include only general statements from participants, and I have withheld a considerable amount of demographic information that I collected.

To maintain the anonymity of my participants whilst also acknowledging the diversity of the participants I was able to recruit, the remainder of this paragraph provides some aggregated, generalised demographic information about my participants. Four of my participants belonged to a Commodore 64 enthusiast community (P1, P3, P4, and P5), while the other three participants repaired a variety of retrogaming devices (e.g. a Sega Genesis, Super Nintendo Entertainment System, and Nintendo Gameboy). Only one of my participants was female (P6). During the interviews, I attempted to draw out the three elements identified by Shove et al., as well as the linkages between those elements. I also asked the interviewees if they would be comfortable sharing photos of their retrocomputing devices or repair stations; three interviewees agreed to this and offered pictures of their repair spaces, tools, and retro devices.

Participant recruitment

I started contacting potential participants in August 2015, immediately after receiving ethical approval for my study. Recruiting participants for this study proved to be a challenge for me. The requirements for participation stated that, to be a participant, a person needed to have recent experience repairing a retrocomputing or retrogaming device. Few people met this requirement. I initially attempted to recruit participants using purposive sampling. The first people I tried to recruit were members of online retrogaming and retrocomputing communities whose posts and articles suggested that they had recent experience repairing their machines. I also visited a few retrogaming shops in my city of residence: Manchester, England. Unfortunately, these preliminary attempts to attract participants failed. At least thirteen people I approached either never responded or declined to participate due to time constraints, lack of interest, or lack of compensation. After these initial disappointments, I turned to convenience and snowball sampling. I reached out to my wide network of computing colleagues, as well as to my father, who had belonged to an international Commodore 64 community for decades. Through these contacts I was able to secure interviews with my seven participants.

4.2.2 Deciding to narrow the focus of my study

Shove et. al explain that, for the sake of thoroughly examining the complexities of one practice, it can be helpful to "[narrow] the scope of inquiry and [concentrate] on how practices grow and shrink within pockets of niches of possibility, remembering that these pockets change shape as practices develop" [231, p. 65]. During the first round of coding my interview data, I realised that the repair practices of Commodore 64 enthusiasts could likely be labeled a "niche of possibility" within broader retrocomputing repair practices. Commodore enthusiasts appeared to undertake more complex repairs, establish more offline and online relationships, and generate more documentation than my non-Commodore participants. This led me to spend additional time immersing myself in their online materials, and in some of the physical magazines that my father had at his house. The thorough and accessible, additional documentation gave me access to supplementary secondary data, which complemented the limited number of interviews I was able to conduct.

4.2.3 Secondary data

I sought out additional complementary data based on: 1) recommendations from my interviewees, 2) the materials available at my father's house, and 3) keyword search terms in Google. I found hundreds of Commodore enthusiast community forums and websites (e.g. [155, 74, 41, 27]), blog posts (e.g. [70, 61]), archived magazines (e.g. [100]), and books (e.g. [275]) to supplement my interview data. I have included much of this information below via citations and quotes.

4.3 Introducing Commodore Inc. and the Commodore 64

> "A lot of people think that digital social interaction started with the Internet. This is not true. There's an untold part of our current history that's about the origin of the IT, music, and gaming [industries]. The story is about the most-sold

> computer in the world—the Commodore 64, and a group of youths who, during the 1980s, started building their lives around it. This generation is all grown up, but as teenagers they transformed their computers to be a natural tool to network, create, share and have fun with" - [275, p. 7].

Jack Tramiel, an Auschwitz survivor and Polish-American businessman, founded Commodore International Incorporated in 1955 [130]. Commodore initially operated as a low-cost typewriter repair business, but Tramiel spent much of the 60s and 70s transforming Commodore into a successful North American personal home computer and electronics manufacturer. At the time, many computer and electronics manufacturers focused their work on designing products that met specific business needs (e.g. banking ATMs, NASA supercomputers, MIT's Silver Arm [41, 190, p. 60-61]). However, in the late 1970s and early 80s, more companies began releasing personal home computers (e.g. the IBM 5100, Apple II, TRS-80, Atari 400) [190, p. 60-61]. These personal computers were often considered luxury goods, and carried price tags reflecting their luxury status [276]. Tramiel's motto for Commodore was "computers for the masses, not the classes" [130, 276], so the company endeavoured to make personal home computers that would be affordable by all (Figure 4.1). Commodore's first affordable, personal home computer was the Commodore Personal Electronic Transactor (PET), which they released in 1977 [190, p. 61]. The PET was quickly followed by the Commodore CBM-II and Vic-20, which offered better sound and graphics modules than the PET [190, p. 61]. In January 1982, Commodore released the "Commodore 64", an 8-bit personal home computer with 64K Ram, superior graphics and sound chips, and an affordable price-tag [40, 190, 276]. This combination of tech specs and affordability made the Commodore 64 (C64) incredibly popular for computer hobbyists, gaming enthusiasts, and educators [40, 190, 276]. Software producers and C64 enthusiasts released thousands of games and productivity tools for the C64 during its lifespan [40].

By the early 1990s, personal home computers had become affordable for and commonplace in many North American and European homes. New machines and services were being released regularly, and the marketplace for computers was in the process of changing dramatically [191]. Brands that had been popular in the 1980s, including Commodore, Atari, and Acorn, were losing favour to newer Windows-based personal computers, Apple PowerBooks, and portable devices [61]. Although Commodore had released the first 'portable' full-colour machine, the SX-64, in 1983, long before many of its competitors [18], it was struggling to compete in the new portable marketplace. It had developed a reputation for poor customer service and technical support [56], and many people saw the flagship Commodore machines—including the Commodore 64—as 'cheap [and] disposable' [56].

Fig. 4.1 An early advertisement for the Commodore 64, emphasising its low cost and accessibility to "person persons" [38].

When Commodore discontinued the C64 in 1993, it had sold between 17-22 million units, earning it the Guinness Book of World Records title as the world's best selling personal computer—a record that the C64 holds to this day [130, 190, 276]. In April 1994, Commodore Inc. filed for bankruptcy and closed its operations around the world [28]. Despite Commodore Inc.'s closure, many organisations continued to use the machines in the workplace [23, 70] and many Commodore enthusiasts remained committed to the company's systems [186]. Some of those enthusiasts had created Commodore User Groups for the purpose of hosting Commodore-focused events, sharing Commodore-specific resources, and connecting active members from around the world [107]. According to my participants (P1, P3 and P5), these User Groups remained active after Commodore Inc. closed, and played a role in how people, organisations, and communities conducted Commodore 64 repairs in the early 1990s and beyond.

4.4 Repairing the Commodore 64

The practice of repairing a C64 has shifted considerably since Commodore Inc. released the C64 in 1982. In this section, I attempt to describe the present-day nature of the C64 repair practice, while linking it to its history. I begin by examining the competences, materials, and meanings associated with repairing a Commodore 64, and then shift focus to the linkages between those elements by describing specific instances of repair. I follow this with a discussion of the careers of the people 'carrying' this repair practice, and a reflection on the future persistence of this practice alongside the inevitable ageing of its practitioners and technologies.

4.4.1 Competences: software, hardware, and knowledge-sharing

The competences needed to repair a Commodore 64 vary considerably depending on which piece of hardware or software has stopped working. Has the power supply fritzed? Has a fuse blown? Has the Sound Interface Device (SID) chip died? Was there a bug in a newly installed software package? These are some of the questions that a person might ask if they encounter a problem with their C64, and each question would demand a slightly different set of competences to address (P3[6]). If the power supply stopped working, a person could fix that by replacing the power supply entirely or by opening and repairing specific parts of the power supply [31]. If there was a bug in a newly installed software package (e.g. geoBasic [113]), a person could address that by deleting and reinstalling the software package or attempting to debug it. In any repair scenario, personal preference, technical skill, access to materials, and the length of time needed to complete the repair could influence what took place and how it unfolded (P1[7], P3, P5[8]).

There are—and have been for the entirety of the C64's life cycle—a variety of ways to acquire the skills and knowledge needed to conduct any of the aforementioned repairs. In the 1980s and '90s, Commodore Inc. offered formal diagnostic test cartridges to their official repairers, so that they could quickly identify and address software and hardware problems (P1). According to P1, most unofficial repairers did not have access to Commodore's formal

[6]P3 is a male, amateur repairer who has owned several C64s since the 80s and is based in Europe.

[7]P1 is a male, professional repairer who has owned several C64s since the 80s and is based in North America.

[8]P5 is a male, amateur repairer who has owned several C64s since the 80s and is based in North America.

diagnostic test cartridges, so they had to identify problems and conduct repairs in other ways. Some people learned how to conduct repairs through formal classes at technical colleges and universities (P1, P4[9]). These classes included software language training (e.g. in Commodore's BASIC language, C, Pascal, or assembly language), as well as hardware design and repair courses. Not everyone attended formal classes, though. Some people learned their skills through informal knowledge sharing with friends (P3, P5), by reading repair and hardware design books and magazine articles (P3, P4, P5), through personal initiative and curiosity (P1, P3, P4, P5), or by accessing Commodore User Group materials and attending their events (P3, P5). Some people even sought support from technicians in other fields. In P5's case, he sought mentorship from "HAM radio operators [who] were good with electronics and got into computers. They were helping many hobbyists because they knew the electronics". Of course, not all Commodore 64 owners had access to similar mentorship opportunities. Moreover, not all owners were mechanically and technologically competent or confident enough to diagnose and fix the problems with their machines.

In the 1980s and 90s, formal computer repair shops offered repair services for a price. By the time my interviews took place in 2015, most repair shops were of little help to Commodore 64 owners. New sources of support and competency-development had emerged, though. Many of the C64 community groups that were active in the 1990s had stopped hosting formal meetings by 2015, but a few, including the Toronto PET Users Group, remained very active [260] and helped repairers develop their use and repair competences. The Internet had also begun to fill many gaps left by the inactive community groups; it offered access to recently established, international Commodore communities, as well as to new blogs, magazines and websites run by individual enthusiasts (P1, P3, P4, P5). Some of the freshly available online educational resources included component-specific repair guides [31], detailed repair videos posted on YouTube [74], and discussion forums with repair advice [2, 100, 155]. For people who had an Internet connection and who thought to search for Commodore resources, the World Wide Web played an active role in changing how, where, from whom, and when they accessed information related to repair. The ability to identify and interpret online information is itself a form of competence used when undertaking C64 repairs in the 21st century.

4.4.2 Materials: commonplace parts, donated machines, and household tools

Once a piece of faulty software or hardware is identified, a repairer needs to be able to replace or mend that faulty component. In the 1980s and even the 90s, repairers could purchase

[9] P4 is a male, amateur repairer who has owned several C64s since the 80s and is based in North America.

or order many replacement parts from computer hardware stores, international distributors listed in Commodore magazines, or from people selling items on local C64 Bulletin Board Systems (BBSs) [25]. Alternatively, some people brought spare parts to Commodore User Group events (P1, P3, P4, P5). As P5 explains,

> “mostly the Commodore was built with off-the-shelf parts, aside from the proprietary ROM chips that Commodore had, but you could even buy those if you wanted to buy them. Everything was for sale. There wasn’t a lot on the shelves [of local stores]. You’d have to order it. But you could get it."

This made acquiring parts for C64s much simpler than doing so for other computers whose components were only available to order if you were an official, certified repair technician (P1). According to my participants, some members of the Commodore community also received donations of broken or functioning computers and equipment from friends, families and other organisations (P1, P3, P4, P5). In some cases, this donation and acquisition process started in the 1990s and continued well into the 21st century (P1, P3, P4, P5).

Fig. 4.2 A small portion of P5’s collection of Commodore PETs and other retro digital devices.

Eventually computer stores and international distributors stopped carrying replacement parts for C64s, partially due to Commodore’s bankruptcy and an overall decreasing demand for components, which was likely fueled by households upgrading to newer machines. This created a spare parts void, which some C64 repairers were able to address by visiting second-hand shops, flea markets, and auction houses in search of materials (P1, P3, P4, P5). In the late 1990s, the Internet also emerged as a tool for selling, acquiring, and designing replacement parts (e.g. high capacity storage upgrades [27]). This Internet-enabled, international distribution of parts amongst collectors, enthusiasts, and repairers persists to this day [59]. All of my participants reported that they had recently acquired some of their parts from online reseller sites. One of my repairers who had stockpiled his inherited parts and machines told us that he had taken an active role in re-selling and redistributing parts. As he explained,

> “I’ve sold stuff on eBay all around the world. It’s amazing. I’ve shipped Commodore computers to Korea—South Korea—where it cost, y‘know, they paid me $60 [for the computer] on eBay and then it’s $100 for shipping! I’ve shipped stuff all over the world. And that’s part of, like I said, a lot of people have given me their collections” (P3).

Not all repairers take on active sales roles, though. P1 and P5, who had inherited large Commodore collections over the years, admitted to ‘hoarding’ or ‘stockpiling’ devices and parts over the years (see: Figure 4.2). They did so out of concern for what they saw as an increasingly scarce supply of parts. Their concerns are echoed online, where certain components have already achieved ‘rare’ status [32]. This scarcity of parts has inspired some enthusiasts to design new components that address supply issues and expand the Commodore’s functionality. For example, many RAM expansion kits have become popular in the past decade [13], as have some Commodore-to-VGA monitor adapters [154] and mass storage devices [27]. These newly designed materials have been used to repair damaged C64s and to replace functioning-yet-lesser parts.

The Commodore 64 underwent several formal redesigns during its product lifetime, including two changes to its motherboard and location changes for the video interface (VIC-II), SID, and programmable logic array (PLA) chips [82]. Despite these material changes to the machine, the tools needed to conduct many of the most common C64 repairs on all design iterations of the C64 remained consistent. These tools included multimeters, soldering irons, and screw drivers (P1, P3, P4, P5). To acquire these necessary tools, people had to own, borrow, or otherwise acquire them. None of these tools were specific to Commodore 64 repairs; they could be used to service many other digital and non-digital objects alike, which meant that some people had acquired their tools for purposes other than repairing C64s. In the case of one of my participants, "my father bought me my first tools and test equipment [and] before I was out of high school, I took a temp job at a repair shop fixing tape recorders and radios" (P1).

4.4.3 Meanings: satisfaction, community, and retro-cool

People have associated a variety of meanings with the process of repairing Commodore 64s, as well as with the tools and competences needed to repair C64s. Disentangling and addressing all of those meanings is a challenge perhaps best addressed by the accounts of my interviewees, who repaired their machines in the 1990s because it was a fun, innovative, community-building activity, that involved knowledge sharing, skills development, a sense of accomplishment, and camaraderie (P1, P3, P4, P5).

P3 and P5 explained that being able to repair a Commodore meant they belonged to a community, and that sense of belonging was very important to them. P5 made efforts to help people repair their machines in-person, and he intentionally purchased many of his materials at local shops so that he could develop strong connections with them. In his words, "I tried to support the local community so that I would have somebody close by [when I needed help]" (P5). One of my other participants enjoyed the innovation involved with belonging to the community, and spoke proudly about how "people were more than willing to share their knowledge and ideas and skills for the betterment of others" (P3). Although he was less driven to be an active member of any single community, P1 also noted how much fun he had sharing his knowledge with other people. Most importantly for him, though, was the satisfaction of finding a solution to a problem. "I enjoy repair work since it's much like a puzzle," he explained. "Finding the solution and making a device work again is very satisfying" (P1).

By the 21st century, a certain 'cool' factor had grown to be associated with many retrocomputing and retrogaming devices [60, 244, 266]. This 'cool' factor was visible in the production of objects like Jeri Ellsworth's C64 Direct-to-TV device [208] (mentioned by P5 and P6[10]) and in various art projects or installations that were inspired by retrocomputing devices (e.g. pixel art galleries online [160] and curated exhibits in museums [262]). These developments—and the nostalgia underpinning and inspired by them—likely influenced some C64 repair practices, including those of my participants. My participants also had a nostalgia for the days when they were active in their local Commodore User Group. In the case of P1, he had "a soft spot for [C64s] because they were part of my education into computers. Even if they are considered worthless, I would still hate to see them go in the trash". P4 simply explained that "when I'm loading something from a tape, I still get that feeling that I got years ago". My participants used other words, too, such as familiarity and reliability, to express their lingering attachment to C64s. Unlike in the early 1990s, the sense of belonging to a community, the fun associated with owning, using and repairing a C64, and

[10]P6 is a female, amateur repairer who has owned numerous retrogaming devices since the 90s and is based in North America.

the pursuit of knowledge appeared to be less important in 2015. However, those motivations still operated in the background of some repair practices. P3 noted that he had personally inherited collections from friends who had “moved onto other things and didn’t want to throw out their computers because, you know, they liked them, and they wanted to know that they were going to a nice home".

I also prompted my participants about other potential meanings for conducting repairs, including valuing privacy and sustainability. These two issues were prevalent in the news in 2015 and I wanted to know how and if those issues influenced my participants’ motivations for using and repairing their C64s. All four denied that privacy had anything to do with their decisions to use or repair C64s in 2015, even though they each acknowledged that a C64 would offer a more secure computing experience compared to many contemporary computer systems (P1, P3, P4, P5) [263]. In the words of P5, “with these old [computers], everything was in ROM. The operating system, the basic programming language, the controllers inside these drives. Nobody could screw with anything. I mean, to physically change the operating system, you have to break into my house, strip out the chips and replace them". Similarly, environmental sustainability was not a motivation for my participants. Although three of my participants expressed a desire to keep Commodores from going into the trash (P1, P3, P5), their concerns were more out of respect for the hardware in the machines than for their impact(s) on the environment. P3 even stated “the sustainability end of it, I haven’t considered."

4.4.4 Linking the elements of repair: specific instances of repair

C64 repairs could and can only take place through some combination of the aforementioned materials, meanings, and competences. For example, P4 described a time when his C64 broke down and he initially could not figure out the problem with it. After some consideration, he responded by systematically exchanging parts with one of his other functioning C64s. In that instance, he explained, “I had another Commodore 64, and I just started transplanting chips because I knew the other one was working. So I tried one at a time, and then put them back and, eventually just came across, ‘ahh, it’s booting up now’, so I knew it was the SID chip” (P4).

To conduct this repair, my participant needed to have the appropriate materials (i.e. the second, functioning Commodore 64) already at hand to conduct the repair. Fortunately, he had “bought [the other] one mainly for games. So as one was loading a game, [he] could be playing a game on the other one" (P4). In addition to the spare C64, he also needed to have the knowledge and confidence to systematically check the pieces of equipment that could have failed. He hadn’t taken any formal electronics repair training nor had he attended any Commodore user group meetings that involved learning or sharing repair skills; he had “just learned by doing" (P4). He was driven to learn his competences “by doing" for a few reasons. Earlier in the interview, he explained that many of his peers in the UK hated C64s initially “because they were American" (P4) and that he continued to use his C64 despite this widespread hatred, even after more advanced machines became popular. Owning, using, and repairing a Commodore made him feel special and unique (P4). This, along with the sense of nostalgia he associated with the machines, is what drove him to continue repairing his C64s. He openly admitted to placing special value on Commodore-branded machines. In his words, “anything else, if it was beyond my skill level [to repair], then I’d throw it away" (P4).

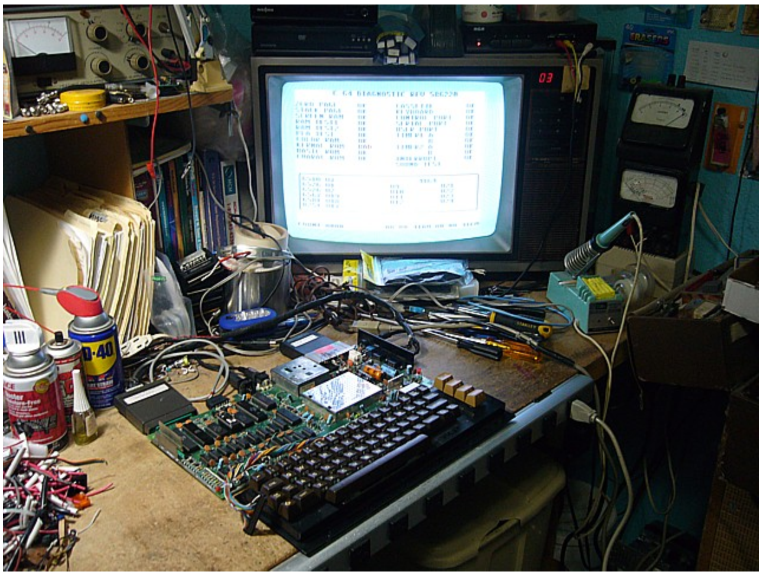

Fig. 4.3 A repaired Commodore 64 being tested at P1’s personal repair station.

Peer-supported C64 repairs were commonplace throughout the 1980s and 90s in Canada and the USA (P1, P3, P5). Repairers often undertook these collaborative repairs in personal homes that had been equipped with repair stations (e.g. P1’s station shown in Figure 4.3) and in public or private spaces where Commodore User Group events took place (P3, P5). These events and activities were coordinated in different ways. Many Commodore enthusiasts used Bulletin Board Systems (BBSs) [25] to communicate with each other (P3, P5). Dozens of Commodore magazines were being printed with information about local events (P3), and telephone calls, physical mail, and word-of-mouth also played a role in connecting people (P1, P3, P4, P5).

> “Whenever I had questions that the books seemed to be ambiguous about, I would go to [friends] for the final word. And then it’d be like ‘OK, that piece of knowledge is tucked away.’ There was a lot more of a congenial atmosphere in

> those days. Everyone wanted to help everyone else. And vice versa. I wouldn't pretend to be interested; [when] someone sees someone else interested in what they're into, they'll help you." (P5)

These collaborative repairs relied on a complex web of materials, meanings, and competences. The people involved needed to feel that their 'cheap' and 'disposable' C64s [56] were worth salvaging. Some people also needed to feel that their repair skills and knowledge were worth sharing. Those knowledgeable repairers needed to feel comfortable sharing their tools, spare parts, and knowledge with whichever friend, colleague, or stranger needed help. The User Group or individual with a community repair space at home needed to set up the physical meeting space for these collaborative repairs to take place. That involved coordinating—and in some cases (P5), purchasing new—tools, spare parts, and work spaces.

My interviewees mentioned hosting events in schools, community league buildings, and businesses (P3,P5). They often relied on personal connections to secure those locations (P3, P5). The locations may have unintentionally been exclusive spaces in terms of location or wheelchair accessibility, which would have influenced who could and could not attend. However, one of my participants (P5) had mobility issues throughout much of his involvement with his local Commodore User Group, so their events were often accessible. Underlying many of these collaborative events was a notion of community that extended beyond the User Group's membership boundaries. In Edmonton, computer "stores would give memberships to the [Commodore User] group when you bought a Commodore Amiga 500 for example. So stuff like that really increased membership" and the User Group's ability to attract people to their events (P3). Moreover, the willingness of businesses, schools, and community leagues to host events related to a computer interest group was what made many events possible.

In-person peer-supported repairs became less common by the 21st century, in part due to the dwindling activity of Commodore User Groups and the dwindling number of hobbyists. Even some online communities struggled to get users to offer to help one another with repairs [236]. It's difficult to comprehensively speculate why that may be; however, some of my interviewees' comments suggest potential reasons for this shift. The limited supply of spare parts might lead people to be less generous with sharing their parts, although this was not the case with my interviewees specifically (i.e. P1, P3, P4 and P5 all expressed an openness to sharing their spares). Alternatively, perhaps due to the prevalence of comprehensive online repair guides (e.g. [2, 31, 121]), people are less likely to feel the need to coordinate in-person events. There might also be a lack of awareness about existing User Groups, leading their events to be poorly attended and therefore less likely to take place (P3, P5). Unlike the period in the 80s and 90s with membership-handouts from computer sales outlets (P4), in the 21st century, there's no clear way for a person to discover a local Commodore User Group upon acquiring a C64, unless that person already knows someone currently or previously involved with a group. Local culture likely also influences the prevalence of events. In P5's experience, "I used to be in various Commodore clubs and most of them have closed down now. There's internet clubs, which I'm a member of a few of those. But um, they tend not to meet very regular. Not in the UK. In America, they're quite active. But in the UK, it seems very quiet."

4.4.5 Careers of carriers: professionals, hobbyists, novices and looking to the future

As mentioned in Chapter 3, and as Shove et al. explain, "following the careers of carriers as commitments develop and wane, we get a sense of how some practices become more deeply anchored and embedded in society while others disappear" [231, p. 64]. In the case of C64 repair, some people formally carried the practice of C64 repair in their employment as repair technicians for Commodore Inc. prior to its insolvency. Others formally carried the practice, before and after Commodore Inc.'s insolvency, as generalist repair technicians who would work on a variety of computer systems (e.g. P1). In both of those cases, those repair technicians may have come from previous careers as HAM radio technicians or electricians, and they might have had access to diagnostics cartridges to help them identify issues with faulty machines (P1, P5). At least a few of these formally employed C64 repair practitioners joined the hobbyist communities that carried the practice after Commodore Inc. went bankrupt in 1994.

The careers of hobbyist C64 repair practitioners vary considerably, as they likely would in any hobbyist community. People come and go for various lengths of time, bringing with them some of the competences, materials, and meanings that they would have learned or applied in their other daily routines. My participants included a retired electronics technician (P1), a long-haul-truck-driver-turned-computer-lab-manager (P3), a joiner-turned-computer-engineer (P4), and a retired secondary school teacher (P5). These carriers of the repair practice had all acquired their technical skills for non-C64 specific purposes, but applied those skills to maintain and repair their cherished Commodore devices. Only one of my repairers reported having mobility impairment issues following an accident (P5), and he was still able to repair computers despite those issues. In his words, "before I could walk again after the accident, I was actually doing soldering on my bed, which I know is a big safety issue" (P5). However, the physical nature of repairing C64s, and acquiring the materials and competences to do so, indicates the physical, bodily inequities of the practice.

At present, it also appears to be quite difficult for any extremely late adopters to become C64 repair practitioners (e.g. the person who purchased their first C64 in 2014 [39]).

Although many useful materials and instructions are available online, there are almost no training opportunities that address retrocomputing and retrogaming devices in universities or colleges [11]. Community support, either online or in-person, would likely be critical to how a novice could undertake any repairs [39], but this in-person support is limited, as we've already mentioned. Moreover, there appear to be few clear reasons why a novice would now undertake a C64 repair. Perhaps they could become inspired by curiosity, or perhaps they could be required to do so as a requirement in one of the few relevant university-level courses [11]. My attempts to contact owners who might fit this category have failed thus far, and this points to a considerable gap in my knowledge about how this repair practice might be carried forward, particularly as many of the original hobbyists age and retire.

Many older C64 owners and enthusiasts have become concerned about what they will do with personal collections as they retire, grow bored of their repair hobby, or die (P1, P3, P4, and P5). I could not find much information about these concerns online, but all four of my participants spoke to this concern. P1 and P5, who were 72 and 63 respectively, had retired from their careers and mentioned that they were unsure about what would happen to their collections when they passed away. As P1 explained, "it concerns me. What happens to my goods after I'm gone? I honestly don't know. My sons would have no use for those old computers". P3 maintained some hope that one of his children would be interested in inheriting his collection, but he stated that the computers were not in his will and that "the kids are all going to have to fight over it". Only P4—the youngest participant, in his forties—intended to pass down one of his machines. He planned to pass down "the one that I've got boxed, that has never been outside of the box, I'm intending to pass that down [to my son]. He's only 9. But he prefers Windows machines". When prompted, all of my participants stated that they would ultimately prefer their collection to go to someone—or something, such as a gaming or computing museum—that would make use of the machines. Anywhere but the trash.

4.5 Discussion

Repair practices are often presented as a way to extend the life of a digital device, thereby reducing its impact on the environment [21]. My study has examined how digital device repair practices exist, persist, and shift over time. As indicated earlier, many aspects of the practice of C64 repair have changed over time. The materials have changed, in terms of what parts are available, where they are available, and how they can be accessed. The competences have changed, due to training material and support being shifted online. The meanings have also changed, including in the way meanings are validated and passed on to younger people.

Despite these changes, the niche practice of C64 repair has persisted for over thirty years. This can be partially attributed to the design of the C64, but it must also be attributed to the efforts of its enthusiast community members, who shared their passion openly for over three decades. What does this mean in terms of understanding the environmental footprint of digital technologies? And what does this mean for HCI?

4.5.1 Connecting retrocomputing repair to the environmental footprint of digital technologies

Commodore 64s were initially designed as cheap, disposable machines, and yet thousands are being actively used over 30 years after their release. These machines have achieved—and may continue to achieve—the hardware longevity discussed and desired by many papers in sustainable HCI [21, 77, 182, 212]. But my study of retrocomputing repair practices highlights several unexpected environmental costs that appear to be missing from the discourse about heirloom computers, device longevity, and LCA: global material sharing, creation of replacement parts, and knowledge-sharing.

With current levels of material scarcity, retrocomputing repairers have to resort to environmentally demanding practices. The two most demanding practices noted by my participants involve sharing materials globally and creating new or replacement parts. In the case of sharing materials globally, this can involve selling and shipping entire machines, which will then be disassembled for specific parts upon arrival in their destination country, or selling and shipping individual components. The carbon footprint associated with these two options is unclear. Obviously, selling and shipping individual parts would have a lower carbon footprint than shipping an entire machine, but some sellers and purchasers are not concerned with this. Ultimately, this environmentally relevant dimension of repair is often absent from discussions about the practice. Further studies could attempt to measure this aspect of digital device repair, which would apply to retrocomputing device repair as well as contemporary device repair.

The creation of replacement parts also carries unaccounted for environmental costs. 3D printing (or other methods of home fabrication) of replacement parts is often assumed to be more environmentally friendly than replacing a digital device, but I was unable to find any measurements to support that claim. The process of designing, prototyping, and manufacturing replacement parts for ageing machines—or even contemporary machines, wherein the manufacturer has stopped creating a specific part—requires the use of natural resources, at an unknown scale (e.g. designing and printing components that can connect to the larger motherboards in retrocomputing devices presumably demands more plastics, metals, or silicon). Future studies could explore this unknown environmental cost.

Lastly, as Hazas et al. [101] and Preist et al. [204] have demonstrated, our reliance on the Internet and its digital services carries a considerable and possibly growing environmental cost. As digital technology companies limit their device support to seven years, and as in-person training and support for unsupported devices shifts online, we could be adding to the already considerable footprint of the Internet. Certainly, there would have been an environmental footprint associated with offline support services, too. However, I have been unable to find any existing comparative studies of the footprints associated with these practices. Future research could explore this issue.

4.5.2 Connecting retrocomputing repair to existing HCI research

All of my participants—including those who repair non-C64 retrocomputing devices (P2, P6, P7[11])—mentioned that they repair other household objects and digital systems. This suggests that their niche retrocomputing practices are connected with other repair practices. This aligns with the practice theory notion of 'threading through', which "captures the idea that things, for instance, an object or a practice, can move or advance through the nexus of practices, thereby linking the practices through which they pass or to which they are connected" [118, p. 4].

Wakkary et al. describe 'everyday' practices of repair, which primarily involve repairing non-digital artefacts [269]. There are many similarities between these 'everyday' repair practices and retrocomputing repair practices. One is that both repair practices involve people with a "personal interest in repairing and keeping an object. Individuals are driven to preserve an object's perceived meaning and beauty. Personal attachment to objects for emotional, sentimental and familial reasons are also part of the motivations people have when repairing" their everyday objects and retrocomputing devices [269]. Although one of my participants claimed he wouldn't bother repairing non-C64 digital devices, he acknowledged that he mended other household objects due to personal attachment and perceived usefulness (P4). Similarly, like the everyday repairers described by Wakkary et al., the retrocomputing repairers I interviewed all used "impromptu and in-situ problem solving approaches" and relied heavily on their hands to "transform and reconstruct broken objects" [269]. These impromptu and in-situ problem-solving skills were also described by Jackson and Kang in their study of artists who engage in repair practices [128]. Although none of my interviewees

[11] P7 is a male, amateur repairer who has owned numerous retrogaming devices since the 90s and is based in North America.

considered themselves artists, I noted in my discussion of 'meanings' that artistic practices can influence the 'cool' factor associated with retrocomputing devices.

A key difference between everyday or artistic repairers and my retrocomputing repairers, though, is how my repairers sourced their materials. Unlike the everyday repairers who rarely sourced "specific materials away from their near environment" [269], my retrocomputing repairers sourced—and supplied—materials locally and globally. These globally sourced and supplied materials needed to be specific parts; unlike the everyday repairers, it would have been much more difficult for retrocomputing repairers to resolve a problem using an everyday, household material "similar" to the digital device component in need of repair. A "similar" component from a different machine would not necessarily have worked in the C64 (e.g. a soundcard for an Apple II would not have worked in a C64). This does not imply that the retrocomputing repairers lacked the creativity described in Maestri and Wakkary's foundational work on everyday repairers [164]; rather, the creativity of retrocomputing repairers simply manifested itself in different ways, such as through their diagnosis of issues using trial-and-error testing of parts, or through their design of new materials to fill existing material gaps.

The practices of repair unfolding at community repair spaces, such as those described by Rosener et al. [2014] and Houston et al. [2016], share some patterns with some of the practices of the C64 repair community. Specifically, the amateur Fixit Clinic in the Bay Area, the Fixers' Collective in New York, and the Repair Cafes across Europe [115, 218] all offered "public and collaborative space where repair skills can be practiced, shared, and supported" [115]. These gatherings involved an eclectic group of regulars and "occasional or one-off participants ranging in age" [115], much like the community events organised by Commodore User Groups (described by P3 and P5). However, the Commodore User Group meetings rarely focused on repair of devices alone; many Commodore User Group meetings addressed an eclectic range of topics, including game sharing, system modification, and repair (P3, P4, P5) [260]. My interviewees also made no mention of Commodore User Groups offering advice "on the best way of disposing of broken items" [115], nor of the Commodore User Groups specifically aligning themselves with the ethics or values of sustainability [218].

Hardware that can be repaired

My research supports the claim that complex hardware systems are a barrier to repair [21]; all four of my C64 participants stated this, as did my non-C64 participants, who explained that they would either replace, store or dispose of their retro digital devices if it was too difficult, expensive or time-consuming to repair their device(s) (P2, P6, P7). However, my retrocomputing repairers faced serious barriers to repair, even though C64s had initially been designed with mostly off-the-shelf parts and an easy-to-repair architecture. Replacement parts are becoming progressively more difficult to acquire thirty-three years after the release of the C64. By 2015, the flow and availability of many spare parts had fallen into the hands of hobbyists, second-hand shops and auction houses, so people who had not thought to stockpile replacement parts earlier faced paying a premium if they needed to acquire anything. According to my participants, the increased cost associated with acquiring replacement parts influenced their decision to repair or dispose of a retro digital device (P2, P6, P7). Furthermore, in the case of the C64, although online repair instructions were available in video and text formats, in-person, device-specific repair support groups had dwindled by 2015. Anyone without the confidence to undertake a repair themselves had few mentorship opportunities available to them. This raises some serious questions for designers interested in the long-term effectiveness of designing 'for longevity' or 'for repair' [21, 77, 212, 218]. An initial commitment to design 'for longevity' or 'for repair'—e.g. by using off-the-shelf parts and an open design—might still leave repairers to encounter difficulties over time, particularly because it is difficult to account for and ensure the future accessibility of parts, skills and support for repair.

Community support systems

The communities that have grown to support C64s are inspiring and inspired. They have extended the functionality of their machines through hardware and software modifications, they have produced websites, magazines, and videos about common issues, and they have also used new communication technologies to build new support networks online. A mini-industry has also grown around the C64, with some members of the community—including my participants—earning supplementary income from selling parts and helping other people repair their systems. People within C64 communities have made international friends, organised events and challenged themselves to learn new skills. Their active efforts have helped extend the life of the C64 well beyond some of its younger competitors, including Dell's 325NC laptop and IBM's Thinkpad 700c, both of which appear to have no existing support groups or online communities, and no online instructions guiding a person through various repairs. This seems to suggest that the existence of an active community, passionately using their machines and sharing their knowledge, can influence when, how and if a retro device gets repaired. The activities of that community can act as a substitute for the lack of official support from companies, and extend the functionality of machines that may have otherwise been deemed obsolete. But these communities are not for everyone, including three of my seven participants (P2, P6, P7), and it is difficult to imagine a formula for replicating their growth, development, and activities. With this in mind, it could be worthwhile too for researchers to help establish or support device-specific repair communities, especially if we wish to encourage device longevity and re-use.

Attachment to retro devices

All of my participants kept and repaired their retro digital devices because they were attached to them, but that attachment was not static. Some of the C64 owners transitioned from being attached to their machines due to the fun, problem-solving and community-building that the machines enabled in the 1990s, to the nostalgia they enabled in 2015. Moreover, all of my participants, including the non-C64 participants (P2, P6, P7), stated that nostalgia for experiences was one of the main reasons they kept and repaired their machines in 2015. The original hardware was just a part of that experience, and not necessarily the most important part, as evidenced by some participants' use of emulators instead of original hardware (P3, P4, P6, P7). In fact, some participants acknowledged that they would discard their beloved machines if they ran out of space in their home (P6, P7), saw no future monetary value in keeping the machines (P1, P5), or if no one else wanted the machines as the owner approached the end of his or her life (P3, P4). These latter reasons for not keeping or repairing a machine have little to do with the physical traits of the machine; they are socially, financially and temporally specific reasons that relate to the owner's life stage, among other factors. Those reasons and factors are not within the control of the designer who initially makes the machine. What this suggests is that, much like the processes of breakdown and repair [218], designers cannot effectively script attachment ahead of time. And attempts to 'design [a] high strength of attachment' [182] into a device might be insufficient if we focus solely on the physical traits of the device. Although most of my participants were attached to their machines for the reasons outlined in Gegenbauer and Huang's extended Attachment Framework (i.e. histories, augmentation, engagement, perceived durability, earned functionality, perceived worth, and sufficiency) [76], the Framework does not—and cannot—account for a person's financial stability, space at home, social circle, or proximity to death, all of which ultimately influence attachment, preservation and repair of a digital device.

Teaching retrocomputing subjects

My C64 interviewees lamented how difficult it can be to learn about retrocomputing use, design, and repair nowadays, and these sentiments were also echoed in the online community forums I visited. This suggests there could be opportunities to incorporate topics related to retrocomputing and retrogaming devices into HCI education and research. Retrocomputing devices offer a uniquely constrained programming environment, in terms of the types of software that can be developed for and on their limited hardware; there is also a limited supply of replacement parts in the event of hardware failure. Designing with and for retro devices demands that a person negotiates with those unique material and digital constraints. These constraints could offer unique challenges for interaction designers who are often faced with rhetoric about limitless growth, complex systems design, and increasingly large sets of ‘big’ data. Moreover, as John Aycock, who teaches an ‘applied computer history’ course at the University of Calgary, explains “one critical reason why historical, constrained computing systems matter to contemporary students is that some techniques from old, constrained environments are still in use today” [11]. Indeed, legacy systems are a reality in many business environments [70], even though they may be increasingly uncommon. Equipping students with the skills to work on legacy systems might be useful for them and their future workplaces. John’s ‘constrained computing’ course appears to be one of the few contemporary examples of teaching retro digital technologies in university classrooms, and it is an exemplar of the types of course that interaction design or computing educators could offer.

4.5.3 Limitations

The most obvious limitation of this study—and the primary limitation raised by a reviewer of the version of this chapter that I submitted to DIS2016—is the number of participants I interviewed. If I had more time to dedicate to this research (i.e. if I had more time to establish connections with, and gain access to, the communities of retrocomputing repairers), I would have continued recruiting participants, developing this research, and attempting to draw parallels between the retrocomputing repairers in the C64 community and outside of it. Fortunately, I believe that I have found an appropriate solution to this particular limitation by complementing my primary data with considerable secondary data. Moreover, I also believe that my research was sufficiently thorough enough to offer groundwork for future research related to retrocomputing repair.

Beyond this limitation, though, are the limitations brought on by my choice to conduct this research using an interview-based approach. There are numerous other ways that I could have conducted this research. At one point, I considered ordering a Commodore 64 online and trying to repair it in my office at Lancaster University. Due to lack of funding to support this endeavour, I didn’t follow through with my idea. But this meant that, unlike in the case of HCI practices, I had no personal experience with retrocomputing repair upon which I could draw and reflect. Furthermore, I did not seek to remedy this gap in my knowledge by asking my participants to undertake a journal study, nor allowing me to sit-in on one of their repair sessions. These choices have almost certainly limited the depth of what I have been able to say and reflect upon in this chapter. Moreover, much like in the last chapter, I failed to overtly link this research to my emergent study on public policy and digital technologies. By this I mean, I failed to ask any of my interviewees about public policy—even just in terms of local electronics waste management practices—and what role it did or did not play in their practices. Future research could address many of these shortcomings and offer new insights to the academic community.

4.6 Summary

This chapter examined the social practices of a niche community of retrocomputing repairers, and linked their practices to the growing environmental footprint of digital technologies. In addition to the rich description of retrocomputing repair practices, this chapter offered several contributions to the SHCI community. Those contributions included identifying hitherto unexamined ways that the practice of retrocomputing device repair affects the environment (i.e. through the: fabrication of new parts, sharing of existing or original parts, creation of online support materials), and also by linking retrocomputing repair to existing HCI research. These contributions are summarised in Table 4.2.

Table 4.1 Summary of contributions

Contribution	From which findings or observations	Relevant to...	Intended outcome
Materials: the global sharing of retro materials carries an unknown environmental footprint	Participants' description of retro repair practices and my comparison with existing repair literature.	SHCI and HCI researchers	Consider mechanisms for measuring this unknown environmental footprint.
Materials: creating replacement parts (via 3D printing or other forms of hardware hacking) for retrocomputing devices carries an unknown environmental footprint			
Competences: knowledge-sharing using digital services carries an unknown environemtnal footprint			
Retrocomputing repair is distinct from other repair practices	Participants' description of retro repair practices and my comparison with repair literature.	SHCI researchers interested in sustainable social practices	Acknowledge the unique nature of retrocomputing repair; incorporate and address in future research.
Hardware that can be repaired: consider how to mitigate the temporally dynamic social and material factors influencing repair	P1, P3, P4, and P5's description of repair practices; observation that HCI literature on designing `for longevity' or `for repair' often does not address these temporal issues	SHCI, HCI, CSCW, ixD researchers studying or designing devices `for longevity' or `for repair'	Expand the focus of research to consider some of the materials, competences, and meanings that might be necessary to support device repair and longevity.
Community support systems: help establish or support device-specific retrocomputing communities	P1, P3, P4, and P5's description of repair practices; observation that few HCI, CSCW, IxD researchers appear to be engaged with device-specific retrocomputing communities	SHCI, HCI, CSCW, ixD researchers studying or designing devices `for longevity' or `for repair'	Expand the focus of research, and increase the likelihood that devices will achieve heirloom status.
Attachment to retro devices: attachment cannot be effectively scripted by designers	P1, P3, P4, and P5's description of repair practices; observations from HCI literature on attachment	SHCI, HCI, CSCW, ixD researchers studying or designing for device attachment	Reconsider the long-term effectiveness of the attachment framework.

End of Part I

In Part I, I used social practice theory to study the practices of HCI academics and retrocomputing repairers. While many of the HCI researchers worked to conceive of new digital products and services, the repairers actively worked to maintain their ageing digital products in the face of increasingly scarce resources. Their complex and varying practices influence the environmental footprint of digital technologies in distinct yet connected ways, which I explored in Chapters 3 and 4. At the end of each chapter, I included a summary table of my contributions, who they are relevant to, and what the intended outcome is from each contribution (see: 3.1 and 4.1).

Reflections on Part I

I enjoyed learning about and applying the Shove et al. [231] interpretation of practice theory, and I especially enjoyed reading the recent Hui et al. [119] volume on practice theory. As an outsider to practice theory, learning about and applying it was a delightful challenge. One thing that I struggled with was the lack of a clear and agreed upon structure for writing about practices. This lack of an established structure meant I made my structural choices based on practicality, rather than any other set of reasons (i.e. by that I mean, I chose to mirror the structure found in Shove et al. [231] because it offered me a template from which to work). I can already foresee there being challenges related to publishing my practice-focused research in HCI venues[12]. I don't mean for this to sound like I am calling for standardisation of practice theory texts, as that is not something I'd wish to see. Rather, it is merely an open lament; as an outsider writing for a largely technical audience, this is something I struggled to make sense of and address.

Another thing I struggled to make sense of and address was the sheer difference in scope and scale of my two studies. Although the analysis and write-up of my retrocomputing repair chapter was by no means easy, it felt like a laughably manageable project in comparison

[12] I will have to hope I get the "right" reviewers, not the ones—like I had on my original retrocomputing DIS submission—who take issue with qualitative interviews lasting different lengths of time.

with the HCI academic study. This caused me to endure a considerable period of writer's block. I was struggling to understand the difference until I started reading Morley's [173] and Nicolini's [179] chapters in *The Nexus of Practices*[119]. Reflecting on the concept of "largeness" [13] helped me realise that the difference between my retrocomputing repair community and HCI academic practitioner community studies was the scale and scope of my work. Perhaps this seems like it should have been obvious to me, but the "largeness" of academic practices, and of HCI academic practices specifically, were a surprise and a challenge for me. This realisation, much like my engagement with academic practice literature, likely arrived too late in my doctoral process; if I had more time, or if I were hoping to make a contribution to practice theory, I would want to spend a considerable amount of time writing about and reflecting upon the differences in scope and scale between my two studies.

[13]According to Hui et al., studying "largeness" involves "examining processes involved in the construction of large phenomena or elements of their composition or workings" [119, p.5]. Examples of studying largeness include "markets, governments, international coalitions, football leagues and world religions" [119, p.5]

Part II

Public Policies

On the tips of tongues,
In the SHCI field:
Public policy.

#PartIIHaiku #haiku

Overview of Part II

In Part II, I examine some of the ways that public policy, human-computer interaction (HCI), and environmental sustainability intersect. Chapter 5 offers a direct response to calls for the HCI community to engage with and inform public policy related to environmental sustainability, security, and justice [83, 139, 152, 232]. It draws on research that I conducted for Global Affairs Canada (GAC) and that I used to help inform—or at least attempt to inform—Canadian public policy. The chapter draws on my GAC research, but is targeted at an HCI audience; it examines climate change, "waste electrical and electronic equipment" (WEEE), and "green public procurement" (GPP) policies and evaluates how they could inform and be informed by the HCI community.

Climate change and waste,
And procurement matters, too.
Let’s embrace them all.

#ChapterFiveHaiku #haiku

Chapter 5

Environmental Public Policies and HCI

Portions of this chapter have been published [251, 256] or are in the process of being published [254]. This chapter expands upon those texts by using updated stories, describing the desk research more thoroughly, and shifting the focus of the discussion. See Appendix A for more details about publications contributing to this thesis.

5.1 Introduction

Since his inauguration on 20 January 2017—mere months ago—Donald Trump has had a considerable impact on national and foreign policy in the United States of America. Executive Order 13769, colloquially referred to as Trump's "Muslim Ban", offered an early and visceral sign of the policy changes to come. The Trump Administration quickly muzzled federal scientists, and replaced—or indicated their intention to replace—climate change, wildlife management, and health care policies. Meanwhile, in Canada, Justin Trudeau's election in 2015 brought about swift and considerable change to his country's national and foreign policies, seeking to undo some of the restrictive measures put in place during Stephen Harper's decade in power. Some of Trudeau's early changes included: permitting federal scientists to speak freely with the media and at conferences, funding international abortion services again, and renewing Canada's commitment to peacekeeping. Trudeau's changes—and those of the Trump Administration—indicate how governmental election cycles can affect public policies.

Public policies influence what we can do, where, when and how we can pursue certain services or activities, and who is involved along the way. Whether we're aware of them or not, public policies are everywhere. They are 'ubiquitous'—much like our digital technologies—

and they quietly shape many aspects of our daily lives. For example, public policies influence the environmental footprint of our digital technologies by: specifying how natural resource extraction companies are allowed to operate locally and globally; defining the material and chemical composition of digital technologies, and; dictating the availability of e-waste recycling facilities that process our end-of-life digital technologies [7, 134]. Members of the HCI community have been engaging with public policy for decades, both directly and indirectly (e.g. [45, 92, 152]). Several recent publications have included open calls for the HCI community to engage with and inform public policy related to environmental sustainability, security, and justice [83, 139, 152, 232]. This chapter offers a direct response to those calls.

In this chapter, I explore some of the ways that public policy, human-computer interaction (HCI), and environmental sustainability intersect. I focus on three environmental public policy domains: climate change, "waste electrical and electronic equipment" (WEEE), and "green public procurement" (GPP) policies. Other environmental public policy topics will no doubt be of interest and relevance to the HCI community (e.g. energy and food policies). However, I have selected these three policy domains as a starting point for exploration because they have been discussed at length by policy research communities, and they relate directly to Blevis' original sustainable interaction design principles [21]. To give structure to this discussion, I introduce how these policies operate at different scales[1], and then focus on how they could inform and be informed by the work of the HCI community.

5.2 Desk research: timeline and methods

This chapter is based on desk research that I conducted for nearly thirteen months (February 2016 to March 2017). It began in February 2016 when Global Affairs Canada (GAC) released a call for their inaugural International Policy Ideas Challenge (IPIC). The competition was designed to help GAC identify innovative and concrete solutions to emerging "international policy challenges", including:

> 1) Strengthening Canada's relations with North American partners, particularly the United States.
> 2) Adopting a North American approach to climate change and clean energy.
> 3) Re-energizing Canadian diplomacy and leadership in managing complex international crises.
> 4) Partnering with non-state actors in addressing global governance challenges.

[1] By 'different scales', I mean to address the 'domestic' (e.g. municipal or national) and 'international' (e.g. United Nations [UN] or African Union [AU]) policy scales identified by Nathan and Friedman [178].

5) Making better use of data and technology in the development of international policy [80].

I immediately saw connections across all five challenges, as well as with my recent work in HCI. I began looking through GAC's online policy documents, as well as recent news stories they had posted about the priorities listed for the competition. I also looked through GAC's project partners and locations, and began reviewing academic and non-academic publications about the environmental costs of digital technologies. Reading and reviewing these websites, news stories, policy documents, and publications marked the beginning of my secondary data collection for this chapter.

After three weeks of reading diverse materials, making notes, and preparing an argument, I wrote a plain language research proposal focused on the entwined nature of digital technologies, environmental change, and public policy. I submitted it to the IPIC on 16 March 2016 and, on 4 May 2016—24 hours before I was scheduled to fly to CHI'16—I received confirmation that I made it through to the final round of the competition. In those 24 hours before flying to CHI, I needed to prepare a supplementary video and update my work plan. I quickly revised my proposal's text, wrote a script for my video, filmed my video, and submitted the updated documentation (including a link to a private YouTube video [252]) to the competition organisers. On 31 May 2016, I received notification that I was one of five winners of the IPIC, so I set out to write a research and policy brief focused on the digital technologies, public policy, and environmental change.

To write the research and policy brief, I began by conducting a literature survey of recent [i.e. in the past 10 years] academic publications in databases and journals focused on policy, management, computer science, and environmental sciences research, including: GreenFile, JSTOR, Environment and Planning, Nature, and the ACM's Digital Library. At first, I used the search terms: "green computing", "life-cycle assessment", "e-waste", "cradle-to-grave", "circular economy", and "electronics manufacturing". I chose these search terms based on my existing familiarity with sustainable computing discourses. My search led me to read, analyse, and make notes on *hundreds* of papers from a variety of disciplines. To structure my notes, I began grouping my readings according to the lifecycle stage(s) that they addressed (i.e. beginning of life, in-use, and end of life). This reading, analysis and note-making phase allowed me to identify a variety of policy domains that influenced the environmental footprint of digital technologies, including: climate change, energy, waste management, procurement, innovation, water, mining, open data, project management, and indigenous peoples policies. These policy domains are diverse in terms of the actors involved in shaping them and in terms of the industries they address. With all of this information at hand, I began writing a literature review related to the environmental footprint of digital technologies [2]. While writing the literature review, I also began reviewing public policies listed on the Government of Canada's (GoC) [85] and Global Affairs Canada's [81] websites. I did this because my GAC policy brief needed to include a list of specific policy recommendations. To conceive of and produce my list of recommendations ([251, p. 16]), I read as much as I could about GAC's and the GoC's policies on project management, procurement, open data, waste management, and climate change.

In mid-August, I began parlaying much of the research I conducted for GAC into an ACM SIGCHI conference paper [256] and an SHCI-focused book chapter [254]. These outputs represented a considerable shift in the audience of my research, so I needed to familiarise myself with the public policy landscape in HCI. I spent much of August, September, and October reading about HCI researchers working with public policy, and connecting their research to the GAC and GoC policies I had just read about for the GAC award. As I learned about the two 'frameworks' for policy analysis offered by Lazar et al. [152, p. 74] and Nathan and Friedman [178][3], I began to think about how I could use those frameworks and the aforementioned public policies I had encountered to speak to the HCI community. Reflecting on Nathan and Friedmans' "levels" of policy analysis led me to conduct a separate, complementary review of policies. From late October 2016 to March 2017, I spent time reviewing new and additional research related to HCI, public policy, and the environmental footprint of digital technologies. As I noted gaps in my knowledge about specific levels of policy, I began seeking copies of public policies posted openly on cities', federal governments', and international organisations' websites. I read several European Union and African Union policies, city-level government policies, and federal government policies (especially related to e-waste) to complement the knowledge that I had acquired from reviewing academic literature.

5.2.1 Presenting my findings: policy analysis for HCI

Although public policy analysis has well-defined methods and approaches for presenting findings, I intentionally do not draw on those methods in this chapter. That is because, as mentioned in Chapter 2, most established public policy analysis methods do not target the HCI community—*my* audience[4]. I have chosen to fuse Lazar et al. [152, p. 74] with Nathan and Friedman [178] because they are already familiar to the HCI community (e.g.

[2]Much of that literature review is included in Chapter 2 of this thesis and in the final version of the policy brief that I submitted to GAC in August 2016 [251]

[3]These policy frameworks are described in greater detail in Chapter 2 and again below.

[4]Reminder: there is currently no established, sufficiently complex process for conducting public policy analysis directed at the HCI community.

[151, 152, 178]) and they address different levels of complexity related to public policy. For those who are not familiar with Lazar et al. [152, p. 74] or Nathan and Friedman [178], I now present an overview of what they are and why I have attempted to fuse them.

In their recent monograph, Lazar et al. outlined two compelling reasons for the HCI community to engage with public policy: “first, public policies can influence how HCI researchers and practitioners perform their work. Second, the HCI community can inform public policy by providing expertise, taking part in the development of policy, and researching the impact of various policies related to HCI” [152, pp. 74]. In addition to explaining why and how HCI researchers could engage with public policy, I believe these two reasons offer loose guidelines for how to usefully communicate about public policy to HCI audiences. Unfortunately, the reasons noted by Lazar et al. are so broad that they offer little guidance for how to specifically address and explore the complexities of multiple public policy domains. As a result, I draw on the notion of policy ‘scales’ identified by Nathan and Friedman [178] to narrow the focus of policy analysis in HCI. In particular, I draw on two of Nathan and Friedman’s policy scales: the ’domestic’ (e.g. municipal or national) and ’international’ (e.g. United Nations [UN] or African Union [AU]) policy scales [178]. These scales help to narrow the scope of analysis into manageable—if still incredibly large and complex—niches.

By fusing Lazar et al. [152] with Nathan and Friedman [178], I turn two separate-yet-related and familiar conceptual frameworks into a mechanism through which to analyse public policies for an HCI audience. I consider this fusion to be an adequate, if nascent, solution for the lack of clear public policy analysis structures in HCI[5].

In the following sections, my fusion of Lazar et al. [ibid., p. 74] with Nathan and Friedman [ibid.] informs the structure and narrative format of my text. I begin by describing each of the individual environmental public policy domains (i.e climate change, WEEE, and GPP policies) in terms related to Nathan and Friedman’s ’domestic’ and ’international’ policy scales [ibid.]. These descriptive introductions provide background information for the subsequent anaytical contributions, which are framed in terms of the "two reasons" identified by Lazar et al. (i.e. public policy informing HCI, and HCI informing public policy) [152, p. 74]. By structuring the narrative this way, I hope to be able to thoroughly describe the complexities of public policy while demonstrating its specific relevance to the HCI community[6].

[5]I recognise that my approach is merely one of many possible solutions, most of which have not been proposed or adopted yet by the HCI community. As I discuss in the conclusion, I believe that articulating public policy analysis for HCI audiences is one of the future areas of work that I could pursue.

[6]As mentioned in Chapter 2, though, I believe that this is an avenue for future debate and discussion within the HCI community.

5.3 Environmental public policies and HCI

Environmental public policy is a broad group of policies that attempt to address environmental issues, including energy production and consumption, non-renewable resource extraction, biodiversity, water and food security, and 'green' economic growth [62]. These policies range in scope and scale from locally specified waste management policies to nationally set objectives for reducing greenhouse gas emissions and internationally negotiated methods for combating climate change. In this section, I describe three sets of environmental public policies (climate change, GPP, and WEEE policies), how they operate at different scales, and how they could inform or be informed by the work of the HCI community.

5.3.1 Climate Change policies

Climate change is one of the most pressing challenges facing humanity; its effects are already influencing food, water, health, political and economic security worldwide [125]. Scientists and activists have been raising concerns about climate change for over three decades (e.g. [84, 167]), and public policy responses throughout that time have varied considerably. When the Conference of the Parties (COP 22) took place in Marrakech in 2016, there were "854 climate change laws and policies, rising from only 54 laws and policies in 1997, and 426 in 2009 when the Copenhagen Accord was signed" [86]. With such a large quantity of laws and policies, it is no surprise that many cities, national governments, and intergovernmental organisations have designed unique policy programs and legal frameworks to address climate change [94, 125, 221, 230, 265].

At the international scale, the United Nations has had a longstanding commitment to addressing the effects of climate change [265]. The United Nations Framework Convention on Climate Change (UNFCCC) was initiated in 1992 and led to the creation and adoption of the 1997 Kyoto Protocol, which legally required its signatories to meet certain emission reduction targets. [94, 265]. This was more recently replaced by the 2015 Paris Agreement, which was adopted in December 2015. According to the UNFCCC's website,

> "The Paris Agreement seeks to accelerate and intensify the actions and investment needed for a sustainable low carbon future. Its central aim is to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. The Agreement also aims to strengthen the ability of countries to deal with the impacts of climate change." [265]

Although the United Nations does not have any specific policies to help its member states meet these targets, it does support its members in designing climate change adaptation and mitigation strategies [265]. More importantly, its various agreements and strategies have influenced regional policy development related to climate change. For example, in the European Union, "the EU climate and energy package was adopted in 2009 to implement the 20-20-20 targets endorsed by EU leaders in 2007: by 2020 there should be a 20% reduction of GHG emissions compared with 1990, a 20% share of renewables in EU energy consumption, and energy improvement by 20%" [65]. These 20-20-20 targets were directly influenced by the Kyoto Protocol agreements, and have been supported through the design and development of EU-level policies related to energy consumption, renewable energy development, automobile design, manufacturing industry requirements, and landfill management [65, 135, 278].

At the domestic scale in Europe, the 20-20-20 targets were implemented using a variety of policies to meet a variety of country-specific emissions reductions targets [135, 221]. For example, in the United Kingdom, a centre-left government passed the 2008 Climate Change Act, which included a series of sector-specfic policies related to decarbonising the economy [161, 221]. Meanwhile, Austria's government relied on a combination of "high incentives and subsidies; moderate education and outreach, financial and regulatory instruments, and framework policies; and low public investments, tradeable permits, and voluntary agreements" [221]. Nearly every national government in the EU adopted their own unique policy program to address climate change and, due to the global scale of climate change, those national policies affected city-level policies [147]. Public policy responses at the domestic scale elsewhere in the world varied considerably, too. New Zealand, Canada, the United States of America, South Korea, China, and dozens of other countries have set national greenhouse gas emissions reduction targets [78, 94, 126, 221].

Reducing CO_2 emissions is by no means the only issue championed by climate change policies. Sector-specific policies related to deforestation, water and land management, agriculture, and mining also exist at the domestic and international scales [123, 124, 126]. Many of these policies attempt to help economies and people mitigate or adapt to the ecosystem-level effects of climate change. The Intergovernmental Panel on Climate Change (IPCC) produces a series of detailed, peer-reviewed reports that offer an overview of existing, as well as future, adaptation and mitigation needs and strategies (e.g. [123, 124, 126]). For example, in their recent report on Africa, they explain that "legislative and policy frameworks for adaptation [in Africa] remain fragmented, adaptation policy approaches seldom take into account realities in the political and institutional spheres, and national policies are often at odds with autonomous local adaptation strategies, which can act as a barrier to adaptation, especially where cultural, traditional, and context-specific factors are ignored" [123].

Climate change policy informing HCI

Climate change policies have become widespread and almost certainly should inform HCI research in some capacity of another, if they haven't already. Every region, country, city, and scale that HCI research is conducted in will be influenced by some form of climate change policy. Although no documentation explicitly states that climate change policy has directly influenced the HCI community, the emergence of the sustainable HCI community runs in tandem with the growth in climate change policy adoption worldwide. Some HCI research projects focused on behaviour change technologies, energy and data demand, and sustainable social practices also appear to align with climate change policy goals (e.g. [29, 71, 101, 140, 201, 203]). However, no clear evidence suggests that work undertaken by HCI researchers and practitioners is a direct response to any governmental or intergovernmental climate change policies, projects, targets or goals.

HCI informing climate change policy

Again, there is no evidence to suggest that the HCI community has attempted to influence—or has successfully influenced—climate change policies. However, the HCI community has produced a considerable body of work exploring how social practices and digital technologies affect energy consumption in the home and workplace, as well as through distributed digital service design [14, 99, 101, 204]. The HCI community has also learned many lessons from persuasive technology projects [29, 71, 140, 201, 203]. These findings appear to have gone largely unnoticed by environmental public policymakers, whose efforts remain focused on behavioural change technologies [230], especially related to energy consumption (e.g. [47]). This focus opens a series of opportunities for the HCI community to share their expertise with policymakers, and possibly influence climate change policies. Moreover, the HCI community could engage with the design and development of spatial planning software packages, which help policymakers think about and design climate change adaptation and mitigation projects [147].

5.3.2 Waste Electrical and Electronic Equipment (WEEE) public policies

Throughout the 1990s and early 2000s, countless news stories and research projects exposed the global environmental and human health damage caused by the export of e-waste. Many businesses in the Global North had been shipping their hazardous WEEE to countries in the Global South, where the highly toxic materials were being dumped in open pits or processed in high-risk informal waste sites [156, 223, 274]. As awareness of these issues grew, so, too, did public and political outrage. Governmental and intergovernmental organisations began discussing what sort of policies could be adopted at the domestic and international scale.

At the international scale, the UN took the lead. It proposed amendments to the 1989 Basel Convention [224] and formally recognised WEEE as a priority issue in 2002 at Conference of the Parties (COP) [225]. Four years later, the COP adopted the Nairobi Declaration and "called for more structured and enhanced efforts towards achieving global solutions for management of e-waste problems" [225]. Alongside these developments, several regional international policy responses also emerged. The EU adopted a directive on waste electrical and electronic equipment ('WEEE Directive', Directive 2002/96/EC) and a directive restricting the use of certain hazardous substances in electrical and electronic equipment ('RoHS Directive', Directive 2002/95/EC). Twelve members from the Organisation of African Unity (now the AU) negotiated the Bamako Convention in 1991, which completely prohibited the import of hazardous and radioactive waste [225]. Meanwhile, in Asia, Oceania, South America, and North America, no region-wide international policies or conventions were adopted to directly address WEEE. Despite this latter lack of responses at the international scale, many countries around the world responded with diverse regulations, policies, infrastructures and partnerships at the domestic scale [9, 57, 103, 187, 196, 240, 274].

In Canada, the responsibilities for managing and processing e-waste have been split between provincial and municipal governments via extended producer responsibility (EPR) and product stewardship programs [63, 187]. These programs share WEEE costs and responsibilities between manufacturers and consumers, as well as public sector and private sector recycling facilities. Similarly, India's government recently adopted a set of extended producer responsibility rules, which took effect on 1 October 2016 and set out how manufacturers, consumers, and municipal organisations must collect and manage e-waste [57, 30]. The Chinese government has also established many rules, regulations, policies, and recycling centres across China to support WEEE processing. It also made the import of WEEE illegal [187]. In the EU, many member states implemented their own policies, laws and systems at the domestic scale in response to the WEEE and RoHS Directives. These policies included mandatory WEEE collection schemes for electronics retailers, WEEE recycling codes of practice, and non-profit organisations to manage WEEE recycling and take-back schemes [187]. In the AU, many countries have also responded in diverse ways. Kenya established a public-private partnership between the government and members of the ICT community to create the East Africa Compliant Recycling facility in 2013 [131]. South Africa passed legislation that guides the management of hazardous substances and waste, and the country is home to many formal WEEE processing facilities [58, 187]. In contrast, Benin, Senegal, and Uganda are reported to lack specific policies, legislation and infrastructure to deal with WEEE [187, 225, 238].

Despite these widespread and heterogeneous public policy, regulatory, and infrastructural interventions at the domestic and international scales, many global WEEE problems persist. WEEE continues to be the fastest growing waste stream globally, and it continues to flow from the Global North to the Global South [Lepawsky 2014; Sthiannopkao and Wong 2013]. Large, informal, and often illegal WEEE "dumping grounds" have developed in India, China, Ghana, and Nigeria. The practices of recycling WEEE vary in those informal sites, but they all cause similar damage to air quality, water sources, and human health [196, 187, 225, 238, 240]. Many countries report that residents—including those who work in the dumping grounds—have little awareness of the risks associated with mishandling e-waste [57, 196, 225, 238]. Even when they are aware of the risks, people working in the informal dumping grounds often have few or no other employment opportunities available to them [196, 225, 238].

WEEE policy informing HCI

WEEE policies have already directly influenced the material composition of hardware that we use in HCI. The EU's 'RoHS Directive' required "heavy metals such as lead, mercury, cadmium, and hexavalent chromium and flame retardants such as polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) to be substituted by safer alternatives" [66], and the hardware designed to meet these requirements started selling worldwide. Moreover, WEEE public policy has had a direct influence on if, how, and when people store their end-of-life electronics [9, 57]. Dozens of non-HCI studies have found that policy variations can "lead to an indifferent disposer who, in all likelihood, might be tempted to illegally dump [their] used products or perpetually store them" [57]. Several HCI studies have examined why and how people store, repair, and throw away their technologies [182, 212]; although WEEE policies were not specifically addressed in those studies, policy variations might have unknowingly influenced the practices of participants.

HCI informing WEEE policy

There is no evidence to suggest that HCI research has informed any WEEE policies. However, many HCI studies could be of interest to policymakers looking to address the persistent failures of WEEE policies [9, 156, 187]. In particular, studies about repair practices and cultures (e.g. [128, 219, 247]), as well as many of the studies about obsolescence [212] [Remy and Huang 2015], might offer policymakers new insights about the social practices affecting their WEEE policies, systems and regulations. Moreover, some policymakers who work at the international scale favour the widespread adoption of digital technologies; they might be unaware of the health and environmental issues associated with poor WEEE management. In these cases, members of the HCI community—especially the HCI4D community—could use their interdisciplinary expertise to help inform international WEEE and sustainable development policies (e.g. [19, 35, 67]9).

5.3.3 Green Public Procurement (GPP) Policies

Governments have a great deal of purchasing power they can use to influence the design, production, and consumption of products and services worldwide [26, 95, 250]. They do this through their procurement policies, which they apply whenever they purchase goods, services, and other public works (e.g. support infrastructure). In the case of digital technologies, procurement policies often work in tandem with governmental "digital asset management" programs, which dictate how often digital technologies need to be replaced and what types of technologies should be purchased in their place [10]. With digital technologies entering and reshaping the workplace in the past four decades, many levels of government have adopted sustainable or green procurement policies (GPP) that attempt to integrate broader social and environmental concerns into the purchasing process [26]. The scope and structure of these GPPs vary considerably around the world, but they are generally seen as important tools through which governments can stimulate eco-innovation [17, 26, 95, 250]. This eco-innovation has extended to ICTs, with some governments adopting "green ICT procurement" policies. Like most policies, green ICT procurement policies take different forms around the world and involve the use of various governance tools [10].

Few examples of GPPs appear to exist at the international scale. The sole exception appears to be the international "Sustainable Public Procurement Program" launched by the UN Environment Program (UNEP) in 2014 [264]. But many examples of GPPs exist at the domestic scale. For example, in the United States, green ICT procurement policies were first announced in 2007 when George W. Bush issued Executive Order (EO) 13423 requiring all federal agencies to use the Electronic Product Environmental Assessment Tool (EPEAT). Although President Obama replaced EO 13423 with EO 13693, which now merely asks federal agencies to "prefer" environmentally sustainable electronics [64], EPEAT remains a popular tool within many US federal departments. EPEAT offers third-party assessments of electronic devices. "EPEAT registered products must meet environmental performance criteria that address: materials selection, design for product longevity, reuse and recycling, energy conservation, end-of-life management and corporate performance" [64]. Dozens of governments use EPEAT to meet their green ICT procurement needs, including the Government of Canada, the Australian Government, the Government of the City and County of San Francisco, the Government of New Zealand, Warwickshire County Council (in the UK), and the Hainan Siyuan Province's government [88].

However, many governments do not use EPEAT. Some have their own unique rules, partnerships, and environmental assessment tools. In Korea, the government has a long-established "Korea Eco-label" for many products, including ICT products, and "the 'Public Procurement Minimum Green Condition Product' program went into effect to encourage green technology development" [136]. The Malaysian Government recently adopted a Green IT Guideline for public sector procurement [133]. While there is no specific labeling system or assessment mechanism attached to the guideline, it requires "low energy consumption, minimal use of toxic material and some other environmentally related product features for ICT products procured" by the public sector [133, p. 11]. In the UK, the government has a "Greening Government: ICT Strategy" that addresses the procurement, use, and disposal or decommissioning of computer applications, data centres and cloud computing services, end user devices and peripherals, as well as public service network infrastructures [106]. The strategy is supported by a set of mandatory and voluntary buying standards which explain that publicly procured ICTs must adhere to the EU's Energy Efficiency Directive 2012/27/EU and be built in accordance with several international standards (e.g. ISO 11469 and ISO 9296) [105].

Despite the growing prevalence of GPPs, governments around the world have documented many barriers to implementation and adoption. For example, Beláustegui [2011] identified a list of eleven barriers influencing the adoption of green procurement practices in Latin America, including a lack of: information and knowledge on sustainable public procurement, sufficient offers from suppliers, legislation or internal rules, interest and commitment from procurement system users, and general regard for the environment [17]. These barriers were found in studies from Italy [250], Korea [136], Germany [95], and over a dozen other countries [26]. However, the international "Sustainable Public Procurement Program" launched in 2014 by the United Nations Environment Program (UNEP) aims to address some of these barriers [264].

GPP policy informing HCI

GPPs, and the environmental performance requirements they helped establish, have influenced the material composition and energy consumption of technologies used and studied by the HCI community studies, especially those working with governmental organisations.

Despite this influence, GPPs appear to be absent from HCI research. To date, there have been no direct studies—or even acknowledgements—of GPPs, green ICT ISOs (e.g. ISO 11469), nor EPEAT. However, many of Belvis' initial Sustainable Interaction Design (SID) principles [21] appear to align with the performance criteria set for EPEAT certified products (e.g. they "must meet environmental performance criteria that address: materials selection, design for product longevity, reuse and recycling, energy conservation, end-of-life management and corporate performance" [64]) and there may be opportunities to develop SID further by looking at GPPs, Green ICT ISOs, and EPEAT.

HCI informing GPP policy

Many Green ICT procurement policies focus primarily on hardware procurement, excluding software or digital service procurement. This oversight could be an area where the HCI community could provide expertise [204]. We have access to a broad body of multidisciplinary work that examines the environmental effects of hardware, software, and digital services, and that work could be used to inform narrowly scoped Green ICT procurement policies. Moreover, GPPs have only recently attracted the attention of scholars [26], and few studies of Green ICT procurement specifically exist. The HCI community could undertake research to help governments improve their existing Green ICT procurement policies (e.g. by rethinking their asset management programs or studying how to address the paucity of interest noted by [17]).

5.4 Discussion

Lazar et al. stated that "members of the HCI community need to engage, on a regular basis, with regulatory processes, at the regional, national, and multinational levels" [152, p. 126]. I have demonstrated that this statement extends to environmentally focused regulatory processes, too. Environmental public policies are rich and complex, much like the issues they are attempting to address. Governments have drafted and implemented diverse rules, standards, guidelines, laws and strategies to address climate change, WEEE, and green procurement at the domestic and international scales. And these policies are relevant to the HCI community—especially to those members of the HCI community who are concerned about the environmental footprint of their designs and devices. In this chapter, I demonstrated the relevance of three EPPs to the HCI community by analysing how they might inform and be informed by HCI research.

For HCI researchers interested in engaging with environmental public policy, we could begin by establishing relationships with local and national government departments focused on the environment, or with environmentally focused non-profit and for-profit organisations (e.g., the Green Electronics Council, the International Organization for Standardization [ISO], local WEEE recycling facilities). We could join unions, launch environmentally focused cooperatives, consult with businesses who wish to reduce their carbon footprint (e.g. [204]), write to politicians, or join protest movements. We could partner with environmental policy scholars who may already be working on relevant studies, or with scholars from other disciplines who have engaged with environmental public policy (e.g. [230]) or tangentially relevant policy domains (e.g. [90]). While establishing these relationships, we will likely need to consistently communicate our research findings to these communities and organisations, and incorporate their research findings into our own work. This is all well within the capacities and capabilities of members of the HCI community.

5.4.1 Limitations

The limitations of this research are rooted in my survey methodology, and the scope of the content I attempted to succinctly summarise. Public policy is an immense field of research and activity. Reading and condensing that text, then translating that into language that is accessible to non-specialists is and was a challenge. I may not have succeeded in meeting that challenge perfectly; I can only hope that my existing publications based on this work—accepted for and by the HCI community—indicate I have done adequate work. I also believe that the lack of an established public policy analysis framework for HCI researchers made the task of communicating about EPP difficult; as a result, my fusion of Lazar et al. [152] with Nathan and Friedman [178] may also be a limitation of this research. Indeed, as Samantha MacDonald rightly pointed out to me at LIMITS'18, this fusion—as well as my broader research on public policy and HCI—fails to examine how HCI *currently* influences public policy. This limitation indicates a need for a broader conversation within the HCI community about how best to write about and engage with public policy (if there even is such a thing as a "best" way to do so).

Beyond these limitations, my analysis of how EPPs relate to HCI research is also limited by 1) my own familiarity with the broad corpus of research that is produced by the HCI community, and 2) the content of HCI papers. There could be other research projects that I am unfamiliar with but that relate to climate change, WEEE, and GPP policies. There could also be more explicit links between EPPs and HCI research, but they might not have been stated in publications due to the lack of perceived value within the HCI community of engaging with public policies [152]. By choosing to use a survey methodology, and choosing not to pursue additional insights through qualitative interviews, my research is limited by the content of the publications that I encountered, read, and interpreted. In short, my interpretive lens for this work is one of its limitations. Future research could address these limitations by interviewing HCI academics about public policy, by hosting a workshop for public policymakers and HCI academics, or through other means.

5.5 Conclusion

This chapter has explored some of the ways that public policy, HCI, and environmental sustainability intersect and identified new avenues of enquiry for HCI researchers. Drawing on a fusion of Lazar et al. [152] and Nathan and Friedman's 'domestic' and 'international' policy scales [178], I have described how climate change, WEEE, and GPP policies could inform and be informed by HCI research. By conducting this analysis, including it in my thesis, and publishing it to HCI and public policy audiences [251, 254, 256], I have achieved several outcomes. First and foremost, I have met my initial aim, listed in Chapter 1, to "conduct a policy survey to help guide action within the HCI community and specifically for HCI researchers who wish to influence environmental public policies related to digital technologies". In doing so, I have also responded directly to calls from members of the SHCI community, who asked for this type of research to take place [83, 139, 152, 232]. I believe this has given HCI researchers a glimpse into the complexity and diversity of global environmental public policies, and how they might contribute to that space.

The contributions from this chapter are summarised in Table 5.1.

Table 5.1 Summary of contributions

Contribution	Relevant to...	Intended outcome
Development and use of a potential "public policy analysis for HCI audiences" framework.	HCI researchers interested in public policy.	Demonstrate how my fusion of Lazar et al. with Nathan and Friedman could be used. Start a conversation about how to usefully analyse public policy for HCI audiences.
Description of climate change, WEEE, and GPP policies in terms relevant to an HCI audience.	All HCI researchers, especially those interested in public policy.	HCI researchers get a glimpse of the complexity and diversity of global climate change, WEEE, and GPP policies.
Analysis and summary of how HCI research might have been informed by, and might contribute to, climate change, WEEE, and GPP policies.	All HCI researchers, especially those interested in public policy.	HCI reseachers see how their work is or could be connected to climate change, WEEE, and GPP policies. HCI researchers actively engage with climate change, WEEE, and GPP policies. Further debate and discussion about HCI and EPP.

End of Part II

In Part II, I examined some of the ways that public policy, HCI, and environmental sustainability intersect. Public policies directly influence the environmental footprint of digital technologies, and my research has highlighted how a subset of environmental public policies relates to HCI. Specifically, I examined three types of environmental public policy (climate change, WEEE, and GPP policies) and analysed how these diverse, dynamic policies could inform or be informed by the HCI community. At the end of Chapter 5, I included a summary table of my contributions, who they are relevant to, and what the intended outcome is from each contribution (see: 5.1).

Reflections on Part II

When I submitted my upgrade panel documents, I had planned for this Part of my thesis to feature and expansion and further exploration of design fiction (e.g. [255]). When I won the GAC IPIC award and realised the considerable gap in HCI knowledge related to public policy, this Part changed entirely. I'm happy it did. Having worked in government and studied public policy before coming to HighWire, I really enjoyed re-immersing myself in the messy world of public policy and public administration. I even got to continue applying my version of design fiction whilst engaging with public policy (see: Appendix B in [251]). I hope to continue engaging with this complex space in the future. Of course, I encountered challenges during this phase of research, mostly around trying to ascertain what would be most interesting and relevant to two very different audiences: the public administrators at GAC and the (limited number of?) people interested in EPP in the HCI community. But that only encouraged me to reconnect with my pre-HighWire media and communications training. This was arguably my favourite phase of research, as it forced me to fuse my skills and interests in ways I had not previously managed to do. I look forward to pursuing similar work in the future.

It’s the conclusion!
I revisit all my work,
And look to what’s next.

#ConclusionHaiku #haiku

Chapter 6

Thesis Conclusion

Digital technologies and services affect the earth's biophysical systems. I have spent much of the past four years at Lancaster University learning about those effects, and studying some of the social practices and public policies that influence those effects. In this chapter, I conclude my thesis by revisiting the research aims and objects I set out at the beginning. I summarise my findings and contributions to academic and non-academic knowledge, discuss some avenues for future academic work, and close by reflecting on my personal aims, objectives, and future.

6.1 Revisiting my research aims and objectives

At the outset, I stated that this thesis aimed "to discuss and analyse some of the social practices and public policies that influence the environmental footprint of digital technologies." I believe I have met that aim in every chapter of this thesis, as well as in my publications, public presentations, and social media posts. I have done so by delivering three unique chapters that address the three unique objectives I laid out for this thesis, which were to:

> 1) use social practice theory and qualitative methods to analyse academic HCI practices (chapter 3).
> 2) use social practice theory and qualitative methods to analyse the repair practices of retrocomputing enthusiasts (chapter 4).
> 3) conduct a policy survey to identify which environmental public policies affect the environmental footprint of digital technologies, and link those policies to the research conducted by the SHCI community (chapter five).

6.2 Contributions to academic knowledge

Each chapter contained its own set of contributions to academic knowledge. In Chapter 3, I noted how certain elements and characteristics of HCI academic practice contribute to the environmental footprint of digital technologies in ways that are currently unmeasured. Specifically, I noted that the:

- Global creation and sharing of hardware, software, educational materials, and academic publications carries an unknown environmental footprint; HCI academics do not appear to track this. *(section: materials)*
- Infrastructure to support HCI academics often carries an unknown environmental footprint; universities might have the data, but it is not necessarily clearly communicated to or known by academics. *(section: materials)*
- Academic knowledge-sharing and knowledge-preservation that relies on digital services carries an unknown environmental footprint. *(section: competences)*
- Academic and non-academic conferences carry an unknown environmental footprint, which professionals and organisers do not appear to calculate or share. *(section: careers)*
- Global movement of HCI academics throughout their careers carries an unknown environmental footprint. *(section: careers)*

These issues all contribute to the embodied carbon of our digital technologies in unclear and non-linear ways. This makes them relevant to SHCI and HCI researchers broadly, and especially for those interested in evaluating sustainable interaction design [210]. By highlighting these admittedly complex gaps in our knowledge, my research has contributed a set of new directions for evaluation- and measurement-focused researchers to consider. By highlighting these issues, my research has also contributed a set of insights upon which reflexive, environmentally minded HCI and SHCI researchers could reflect. We, as members of the HCI community, could work on solutions to the issues my research has highlighted, or at the very least discuss what could be done about them.

In Chapter 4, I undertook a unique study of retrocomputing repair practices and also noted how certain elements and characteristics of those repair practices relate to the environmental footprint of digital technologies. Specifically, I noted that the:

- Global sharing of retro materials carries an unknown environmental footprint. *(section: materials)*
- Creation of replacement parts (via 3D printing or other forms of hardware hacking) for retrocomputing devices carries an unknown environmental footprint.

(section: materials)
• Contemporary digital knowledge-sharing tools and services carry an unknown environmental footprint. *(section: materials)*
• Practice of retrocomputing repair is distinct from other repair practices. *(section: discussion)*
• Repair of hardware is temporally dynamic, due to social, economic, and material factors that are well outside of the control of designers. *(section: discussion)*
• Device-specific community support systems appear to influence the repairability of retrocomputing devices, and that there might be space for HCI researchers to help establish or support device-specific retrocomputing communities.*(section: discussion)*
• Attachment cannot be effectively scripted by designers.*(section: discussion)*

The first three issues contribute to the embodied carbon of our digital technologies in unclear and non-linear ways. This makes them relevant to SHCI and HCI researchers broadly, and especially for those interested in evaluating sustainable interaction design [210] or understanding the “sustainability” of heirloom devices (e.g. [21, 77, 182, 212]). The remaining issues that I noted were meant to highlight some of the unique dimensions of retrocomputing repair practices, which will hopefully be used to expand the focus of future SHCI and HCI research.

In Chapter 5, I described three environmental public policy domains that influence the environmental footprint of digital technologies, as well as how they might inform or be informed by HCI research. Specifically, I:

• Developed and used a potential "public policy analysis for HCI audiences" framework.*(section: EPPs)*
• Described climate change, WEEE, and GPP policies in terms relevant to an HCI audience.*(section: EPPs)*
• Analysed and summarised how HCI research might have been informed by, and might contribute to, climate change, WEEE, and GPP policies.*(section: EPPs)*

This chapter demonstrated how my fusion of Lazar et al.[152] with Nathan and Friedman [178] could be applied, which I hope will spark a conversation within HCI about how to usefully analyse public policy for HCI audiences. This chapter also offered HCI researchers a glimpse of the complexity and diversity of global climate change, WEEE, and GPP policies, with the intent of helping HCI researchers see how their work is or could be connected to climate change, WEEE, and GPP policies. I highlighted how and where these environmentally focused public policies may have already indirectly influenced the work of the HCI community, and through this I hope to have demonstrated the value of engaging with those policies.

Overall, the chapter-specific findings from my thesis contribute to the existing research focused on the richly complex ways that social practices and public policies influence the environmental footprint of digital technologies. However, I believe that my research also offers another set of contributions, which stem from the linkages between and across my chapters.

6.2.1 Reflecting on the linkages between and across my chapters

As mentioned in the limitations sections of my chapters, my doctoral research largely failed to directly address the connections between and across the practices and policies that I studied. The sole exceptions being in the discussion section of Chapter 4, wherein I linked the practices of retrocomputing repairers to HCI practices and research. However, I believe that there are some contributions to academic knowledge that can be drawn from reflecting on the potential linkages between my chapters on social practices and the final chapter on public policy.

I mentioned in the limitations section of Chapter 3 that only one HCI academic mentioned public policy in our interview. Most of the researchers I spoke with did not seem to think environmental public policy played a major role in their day-to-day practices, despite a few Europe-based academics mentioning the influence of another set of policies: the UK's REF system. Not a single interviewee seemed preoccupied with how their e-waste was managed, nor with how their travel schedule affected the environment; rather, the notable absence of these topics in conversation seemed to imply that many researchers—including those who considered themselves to be environmentally concerned—felt that these concerns were out of their scope of concern, and perhaps best left to institutional managerial or administrative staff. This suggests that, although environmental public policy will likely influence some dimensions of institutional management culture and how a small percent of academics manage their e-waste, the main drivers influencing the environmental footprint of HCI academic practices are likely not strongly connected with EPP. For example, as long as HCI academics feel the industry-wide, cultural pressure to publish-or-perish, environmental public policy will likely remain unable to influence the number of international flights taken by HCI academics, nor the configuration of the conferences HCI academics attend. This reflection is itself a novel contribution to academia; my research has highlighted an opportunity for HCI academics to examine how the environmental footprint of their practices are influenced by policy domains that are not explicitly "environmental public policy".

In terms of the linkages between my research on environmental public policy and retrocomputing repair practices, my retrocomputing repairers also did not overtly mention how their practices were influenced by public policies—environmental or otherwise. However, at the outset of the chapter on retrocomputing (when describing what "counts" as a retrocomputing device), I summarised how various corporate policies related to device support and age influence the availability of replacement parts. That, in turn, influences retrocomputing repair practices because the supply of replacement parts becomes increasingly scarce, which then leads some people to hoard parts and occasionally sell and ship replacement components around the world. These practice-related decisions influence the environmental footprint of the retrocomputing technologies themselves, as well as the repair practices that maintain those technologies. That these influences appear to be largely absent from HCI research related to attachment and repair, as well as from EPPs related to green procurement, is likely a novel contribution to academic knowledge. My research has highlighted an opportunity for public policy makers and HCI academics to examine how a broad set of corporate policies affect the environmental footprint of digital technologies, if those corporate policies should be factored into green public procurement policies, and if they are influencing repair practices at a larger scale.

6.2.2 Reflecting on the concept of the 'environmental footprint' of digital technologies

Upon reflection, I believe my research might also offer insights to SHCI researchers who are interested in measuring the footprint of digital technologies (e.g. [14, 24, 204, 210]). LCA is one of the most common methods for tracking and measuring the 'environmental footprint' of digital technologies [14, 210], and it has a demonstrably narrow focus on what gets 'counted' towards that footprint [14]. As Bates et al. explain, "because of the complex and layered nature of materials extraction, processing, manufacturing and transport, it is widely acknowledged that there will be inaccuracies in the overall emissions estimates, particularly for sophisticated products such as media and IT devices" [14]. But as Bates et al. demonstrate, the practices related to how we use digital technologies in the home can affect the environmental footprint of those technologies in ways that are also complex and layered, much like the initial materials extraction, processing, manufacturing and transport of our technologies. My research indirectly complements the findings of Bates et al. [14] by highlighting numerous dimensions of workplace and community-space practices that are currently absent from LCA calculations about (listed above in the contributions from each chapter).

Taken together, my complementary findings suggest that current methods (e.g. LCA) for understanding the environmental footprint of digital technologies do not grapple well with the complex and layered practices that occur throughout the various stages of a device's life cycle–beyond merely the issues already identified with measuring the materials extraction, processing, manufacturing and transportation costs. My research examined a small set of design and repair practices that influence various dimensions of the footprint of a digital technology. There are likely countless other domains (e.g. other academic disciplines, non-academic workplaces, and collaborative spaces) that we could study to highlight the lack of nuance in current 'environmental footprinting' methods. By doing so, we could perhaps propose new and more thorough mechanisms for understanding the environmental footprint of our digital technologies and services.

6.3 Contributions to non-academic knowledge

I staunchly believe that my contributions to non-academic knowledge are as, if not more, important than my contributions to academic knowledge. What do I mean by non-academic knowledge? Mostly, I mean knowledge that is used by and for non-academic purposes, as well as by and for non-academic audiences. Why does this matter? This matters because I believe that knowledge—especially publicly funded knowledge, like that which I acquired and pursued during my PhD—should be openly accessible to audiences of diverse backgrounds—not merely to those within academia.

During the doctoral research process, I endeavoured to share my knowledge with as many diverse groups as possible by presenting at Re:publica 2017 and at Edmonton NextGen's PechaKucha 23, both of which target non-academic audiences. I also produced a research and policy brief for Global Affairs Canada, which is a public service organisation. Beyond those concrete and "measurable" outputs, I endeavoured to communicate my research and knowledge in plain language at events I hosted, social and professional gatherings I attended, and meetings I held with non-academics. Unfortunately, I failed to keep a list of the conversations, discussions, and knowledge-sharing that I participated in outside of academic structures [1].

[1] There is a lot to be said about what academic systems "value" and how academic, as well as non-academic, outputs are quantified, but that can and should be saved for a different medium.

6.4 Future work

Every other day (or at least once a week), I come up with new ideas for projects to pursue based on my research [2]. To prevent this "future work" section from ballooning into a thirty page list of ideas and proposals, I will limit myself to listing three avenues of future work that I am currently most passionate about pursuing.

6.4.1 Everyday academic futures

I believe that my research on the social practices of HCI academics could be expanded into speculative work for the nascent "Everyday Futures" community [145]. This would align nicely with my longstanding interest in speculative and design fiction. For example, in an unpublished design fiction paper from early 2016[3], I examined an everyday future for an artificially intelligent and self-aware computer that had secured a post in a UK academic institution. That paper built upon my ICT4S design fiction [255] and examined how a future academic workplace might be configured to support and accommodate objects that exercise a level of agency and self-awareness that is often described or envisioned in other academic literature (e.g. literature on ANT and materiality). I could foresee myself returning to that scenario and redeveloping it now that I am more aware of academic practices.

I could also foresee myself producing human-focused, as opposed to object-focused, speculative and design fictions about academia and academics. For example, I could use my HCI academic practices study to speculate about how and by whom HCI will be evaluated in a decade, who will be involved in performing HCI research (will we see the involvement of more biologists?), and what types of theories will dominate the discipline. I could also use speculative fiction to satirise or critique the colonial nature of HCI and academia more broadly. The opportunities within this avenue of future research are broad.

6.4.2 Retrocomputing inheritance

One future retrocomputing-focused research opportunity that I am very passionate about pursuing is the creation of mechanisms and tools to support the inheritance of retro digital systems. Most of my retrocomputing study participants stated that they had no idea what would happen to their collections after they died. They all expressed a preference for their machines to go to 'somebody who would use [them]' (P3), but they had no firm plans as

[2] I have even started a "project ideas" thread in a Slack Channel that I maintain with Oliver Bates and Christian Remy

[3] I submitted this paper to NordiCHI 2016's Future Scenarios track and it was accepted, but I was unable to secure funding to support my travel to the conference.

to who that person would be or how that person would access the collection. I asked two participants about including their retro device collections in their wills and they stated they had no intention of doing so, even though they were strongly attached to their machines. Two of my participants (P3 and P4) were unsure of their children's interest in inheriting their retro computers, while two others seemed sure that their children would simply want to throw away all of their parents' retro digital devices (P1 and P5). This was a source of stress for P1 and P5, and it may be a source of stress for other collectors and connoisseurs [14], as well.

To date, there have been several research projects focused on what happens to our digital devices after we die [165], but I could find no existing projects that have focused on extending the life of the device after its owner has passed away. This offers an opportunity for research and design related to supporting people who want to pass down their cherished digital objects but don't know how or to whom.

6.4.3 Future public policy research

Within HCI, research on public policy is limited, and research on environmental public policy is especially limited. I believe that there are many discussions that could be held about how we present, discuss, analyse, and contribute to public policy, and I would like to contribute to those discussions. I would especially like to take my fusion of Lazar et al. [152] with Nathan and Friedman [178] to the broader HCI and public policy community—most likely at CHI'18—to see if others find it useful [4]. I would also like to try to communicate the value of HCI research to public policy audiences. In this respect, it would likely be wise for me to try to partner with friend and former DEN colleague, Lachlan Urquhart, who has published his research related to IT Law and HCI in several legal outlets. In one of those publications, he rightfully stated that "bridging the gap between IT law and HCI communities is critical. Engaging with the practices, concepts and epistemic commitments of the HCI community, is the first step to unpacking what role design, and designers, can play in IT regulation" [267]. I believe the same could be said of getting public policy makes and academics to engage with the HCI community's work.

6.5 Revisiting personal aims and objectives

From an academic standpoint, I am confident in having met the aims and objectives of my research, and in having "contributed" to academic knowledge. But I must consistently remind

[4]I used a less thorough version of this fusion in my two other HCI-targeted public policy publications[256, 254]

myself: I am not my academic outputs or my academic “career”, nor will I ever be merely a sum of those things. At the very least, I hope I never *feel* like I am merely a sum of those things. I remain firmly committed to having a bonfire this summer, during which I will cathartically burn all of the paperwork I’ve accumulated in the past 10 years of education. I hope that, wherever my career takes me, I can stay humble and reflexive.

When I started my PhD, I wanted to:

1) take a break from my career.
2) build my confidence and decide if I wished to continue working in a male-dominated industry.
3) learn about the environmental footprint of digital technologies.
4) learn how to apply social science methods.

I didn’t *really* succeed at taking a break from my career. Rather, I just... shifted careers. More than anything, when I reflect on that aim, I am reminded of how much I have grown since entering HighWire. That I thought a PhD would be ANY kind of break from my “actual” career shows the sort of arrogance and inexperience I had when I joined Lancaster. I’ve had to work hard to undo that mindset, and that process of undoing my mindset has been incredibly valuable to me.

I have built my confidence and I am happy to continue pursuing my career in a set of male-dominated industries (i.e. academia and ICTs).I have also learned about the environmental footprint of digital technologies and have, indeed, conducted research on that very topic. I recognise I still have more to learn, and that is exciting to me.

Lastly, I learned how to apply social science research methods! Certainly not to the level of expertise of people who have engaged with social science methods for longer and in different ways than I have, but at least to a degree of expertise that I have been able to publish some of my research.

Overall, I feel like I met my personal aims and objectives. I also grew professionally, academically, and personally in many unexpected and exciting ways. I feel so very privileged to have spent the past four years at Lancaster University.

6.6 Where to next...

Undertaking this research project has been incredibly fulfilling and rewarding, but it has also been exhausting. I look forward to taking some time off this summer and spending it amongst friends, family, animals, and ecosystems in Canada. I am especially looking forward to hugging and laughing with people who have known me far longer than most of my friends and peers in the UK.

In the fall, I join Susanne Bødker and her team at Aarhus University, where I will be working as a postdoc on the Common Interactive Objects project. Under Susanne's guidance, I hope to: find new and exciting ways to contribute to academic discourses; pursue some of the ideas listed under "future work", and; work with Mike Hazas to refine and publish some of the research contained in my HCI academic practices chapter. I would also like to find some way to continue collaborating with Ding Wang and Manu Brueggemann on our Lickable Cities project, with an eye to submitting a paper to CHI'18 based on our collaborative research. In the much longer-term, I'd like to return to Canada and ideally relocate somewhere in British Columbia...

...but of course if I've learned ANYTHING in the past four years with HighWire, it's that I am completely unable to predict my personal, professional, and academic trajectories and projects. Who can REALLY guess what I'll be doing and where I'll be doing it in one year's time, let alone in the longer term with my career? I, for one, can't. But I am definitely looking forward to slowly and reflexively figuring it out with the support of my friends, family, research community, and future colleagues.

That’s the end of that!
Though there’s still work to be done.
Let’s see what I do.

#EndOfThesisHaiku #haiku

References

[1] Altbach, P. G. (2004). Globalisation and the university: Myths and realities in an unequal world. *Tertiary Education and Management*, 10(1):3–25.

[2] Antares (2002). Bad rf modulator? http://www.lemon64.com/forum/viewtopic.php?t=4492.

[3] Anyangwe, E. (2011). Working as an assistant professor: research, teaching and administration. https://www.theguardian.com/higher-education-network/blog/2011/oct/26/assistant-professor-role.

[4] Apple Inc. (2014). Environmental Responsibility Report 2014 progress report, covering FY2013.

[5] Apple Inc. (2016a). Environmental Responsibility Report 2016 progress report, covering FY2015.

[6] Apple Inc. (2016b). Vintage and obsolete products. https://support.apple.com/en-gb/HT201624.

[7] Asante, K. A., Agusa, T., Biney, C. A., Agyekum, W. A., Bello, M., Otsuka, M., Itai, T., Takahashi, S., and Tanabe, S. (2012). Multi-trace element levels and arsenic speciation in urine of e-waste recycling workers from Agbogbloshie, Accra in Ghana. *Science of the Total Environment*, 424(C):63–73.

[8] Association for Computing Machinery (ACM) (2017). Chi conference overview.

[9] Atasu, A., Ozdemir, O., and Van Wassenhove, L. N. (2013). Stakeholder perspectives on e-waste take-back legislation. *Production and Operations Management*, 22(2):382–396.

[10] Austerberry, D. (2004). *Digital Asset Management*. Media management. Focal.

[11] Aycock, J. (2015). Applied computer history: Experience teaching systems topics through retrogames. In *Proceedings of the 2015 ACM Conference on Innovation and Technology in Computer Science Education*, ITiCSE '15, pages 105–110, New York, NY, USA. ACM.

[12] Banza, C. L. N., Nawrot, T. S., Haufroid, V., Decrée, S., Putter, T. D., Smolders, E., Kabyla, B. I., Luboya, O. N., Ilunga, A. N., Mutombo, A. M., and Nemery, B. (2009). High human exposure to cobalt and other metals in katanga, a mining area of the democratic republic of congo. *Environmental Research*, 109(6):745 – 752.

[13] Barker, G. (1995). Commodore world's guide to ram expansion. *Commodore World*, 2(8):20–23.

[14] Bates, O., Hazas, M., Friday, A., Morley, J., and Clear, A. K. (2014). Towards an holistic view of the energy and environmental impacts of domestic media and IT. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '14, pages 1173–1182, New York, NY, USA. ACM.

[15] Baumer, E. P. and Silberman, M. S. (2011). When the implication is not to design (technology). In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, pages 2271–2274, New York, NY, USA. ACM.

[16] Bawden, T. (2016). Global warming: Data centres to consume three times as much energy in next decade, experts warn. *The Independent*.

[17] Beláustegui, V. (2011). Las compras pùblicas sustentables en américa latina. estado de avance y elementos clave para su desarrollo. Organisation of American States.

[18] Benford, T. (1985). Sx-64 portable computer. In *Ahoy!*, pages 37 – 38. Ion International Inc., New York.

[19] Bidwell, N. J., Siya, M., Marsden, G., Tucker, W. D., Tshemese, M., Gaven, N., Ntlangano, S., Robinson, S., and Eglinton, K. A. (2008). Walking and the social life of solar charging in rural africa. *ACM Trans. Comput.-Hum. Interact.*, 20(4):22:1–22:33.

[20] Blackwell, A. F. (2015). Filling the big hole in hci research. *interactions*, 22(6):37–41.

[21] Blevis, E. (2007). Sustainable interaction design: Invention & disposal, renewal & reuse. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '07, pages 503–512, New York, NY, USA. ACM.

[22] Bødker, S. (2015). Third-wave hci, 10 years later—participation and sharing. *interactions*, 22(5):24–31.

[23] Boey, R. (2013). Nasa, speech recognition and commodore. http://www.mos6502.com/friday-commodore/nasa-speech-recognition-and-commodore/.

[24] Bonanni, L., Hockenberry, M., Zwarg, D., Csikszentmihalyi, C., and Ishii, H. (2010). Small business applications of sourcemap: A web tool for sustainable design and supply chain transparency. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '10, pages 937–946, New York, NY, USA. ACM.

[25] Boulton, J. (2014). Bulletin board systems. In *100 ideas that changed the web*. Laurence King Publishing, London, UK.

[26] Brammer, S. and Walker, H. (2011). Sustainable procurement in the public sector: an international comparative study. *International Journal of Operations & Production Management*, 31(4):452–476.

[27] breadbox64.com (2016). Sd2iec u1541 drive. http://www.breadbox64.com/blog/sd2iec-u1541-drive/.

[28] Brin, D. W. (1994). Computer firm shutting down. In *The Register-Guard*, page 5B. The Associated Press, Oregon, USA.

[29] Brynjarsdottir, H., Håkansson, M., Pierce, J., Baumer, E., DiSalvo, C., and Sengers, P. (2012). Sustainably unpersuaded: How persuasion narrows our vision of sustainability. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, pages 947–956, New York, NY, USA. ACM.

[30] Bureau, E. (2016). Environment ministry notifies strict new e-waste management rules, 2016. In *The Economic Times of India*.

[31] Carlsen, R. (n.d.). Commodore power supplies, new replacements for your old or missing ps. http://personalpages.tds.net/~rcarlsen/cbm/universal_ps/readme.txt.

[32] cgcmgr (2014). Why can't the c64 chips be recreated? http://www.lemon64.com/forum/viewtopic.php?t=51845.

[33] Chavis, D. M. and Pretty, G. M. (1999). Sense of community: Advances in measurement and application. *Journal of Community Psychology*, 27(6):635–642.

[34] Chayka, K. (2016). Welcome to airspace: How silicon valley helps spread the same sterile aesthetic across the world. *The Verge*.

[35] Chetty, M. and Grinter, R. E. (2007). Hci4d: Hci challenges in the global south. In *CHI '07 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '07, pages 2327–2332, New York, NY, USA. ACM.

[36] Cobbing, M. and Dowdall, T. (2014). *Green Gadgets: Designing the future The path to greener electronics*. Greenpeace International, Amsterdam, The Netherlands.

[37] Cohn, M. L. (2016). Convivial decay: Entangled lifetimes in a geriatric infrastructure. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing*, CSCW '16, pages 1511–1523, New York, NY, USA. ACM.

[38] Commodore Inc. (1983). Commodore 64 advertisement. http://www.computerhistory.org/revolution/digital-logic/12/284/1542.

[39] commodorekaitlin64 (2014). bought my first c64 have questions about the floppy drive. http://www.lemon64.com/forum/viewtopic.php?t=53940.

[40] Computer History Museum (2007). Commodore 64—25th anniversary celebration. http://www.computerhistory.org/events/video/75/.

[41] Computer History Museum (2016). Timeline of computer history—1970s. http://www.computerhistory.org/timeline/1970/#1970s.

[42] Cook, G., Lee, J., Tsai, T., Kong, A., Deans, J., Johnson, B., and Jardim, E. (2017). *Clicking Clean: Who is winning the race to build a green Internet?* Greenpeace International, Amsterdam, The Netherlands.

[43] Crivellaro, C., Taylor, A., Vlachokyriakos, V., Comber, R., Nissen, B., and Wright, P. (2016). Re-making places: Hci, 'community building' and change. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, pages 2958–2969, New York, NY, USA. ACM.

[44] Cuthbert, R. (2002). The impact of national developments on institutional practice. In Fry, H., Ketteridge, S., and Marshall, S., editors, *The Effective Academic: A Handbook for Enhanced Academic Practice*, Times higher education, chapter 2. Kogan Page.

[45] Danielsen, C., Taylor, A., and Majerus, W. (2011). Design and public policy considerations for accessible e-book readers. *interactions*, 18(1):67–70.

[46] de Freitas, A. A., Nebeling, M., Chen, X. A., Yang, J., Karthikeyan Ranithangam, A. S. K., and Dey, A. K. (2016). Snap-to-it: A user-inspired platform for opportunistic device interactions. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, pages 5909–5920, New York, NY, USA. ACM.

[47] Department of Energy and Climate Change (2013). My 2050. http://my2050.decc.gov.uk/.

[48] Digital Economy Network (2017). About the Digital Economy Network. http://www.den.ac.uk/about-the-den/about-the-den.aspx.

[49] DiSalvo, C., Sengers, P., and Brynjarsdóttir, H. (2010). Mapping the landscape of sustainable hci. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '10, pages 1975–1984, New York, NY, USA. ACM.

[50] Dix, A. (2010). Human–Computer Interaction: A stable discipline, a nascent science, and the growth of the long tail. *Interacting with Computers*, 22(1):13 – 27. Special Issue: Festschrift for John Long.

[51] Dix, A. (2015). Ref2014 citation analysis. http://alandix.com/ref2014/.

[52] Dix, A., Finlay, J. E., Abowd, G. D., and Beale, R. (2004a). Chapter 1 the human. In *Human-Computer Interaction (3rd Edition)*, chapter 1, pages 9–11. Prentice-Hall, Inc., Upper Saddle River, NJ, USA, 3rd edition.

[53] Dix, A., Finlay, J. E., Abowd, G. D., and Beale, R. (2004b). Chapter 1 the human. In *Human-Computer Interaction (3rd Edition)*, chapter 9, pages 319–364. Prentice-Hall, Inc., Upper Saddle River, NJ, USA, 3rd edition.

[54] Dix, A., Finlay, J. E., Abowd, G. D., and Beale, R. (2004c). *Human-Computer Interaction (3rd Edition)*. Prentice-Hall, Inc., Upper Saddle River, NJ, USA, 3rd edition.

[55] Dourish, P. (2006). Implications for design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '06, pages 541–550, New York, NY, USA. ACM.

[56] Dvorak, J. C. (1985). Image. In *Ahoy!*, page 5. Ion International Inc., New York.

[57] Dwivedy, M., Suchde, P., and Mittal, R. (2015). Modeling and assessment of e-waste take-back strategies in india. *Resources, Conservation and Recycling*, 96:11 – 18.

[58] E-Waste Association of South Africa (2016). Home. http://http://ewasa.org/.

[59] eBay Inc. (2017). Ebay - commodore 64. http://www.ebay.co.uk/bhp/commodore-64.

[60] Edwards, B. (2012). Tweet from a commodore 64? we do that and more to celebrate the beloved pc's 30th birthday.

[61] Elliot, A.-M. (2011). Personal computers: A history of the hardware that changed the world. In *Mashable Social Media*. Mashable UK.

[62] Elsevier B.V (2017). Environmental science and policy. http://www.journals.elsevier.com/environmental-science-and-policy/.

[63] Environment and Climate Change Canada (2013). Extended producer responsibility. http://www.ec.gc.ca/gdd-mw/default.asp?lang=En&n=FB8E9973-1.

[64] Environmental Protect Agency, USA (2016). Electronic Product Environmental Assessment Tool (EPEAT). https://www.epa.gov/greenerproducts/electronic-product-environmental-assessment-tool-epeat.

[65] European Environment Agency (2014). Climate change policies. https://www.eea.europa.eu/themes/climate/policy-context.

[66] European Union (2017). The rohs directive. http://ec.europa.eu/environment/waste/rohs_eee/index_en.htm.

[67] Fang, A. T., Khozein, R., Mendez-Baiges, S. M., and Shin, E. Y. (2009). extend: Reducing e-waste through redistribution of local it resources. In *CHI '09 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '09, pages 2817–2822, New York, NY, USA. ACM.

[68] Fitzpatrick, G. and Cox, A. (2017). Anna cox on family, work & strategies for making the changes we want. http://www.changingacademiclife.com/blog/2017/3/5/anna-cox.

[69] Fjeld, M. and Bødker, S. (2016). Nordic forum for Human-Computer Interaction 2016 (NordiCHI '16). http://dis2017.org.

[70] Forrest, C. (2015). The ancient commodore pc that haunts a michigan public school system.

[71] Froehlich, J., Findlater, L., and Landay, J. (2010). The design of eco-feedback technology. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '10, pages 1999–2008, New York, NY, USA. ACM.

[72] Fry, H., Ketteridge, S., and Marshall, S. (2002). *The Effective Academic: A Handbook for Enhanced Academic Practice*. Times higher education. Kogan Page.

[73] Fu, J., Zhou, Q., Liu, J., Liu, W., Wang, T., Zhang, Q., and Jiang, G. (2008). High levels of heavy metals in rice (oryza sativa l.) from a typical e-waste recycling area in southeast china and its potential risk to human health. *Chemosphere*, 71(7):1269 – 1275.

[74] GadgetUK164 (2014). Commodore 64 (c64c) color (colour) ram (sram) repair. https://www.youtube.com/watch?v=t2j_8LvpTNk.

[75] Garcia, M. (2013). Space debris and human spacecraft. https://www.nasa.gov/mission_pages/station/news/orbital_debris.html.

[76] Gegenbauer, S. and Huang, E. M. (2012a). Inspiring the design of longer-lived electronics through an understanding of personal attachment. In *Proceedings of the Designing Interactive Systems Conference*, DIS '12, pages 635–644, New York, NY, USA. ACM.

[77] Gegenbauer, S. and Huang, E. M. (2012b). ipods, ataris, and polaroids: A personal inventories study of out-of-use electronics in swiss households. In *Proceedings of the 2012 ACM Conference on Ubiquitous Computing*, UbiComp '12, pages 531–535, New York, NY, USA. ACM.

[78] Geneletti, D. and Zardo, L. (2016). Ecosystem-based adaptation in cities: An analysis of european urban climate adaptation plans. *Land Use Policy*, 50:38 – 47.

[79] Geyer, R. and Doctori Blass, V. (2010). The economics of cell phone reuse and recycling. *The International Journal of Advanced Manufacturing Technology*, 47(5):515–525.

[80] Global Affairs Canada (2016). International Policy Ideas Challenge 2016. http://www.international.gc.ca/world-monde/policy_challenge-defi_politique.aspx?lang=eng.

[81] Global Affairs Canada (2017). Policies, guidelines and key information. http://www.international.gc.ca/protocol-protocole/policies-politiques/index.aspx?lang=eng.

[82] Goetting, B. (2016). Battered but not beaten commodore c64 survives over 25 years balancing drive shafts in auto repair shop. http://hothardware.com/news/battered-but-not-beaten-commodore-c64-survives-over-25-years-balancing-drive-shafts-in-auto-repair-shop#w6lXBSZeDpa14F1U.99.

[83] Goodman, E. (2009). Three environmental discourses in Human-Computer Interaction. In *CHI '09 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '09, pages 2535–2544, New York, NY, USA. ACM.

[84] Gordon, A. and Suzuki, D. (1991). *It's a Matter of Survival*. Harvard University Press.

[85] Government of Canada (2017). Policies, directives, standards and guidelines. https://www.tbs-sct.gc.ca/pol/index-eng.aspx.

[86] Grantham Research Institute (2016). The Global Climate Legislation Study: Summary of key trends 2016.

[87] Grbich, C. (2007). *Qualitative Data Analysis: An Introduction*. SAGE Publications.

[88] Green Electronics Council (2016). EPEAT Purchasers. http://www.epeat.net/participants/purchasers/.

[89] Greenfield, A. (2013). *Against the smart city (the city is here for you to use)*. Do projects.

[90] Grimpe, B., Hartswood, M., and Jirotka, M. (2014). Towards a closer dialogue between policy and practice: Responsible design in hci. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '14, pages 2965–2974, New York, NY, USA. ACM.

[91] Grissom, S., Fitzgerald, S., McCauley, R., and Murphy, L. (2017). Exposed! cs faculty caught lecturing in public: A survey of instructional practices. In *Proceedings of the 2017 ACM SIGCSE Technical Symposium on Computer Science Education*, SIGCSE '17, pages 261–266, New York, NY, USA. ACM.

[92] Gulliksen, J., von Axelson, H., Persson, H., and Göransson, B. (2010). Accessibility and public policy in sweden. *interactions*, 17(3):26–29.

[93] Guo, P. (2014). Why do you want to be a cs professor? http://www.pgbovine.net/why-become-cs-prof.htm.

[94] Gupta, J. (2010). A history of international climate change policy. *Wiley Interdisciplinary Reviews: Climate Change*, 1(5):636–653.

[95] Günther, E. and Scheibe, L. (2006). The hurdle analysis. a self-evaluation tool for municipalities to identify, analyse and overcome hurdles to green procurement. *Corporate Social Responsibility and Environmental Management*, 13(2):61–77.

[96] Håkansson, M. and Sengers, P. (2014). No easy compromise: Sustainability and the dilemmas and dynamics of change. In *Proceedings of the 2014 Conference on Designing Interactive Systems*, DIS '14, pages 1025–1034, New York, NY, USA. ACM.

[97] Hanks, K., Odom, W., Roedl, D., and Blevis, E. (2008). Sustainable millennials: Attitudes towards sustainability and the material effects of interactive technologies. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '08, pages 333–342, New York, NY, USA. ACM.

[98] Hart, A., Northmore, S., and Gerhardt, C. (2009). Briefing paper: Auditing, benchmarking and evaluating public engagement. *National Co-ordinating Centre for Public Engagement, Bristol.*

[99] Hasselqvist, H., Bogdan, C., and Kis, F. (2016). Linking data to action: Designing for amateur energy management. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, DIS '16, pages 473–483, New York, NY, USA. ACM.

[100] Haynes, D. (2016). Commodore magazines. http://www.bombjack.org/commodore/magazines.htm.

[101] Hazas, M., Morley, J., Bates, O., and Friday, A. (2016). Are there limits to growth in data traffic?: On time use, data generation and speed. In *Proceedings of the Second Workshop on Computing Within Limits*, LIMITS '16, pages 14:1–14:5, New York, NY, USA. ACM.

[102] Hearn, A. (2003). Interdisciplinarity / extradisciplinarity: On the university and the active pursuit of community. *History of Intellectual Culture*, 3(1):13.

[103] Heeks, R., Subramanian, L., and Jones, C. (2015). Understanding e-waste management in developing countries: Strategies, determinants, and policy implications in the indian ict sector. *Information Technology for Development*, 21(4):653–667.

[104] Heiskanen, T., Kokkonen, J., Hintikka, K. A., Kola, P., Hintsa, T., and Näkki, P. (2008). Tutkimusparvi: The open research swarm in finland. In *Proceedings of the 12th International Conference on Entertainment and Media in the Ubiquitous Era*, MindTrek '08, pages 154–158, New York, NY, USA. ACM.

[105] Her Majesty's Stationary Office (2012). Sustainable procurement: the GBS for office ICT equipment. https://www.gov.uk/government/publications/sustainable-procurement-the-gbs-for-office-ict-equipment.

[106] Her Majesty's Stationary Office (2016). Government Information Technology (IT) - Greening Government ICT Strategy. https://www.gov.uk/government/publications/greening-government-ict-2015-annual-report.

[107] Heron, M. J., Belford, P., and Goker, A. (2014). Sexism in the circuitry: Female participation in male-dominated popular computer culture. *SIGCAS Comput. Soc.*, 44(4):18–29.

[108] Higher Education Funding Council for England (HEFCE) (2014). Research Excellence Framework (REF). http://www.ref.ac.uk/.

[109] Higher Education Funding Council for England (HEFCE) (2017). Teaching Excellence Framework (TEF). http://www.hefce.ac.uk/lt/tef/.

[110] Highways England (2015). Over £1.5 billion of investment to upgrade motorways in england. *Her Majesty's Stationary Office Press Releases*.

[111] Hinterthuer, A. (2015). Humanity has exceeded 4 of 9 'planetary boundaries', according to researchers. *University of Wisconsin-Madison News*.

[112] Hogan, M. (2015). Data flows and water woes: The utah data center. *Big Data & Society*, 2(2).

[113] Holmer, G. (2016). Geos for the commodore 64. http://www.lyonlabs.org/commodore/onrequest/geos.html.

[114] Houben, S., Golsteijn, C., Gallacher, S., Johnson, R., Bakker, S., Marquardt, N., Capra, L., and Rogers, Y. (2016). Physikit: Data engagement through physical ambient visualizations in the home. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, pages 1608–1619, New York, NY, USA. ACM.

[115] Houston, L., Jackson, S. J., Rosner, D. K., Ahmed, S. I., Young, M., and Kang, L. (2016). Values in repair. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, pages 1403–1414, New York, NY, USA. ACM.

[116] Howlett, M., McConnell, A., and Perl, A. (2016). Weaving the fabric of public policies: Comparing and integrating contemporary frameworks for the study of policy processes. *Journal of Comparative Policy Analysis: Research and Practice*, 18(3):273–289.

[117] Howlett, M. and Ramesh, M. (2003). *Studying Public Policy: Policy Cycles and Policy Subsystems*. Oxford University Press, Don Mills, ON, Canada, 2nd edition.

[118] Hui, A., Schatzki, T., and Shove, E. (2017a). Introduction. In Hui, A., Schatzki, T., and Shove, E., editors, *The Nexus of Practices: Connections, constellations, practitioners*, chapter 1, pages 1–8. Taylor & Francis, London.

[119] Hui, A., Schatzki, T., and Shove, E. (2017b). *The Nexus of Practices: Connections, constellations, practitioners*. Taylor & Francis, London.

[120] IEA (2016). World energy outlook 2016.

[121] iFixIt (2017). Commodore 64 repair. https://www.ifixit.com/Device/Commodore_64.

[122] Iivari, N. (2006). Understanding the work of an hci practitioner. In *Proceedings of the 4th Nordic Conference on Human-Computer Interaction: Changing Roles*, NordiCHI '06, pages 185–194, New York, NY, USA. ACM.

[123] IPCC (2014a). Africa. In Niang, I., Ruppel, O., Abdrabo, M., Essel, A., Lennard, C., Padgham, J., and Urquhart, P., editors, *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, chapter 22, page 1199–1265. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[124] IPCC (2014b). Asia. In Hijioka, Y., Lin, E., Pereira, J., Corlett, R., Cui, X., Insarov, G., Lasco, R., Lindgren, E., and Surjan, A., editors, *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, chapter 24, page 1327–1370. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[125] IPCC (2014c). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

[126] IPCC (2014d). Regional context. In Hewitson, B., Janetos, A., Carter, T., Giorgi, F., Jones, R., Kwon, W.-T., Mearns, L., Schipper, E., and Aalst, M. v., editors, *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, chapter 21, page 1136–1197. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[127] Jackson, S. J., Ahmed, S. I., and Rifat, M. R. (2014). Learning, innovation, and sustainability among mobile phone repairers in dhaka, bangladesh. In *Proceedings of the 2014 Conference on Designing Interactive Systems*, DIS '14, pages 905–914, New York, NY, USA. ACM.

[128] Jackson, S. J. and Kang, L. (2014). Breakdown, obsolescence and reuse: Hci and the art of repair. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '14, pages 449–458, New York, NY, USA. ACM.

[129] Jones, M., Palanque, P., Schmidt, A., and Grossman, T. (2014). Abstract for chi '14: Proceedings of the sigchi conference on human factors in computing systems. New York, NY, USA. ACM.

[130] Jozuka, E. (2015). This documentary explores the life of commodore creator Jack Tramiel. Motherboard.

[131] Judge, P. (2013). Giant kenyan e-waste scheme hopes to clean up toxic tech. In *Tech Week Europe*.

[132] Jung, H., Bardzell, S., Blevis, E., Pierce, J., and Stolterman, E. (2011). How deep is your love: Deep narratives of ensoulment and heirloom status. *International Journal of Design*, 5(1):59–71.

[133] Kahlenborn, W., Mansor, N., and Adham, K. N. (2013). Government green procurement (ggp) short-term action plan 2013 – 2014. Sustainable Consumption and Production – Malaysia.

[134] Kasulaitis, B. V., Babbitt, C. W., Kahhat, R., Williams, E., and Ryen, E. G. (2015). Evolving materials, attributes, and functionality in consumer electronics: Case study of laptop computers. *Resources, Conservation and Recycling*, 100:1 – 10.

[135] Kern, K. (2014). *Climate governance in the European Union multilevel system: the role of cities*. Edward Elgar Publishing, Inc., Cheltenham, UK.

[136] Kim, D.-I. (2014). Korea. In Lember, V., Kattel, R., and Kalvet, T., editors, *Public Procurement, Innovation and Policy: International Perspectives*, pages 191–211. Springer Berlin Heidelberg, Berlin, Heidelberg.

[137] Kirk, D. and Banks, R. (2008). On the design of technology heirlooms. In *International Workshop on Social Interaction and Mundane Technologies (SIMTech '08)*.

[138] Kirman, B. and Lindley, J. (2016). Organisers. http://www.fictionalconference.com/organisers/.

[139] Knowles, B., Blair, L., Coulton, P., and Lochrie, M. (2014a). Rethinking plan a for sustainable hci. In *Proceedings of the 32Nd Annual ACM Conference on Human Factors in Computing Systems*, CHI '14, pages 3593–3596, New York, NY, USA. ACM.

[140] Knowles, B., Blair, L., Walker, S., Coulton, P., Thomas, L., and Mullagh, L. (2014b). Patterns of persuasion for sustainability. In *Proceedings of the 2014 Conference on Designing Interactive Systems*, DIS '14, pages 1035–1044, New York, NY, USA. ACM.

[141] Kostakos, V. (2015). The big hole in hci research. *interactions*, 22(2):48–51.

[142] Kraft, M. and Furlong, S. (2014). *Public Policy: Politics, Analysis, and Alternatives*. SAGE Publications.

[143] Kravets, D. (2015). It's official: Sharks no longer a threat to subsea internet cables. *Ars technica*.

[144] Kuijer, L., Jong, A. d., and Eijk, D. v. (2013). Practices as a unit of design: An exploration of theoretical guidelines in a study on bathing. *ACM Trans. Comput.-Hum. Interact.*, 20(4):21:1–21:22.

[145] Kuijer, L. and Spurling, N. (2017). Introduction. *interactions*, 24(2):34–37.

[146] Kumar, N., Dray, S., Sturm, C., Sambasivan, N., Gaytan-Lugo, L. S., Morales, L., Dahya, N., Ahmed, N., and Peters, A. (2017). Program committee. http://www.hcixb.org/2017-2/program-committee/.

[147] Kumar, P., Geneletti, D., and Nagendra, H. (2016). Spatial assessment of climate change vulnerability at city scale: A study in bangalore, india. *Land Use Policy*, 58:514 – 532.

[148] Kuutti, K. and Bannon, L. J. (2014). The turn to practice in hci: Towards a research agenda. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '14, pages 3543–3552, New York, NY, USA. ACM.

[149] Lancaster University (2017a). Lancaster University manual of academic regulations and procedures (MARP).

[150] Lancaster University (2017b). Postgraduate Certificate in Academic Practice (PGCAP). http://www.lancaster.ac.uk/hr/OED/ED/CAP/index.html.

[151] Lazar, J. (2015). Public policy and hci: Making an impact in the future. *interactions*, 22(5):69–71.

[152] Lazar, J., Abascal, J., Barbosa, S., Barksdale, J., Friedman, B., Grossklags, J., Gulliksen, J., Johnson, J., McEwan, T., Martínez-Normand, L., Michalk, W., Tsai, J., van der Veer, G., von Axelson, H., Walldius, A., Whitney, G., Winckler, M., Wulf, V., Churchill, E. F., Cranor, L., Davis, J., Hedge, A., Hochheiser, H., Hourcade, J. P., Lewis, C., Nathan, L., Paterno, F., Reid, B., Quesenbery, W., Selker, T., and Wentz, B. (2016). Human-Computer Interaction and International Public Policymaking: A framework for understanding and taking future actions. *Foundations and Trends®Human-Computer Interaction*, 9(2):69–149.

[153] Lee, C. and Poltrock, S. (2017). ACM Conference on Computer-Supported Cooperative Work and Social Computing (CSCW '17). https://cscw.acm.org/2017/.

[154] legacy2k (2011). C64 on vga connection??? http://www.lemon64.com/forum/viewtopic.php?t=37385.

[155] Lemon, K. (2016). Lemon 64. http://www.lemon64.com/.

[156] Lepawsky, J. (2014). The changing geography of global trade in electronic discards: time to rethink the e-waste problem. *The Geographical Journal*.

[157] Lewis, C. C. and Abdul-Hamid, H. (2006). Implementing effective online teaching practices: Voices of exemplary faculty. *Innovative Higher Education*, 31(2):83–98.

[158] Li, K., Liang, T., Wang, L., and Yang, Z. (2015). Contamination and health risk assessment of heavy metals in road dust in bayan obo mining region in inner mongolia, north china. *Journal of Geographical Sciences*, 25(12):1439–1451.

[159] Lin, A. Y.-C., Panchangam, S. C., and Lo, C.-C. (2009). The impact of semiconductor, electronics and optoelectronic industries on downstream perfluorinated chemical contamination in taiwanese rivers. *Environmental Pollution*, 157(4):1365 – 1372. The Behaviour and Effects of Nanoparticles in the Environment.

[160] lobogris (2010). My c64 pixel art gallery. http://www.lemon64.com/forum/viewtopic.php?t=36305.

[161] Lockwood, M. (2013). The political sustainability of climate policy: The case of the {UK} climate change act. *Global Environmental Change*, 23(5):1339 – 1348.

[162] Logan, C. (2017). We can shift academic culture through publishing choices. *F1000Research*, 6(518).

[163] Ma, L. and Ladisch, M. (2016). Scholarly communication and practices in the world of metrics: An exploratory study. In *Proceedings of the 79th ASIS&T Annual Meeting: Creating Knowledge, Enhancing Lives Through Information & Technology*, ASIST '16, pages 132:1–132:4, Silver Springs, MD, USA. American Society for Information Science.

[164] Maestri, L. and Wakkary, R. (2011). Understanding repair as a creative process of everyday design. In *Proceedings of the 8th ACM Conference on Creativity and Cognition*, C&C '11, pages 81–90, New York, NY, USA. ACM.

[165] Massimi, M. and Baecker, R. M. (2011). Dealing with death in design: Developing systems for the bereaved. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '11, pages 1001–1010, New York, NY, USA. ACM.

[166] McElvaney, K. (2014). In pictures: Ghana's e-waste magnet. *Al Jazeera*.

[167] McKibben, B. and McKibben, S. (2011). *Eaarth: Making a Life on a Tough New Planet*. Knopf Canada.

[168] McMillan, R. (2014). Sharks wage war on undersea internet cables. *Wired*.

[169] Microsoft Inc. (2016). Lifecycle information for microsoft obsolete products support. https://support.microsoft.com/en-gb/gp/lifeobsoleteproducts.

[170] Middlehurst, R. (2002). The international context for uk higher education. In Fry, H., Ketteridge, S., and Marshall, S., editors, *The Effective Academic: A Handbook for Enhanced Academic Practice*, Times higher education, chapter 1. Kogan Page.

[171] Mirnig, A. G., Meschtscherjakov, A., Wurhofer, D., Meneweger, T., and Tscheligi, M. (2015). A formal analysis of the iso 9241-210 definition of user experience. In *Proceedings of the 33rd Annual ACM Conference Extended Abstracts on Human Factors in Computing Systems*, CHI EA '15, pages 437–450, New York, NY, USA. ACM.

[172] Mival, O., Smyth, M., and Dalsgaard, P. (2017). ACM SIGCHI Conference on Designing Interactive Systems (DIS '17). http://dis2017.org.

[173] Morley, J. (2016). Technologies within and beyond practices. In *The Nexus of Practices*, pages 81–97. Routledge. This is an Accepted Manuscript of a book chapter published by Routledge (on 6/12/2016) in Hui, A., Schatzki, T. and Shove, E. (eds) The Nexus of Practices: Connections, constellations, practitioners. Available online: https://www.routledge.com/The-Nexus-of-Practice-Connections-constellations-andpractitioners/Hui-Schatzki-Shove/p/book/9781138675155.

[174] Mujere, N. and Isidro, M. (2015). Impacts of artisanal and small-scale gold mining on water quality in mozambique and zimbabwe. *Impact of Water Pollution on Human Health and Environmental Sustainability*, page 101.

[175] Nagel, M. (2003). Managing the environmental performance of production facilities in the electronics industry: more than application of the concept of cleaner production. *Journal of Cleaner Production*, 11(1):11 – 26.

[176] Nancekivell, S. (2004). Writing a publishable journal article: A perspective from the other side of the desk. *Science*.

[177] Nardi, B. and Ekbia, H. (2017). *Developing a political economy perspective for sustainable HCI*. Routledge.

[178] Nathan, L. P. and Friedman, B. (2010). Interacting with policy in a political world: Reflections from the voices from the rwanda tribunal project. *interactions*, 17(5):56–59.

[179] Nicolini, D. (2016). Is small the only beautiful? making sense of 'large phenomena' from a practise-based perspective. In Hui, A., Schatzki, T., and Shove, E., editors, *The Nexus of Practices Connections : constellations, practitioners*, pages 98–113. Routledge, London ; New York.

[180] Norgate, T. and Haque, N. (2012). Using life cycle assessment to evaluate some environmental impacts of gold production. *Journal of Cleaner Production*, 29–30:53 – 63.

[181] Odom, W., Banks, R., Kirk, D., Harper, R., Lindley, S., and Sellen, A. (2012a). Technology heirlooms?: Considerations for passing down and inheriting digital materials. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, pages 337–346, New York, NY, USA. ACM.

[182] Odom, W., Pierce, J., Stolterman, E., and Blevis, E. (2009). Understanding why we preserve some things and discard others in the context of interaction design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '09, pages 1053–1062, New York, NY, USA. ACM.

[183] Odom, W., Selby, M., Sellen, A., Kirk, D., Banks, R., and Regan, T. (2012b). Photobox: On the design of a slow technology. In *Proceedings of the Designing Interactive Systems Conference*, DIS '12, pages 665–668, New York, NY, USA. ACM.

[184] Odom, W. T., Sellen, A. J., Banks, R., Kirk, D. S., Regan, T., Selby, M., Forlizzi, J. L., and Zimmerman, J. (2014). Designing for slowness, anticipation and re-visitation: A long term field study of the photobox. In *Proceedings of the 32Nd Annual ACM Conference on Human Factors in Computing Systems*, CHI '14, pages 1961–1970, New York, NY, USA. ACM.

[185] Ojameruaye, B., Bahsoon, R., and Duboc, L. (2016). Sustainability debt: A portfolio-based approach for evaluating sustainability requirements in architectures. In *Proceedings of the 38th International Conference on Software Engineering Companion*, ICSE '16, pages 543–552, New York, NY, USA. ACM.

[186] Oliver, M. (2006). Kidnapper's retro computer offers scant clues. In *Guardian World News*. The Guardian.

[187] Ongondo, F., Williams, I., and Cherrett, T. (2011). How are {WEEE} doing? a global review of the management of electrical and electronic wastes. *Waste Management*, 31(4):714 – 730.

[188] Open Lab (2016). Workshops. https://openlab.ncl.ac.uk/den-summer/program/workshops/.

[189] Ordorika, I. (2015). The state and contest in higher education in the globalized era: Critical perspectives. In *Critical Approaches to the Study of Higher Education: a Practical Introduction*, chapter 6, pages 130–152. Johns Hopkins University Press, Baltimore, MD, USA, 1st edition.

[190] O'Regan, G. (2012a). Developments in the 1950s–1970s. In *A Brief History of Computing*, chapter 4, pages 53–62. Springer London, London.

[191] O'Regan, G. (2012b). Revolutions in the 1980s and 1990s. In *A Brief History of Computing*, chapter 5, pages 63–69. Springer London, London.

[192] Oulasvirta, A. (2016). We must reform chi or start an alternative.

[193] Oulasvirta, A. and Hornbæk, K. (2016). Hci research as problem-solving. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, pages 4956–4967, New York, NY, USA. ACM.

[194] Pain, E. (2017). Ph.D. students face significant mental health challenges. American Association for the Advancement of Science.

[195] Pal, J. (2017). Chi4good or good4chi. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, CHI EA '17, pages 709–721, New York, NY, USA. ACM.

[196] Pandey, P. and Govind, M. (2014). Social repercussions of e-waste management in India: a study of three informal recycling sites in delhi. *International Journal of Environmental Studies*, 71(3):241–260.

[197] Penguin Computing, Inc. (2017). Frequently Asked Questions. http://www.beowulf.org/overview/faq.html.

[198] Penzenstadler, B. (2013). Towards a definition of sustainability in and for software engineering. In *Proceedings of the 28th Annual ACM Symposium on Applied Computing*, SAC '13, pages 1183–1185, New York, NY, USA. ACM.

[199] Pfeuffer, K., Hinckley, K., Pahud, M., and Buxton, B. (2017). Thumb + pen interaction on tablets. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, CHI '17, pages 3254–3266, New York, NY, USA. ACM.

[200] Pierce, J., Brynjarsdottir, H., Sengers, P., and Strengers, Y. (2011). Everyday practice and sustainable hci: Understanding and learning from cultures of (un)sustainability. In *CHI '11 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '11, pages 9–12, New York, NY, USA. ACM.

[201] Pierce, J. and Paulos, E. (2012). Beyond energy monitors: Interaction, energy, and emerging energy systems. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, CHI '12, pages 665–674, New York, NY, USA. ACM.

[202] Pierce, J., Strengers, Y., Sengers, P., and Bødker, S. (2008). Introduction to the special issue on practice-oriented approaches to sustainable hci. *ACM Trans. Comput.-Hum. Interact.*, 20(4):20:1–20:8.

[203] Ploderer, B., Reitberger, W., Oinas-Kukkonen, H., and Gemert-Pijnen, J. (2014). Social interaction and reflection for behaviour change. *Personal Ubiquitous Comput.*, 18(7):1667–1676.

[204] Preist, C., Schien, D., and Blevis, E. (2016). Understanding and mitigating the effects of device and cloud service design decisions on the environmental footprint of digital infrastructure. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, CHI '16, pages 1324–1337, New York, NY, USA. ACM.

[205] Pucciarelli, F. and Kaplan, A. (2016). Competition and strategy in higher education: Managing complexity and uncertainty. *Business Horizons*, 59(3):311 – 320.

[206] Rawas, S., Itani, W., Zaart, A., and Zekri, A. (2015). Towards greener services in cloud computing: Research and future directives. In *2015 International Conference on Applied Research in Computer Science and Engineering (ICAR)*, pages 1–8.

[207] Reckwitz, A. (2002). Toward a theory of social practices. *European Journal of Social Theory*, 5(2):243–263.

[208] Reed, K. (2005). Commodore 64 direct-to-tv. http://www.eurogamer.net/articles/r_c64dtv.

[209] Reed-Danahay, D. (2009). Anthropologists, education, and autoethnography. *Reviews in Anthropology*, 38(1):28–47.

[210] Remy, C., Bates, O., Thomas, V., and Huang, E. (2017). The limits of evaluating sustainability. In *Proceedings of the 3rd Workshop on Computing within Limits (LIMITS '17)*. ACM.

[211] Remy, C., Gegenbauer, S., and Huang, E. M. (2015). Bridging the theory-practice gap: Lessons and challenges of applying the attachment framework for sustainable hci design. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, CHI '15, pages 1305–1314, New York, NY, USA. ACM.

[212] Remy, C. and Huang, E. (2015). Addressing the obsolescence of end-user devices: Approaches from the field of sustainable hci. In Hilty, L. M. and Aebischer, B., editors, *ICT Innovations for Sustainability*, volume 310 of *Advances in Intelligent Systems and Computing*, pages 257–267. Springer International Publishing.

[213] Revette, A. C. (2017). This time it's different: lithium extraction, cultural politics and development in bolivia. *Third World Quarterly*, 38(1):149–168.

[214] Robinson, B. H. (2009). E-waste: An assessment of global production and environmental impacts. *Science of The Total Environment*, 408(2):183–191.

[215] Roedl, D., Odom, W., and Blevis, E. (2017). Three principles of sustainable interaction design, revisited. In Hazas, M. and Nathan, L., editors, *Digital Technology and Sustainability: Acknowledging Paradox, Facing Conflict, and Embracing Disruption*. Routledge.

[216] Rooksby, J. (2013). Wild in the laboratory: A discussion of plans and situated actions. *ACM Trans. Comput.-Hum. Interact.*, 20(3):19:1–19:17.

[217] Røpke, I. (2009). Theories of practice — new inspiration for ecological economic studies on consumption. *Ecological Economics*, 68(10):2490 – 2497.

[218] Rosner, D. K. and Ames, M. (2014). Designing for repair?: Infrastructures and materialities of breakdown. In *Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing*, CSCW '14, pages 319–331, New York, NY, USA. ACM.

[219] Rosner, D. K., Jackson, S. J., Hertz, G., Houston, L., and Rangaswamy, N. (2013). Reclaiming repair: Maintenance and mending as methods for design. In *CHI '13 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '13, pages 3311–3314, New York, NY, USA. ACM.

[220] Saunders, B., Kitzinger, J., and Kitzinger, C. (2015). Anonymising interview data: challenges and compromise in practice. *Qualitative Research*, 15(5):616–632. PMID: 26457066.

[221] Schaffrin, A., Sewerin, S., and Seubert, S. (2014). The innovativeness of national policy portfolios – climate policy change in austria, germany, and the uk. *Environmental Politics*, 23(5):860–883.

[222] Schatzki, T., Knorr-Cetina, K., and von Savigny, E. (2001). *The Practice Turn in Contemporary Theory*. Routledge.

[223] Secretariat of the Basel Convention (2011a). Convention overview. http://basel.int/TheConvention/Overview/tabid/1271/Default.aspx.

[224] Secretariat of the Basel Convention (2011b). E-waste overview. http://basel.int/Implementation/Ewaste/Overview/tabid/4063/Default.aspx.

[225] Secretariat of the Basel Convention (2011c). Where are WEEE in Africa? findings from the basel convention e-waste Africa programme. http://www.basel.int/Portals/4/download.aspx?d=UNEP-CHW-EWASTE-PUB-WeeAfricaReport.English.pdf.

[226] Sedano, T., Ralph, P., and Péraire, C. (2016). Sustainable software development through overlapping pair rotation. In *Proceedings of the International Symposium on Empirical Software Engineering and Measurement International Conference on Software Engineering*, ESEM.

[227] Sedano, T., Ralph, P., and Péraire, C. (2017). Software development waste. In *Proceedings of the 2017 International Conference on Software Engineering*, ICSE.

[228] Sengers, P., McCarthy, J., and Dourish, P. (2006). Reflective hci: Articulating an agenda for critical practice. In *CHI '06 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '06, pages 1683–1686, New York, NY, USA. ACM.

[229] Shidham, V., Pitman, M., and DeMay, R. (2012). How to write an article: Preparing a publishable manuscript! *CytoJournal*, 9(1):1.

[230] Shove, E. (2010). Beyond the abc: Climate change policy and theories of social change. *Environment and Planning A*, 42(6):1273–1285.

[231] Shove, E., Pantzer, M., and Watson, M. (2012). *The Dynamics of Social Practice: Everyday life and how it changes*. Sage Publications.

[232] Silberman, M. S., Nathan, L., Knowles, B., Bendor, R., Clear, A., Håkansson, M., Dillahunt, T., and Mankoff, J. (2014). Next steps for sustainable hci. *interactions*, 21(5):66–69.

[233] Slevitch, L. (2011). Qualitative and quantitative methodologies compared: Ontological and epistemological perspectives. *Journal of Quality Assurance in Hospitality & Tourism*, 12(1):73–81.

[234] Smith, M. (1998). *Social Science in Question: Towards a Postdisciplinary Framework*. Published in association with The Open University. SAGE Publications.

[235] Sony Electronics Inc. (2016). Discontinued products. https://pro.sony.com/bbsc/ssr/services.servicesprograms. bbsccms-services-servicesprograms-discontinuedproducts.shtml.

[236] spannernick (2016). Hardware repair services. http://www.lemon64.com/forum/viewtopic.php?t=60575&sid =5a635ab1333ca0bb00e0387cc42ca1bc.

[237] Squadrone, S., Burioli, E., Monaco, G., Koya, M., Prearo, M., Gennero, S., Dominici, A., and Abete, M. (2016). Human exposure to metals due to consumption of fish from an artificial lake basin close to an active mining area in katanga (d.r. congo). *Science of The Total Environment*, 568:679 – 684.

[238] Ssekandi, J. (2016). Uganda: Environmentalists alarmed over growing e-waste. In *The Observer (Kampala)*.

[239] Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., de Vries, W., de Wit, C. A., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., and Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science*, 347(6223).

[240] Sthiannopkao, S. and Wong, M. H. (2013). Handling e-waste in developed and developing countries: Initiatives, practices, and consequences. *Science of The Total Environment*, 463–464:1147 – 1153.

[241] Strengers, Y. (2016). Envisioning the smart home: Reimagining a smart energy future. In Pink, S., Ardèvol, E., and Lanzeni, D., editors, *Digital Materialities: Design and Anthropology*, chapter 4, pages 61–76. Bloomsbury Academic, London.

[242] Strengers, Y., Morley, J., Nicholls, L., and Hazas, M. (2016a). The hidden energy cost of smart homes. *The Conversation*.

[243] Strengers, Y., Nicholls, L., and Maller, C. (2016b). Curious energy consumers: Humans and nonhumans in assemblages of household practice. *Journal of Consumer Culture*, 16(3):761–780.

[244] Stuart, K. (2014). The six best retro consoles for modern gamers. Guardian News and Media Limited, UK.

[245] Sturdee, M. and Vermeulen, J. (2016). Call for participation: Posters. https://iss2016.acm.org/authors/posters/.

[246] Stylianidis, A., Vermeulen, J., Houben, S., MacDonald, L., and Beale, R. (2017). Sensebelt: A belt-worn sensor to support cross-device interaction. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, CHI EA '17, pages 2123–2131, New York, NY, USA. ACM.

[247] Sun, Y., Lindtner, S., Ding, X., Lu, T., and Gu, N. (2015). Reliving the past & making a harmonious society today: A study of elderly electronic hackers in china. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*, CSCW '15, pages 44–55, New York, NY, USA. ACM.

[248] Sustainability and Health Initiative for NetPositive Enterprise (SHINE) (2017). Handprint: A new framework for sustainability. http://www.chgeharvard.org/topic/handprint-new-framework-sustainability.

[249] Teehan, P. and Kandlikar, M. (2013). Comparing embodied greenhouse gas emissions of modern computing and electronics products. *Environmental Science & Technology*, 47(9):3997–4003. PMID: 23458212.

[250] Testa, F., Grappio, P., Gusmerotti, N. M., Iraldo, F., and Frey, M. (2016). Examining green public procurement using content analysis: existing difficulties for procurers and useful recommendations. *Environment, Development and Sustainability*, 18(1):197–219.

[251] Thomas, V. (2016a). Digital technologies and environmental change: An emerging global issues brief. Technical report, Lancaster University.

[252] Thomas, V. (2016b). Policy Ideas Challenge Submission. https://youtu.be/1Wb-NHOtg78.

[253] Thomas, V. (2016c). Tweet 805375626404331522 from 4 dec 2016. https://twitter.com/van_tho/status/805375626404331522.

[254] Thomas, V. (2017). Negotiating and engaging with environmental public policy at different scales. In Hazas, M. and Nathan, L., editors, *Digital Technology and Sustainability: Acknowledging Paradox, Facing Conflict, and Embracing Disruption*. Routledge.

[255] Thomas, V., Hohnekamp-Bruggemann, M., and Feldman, D. (2015). *i am more than the sum of my parts: an e-waste design fiction*, pages 57–65. Atlantis Press. Date of Acceptance: 21/05/2015 © Atlantis Press. This article is distributed under the terms of the Creative Commons Attribution 3.0 Unported License, which permits commercial and non-commercial use, distribution and reproduction in any medium, provided the original work is properly cited.

[256] Thomas, V., Remy, C., Hazas, M., and Bates, O. (2017). Hci and environmental public policy: opportunities for engagement. In *Proceedings of the 35th Annual ACM Conference on Human Factors in Computing Systems*, CHI '17. ACM.

[257] Thomas, V., Wang, D., Mullagh, L., and Dunn, N. (2016). Where's wally? in search of citizen perspectives on the smart city. *Sustainability*, 8(3):207.

[258] Tian, X. and Slocum, J. W. (2016). Managing corporate social responsibility in china. *Organizational Dynamics*, 45(1):39 – 46.

[259] Tomlinson, B., Blevis, E., Nardi, B., Patterson, D. J., Silberman, M. S., and Pan, Y. (2008). Collapse informatics and practice: Theory, method, and design. *ACM Trans. Comput.-Hum. Interact.*, 20(4):24:1–24:26.

[260] Toronto PET Users Group (2016). Links. http://www.tpug.ca/links/.

[261] Tsaknaki, V., Cohn, M., Boer, L., Fernaeus, Y., and Vallgårda, A. (2016). Things fall apart: Unpacking the temporalities of impermanence for hci. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction*, NordiCHI '16, pages 141:1–141:3, New York, NY, USA. ACM.

[262] Turi, J. (2015). Reinvigorate your inner nerd at this retro-computing exhibit. https://www.engadget.com/2015/04/03/the-interface-experience/.

[263] Turner, F. (2006). How digital technology found utopian ideology: Lessons from the first hackers' conference. In Silver, D., Massanari, A., and Jones, S., editors, *Critical Cyberculture Studies*. NYU Press.

[264] United Nations Environment Programme (2017). Sustainable public procurement. http://web.unep.org/10yfp/programmes/sustainable-public-procurement.

[265] United Nations Framework Convention on Climate Change (2014). Background on the UNFCCC: The international response to climate change. http://unfccc.int/essential_background/items/6031.php.

[266] Urquhart, L. (2014). Bridging the gap between law & hci: Designing effective regulation of human autonomy in everyday ubicomp systems. In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication*, UbiComp '14 Adjunct, pages 355–360, New York, NY, USA. ACM.

[267] Urquhart, L. (2017). Ethical dimensions of user centric regulation. In *Proceedings of ETHICOMP / CEPE 2017, Università di Torino, Italy, 3-5th June 2017*.

[268] Vlachokyriakos, V., Crivellaro, C., Le Dantec, C. A., Gordon, E., Wright, P., and Olivier, P. (2016). Digital civics: Citizen empowerment with and through technology. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*, CHI EA '16, pages 1096–1099, New York, NY, USA. ACM.

[269] Wakkary, R., Desjardins, A., Hauser, S., and Maestri, L. (2008). A sustainable design fiction: Green practices. *ACM Trans. Comput.-Hum. Interact.*, 20(4):23:1–23:34.

[270] Watson, D. (2002). Introduction. In Fry, H., Ketteridge, S., and Marshall, S., editors, *The Effective Academic: A Handbook for Enhanced Academic Practice*, Times higher education. Kogan Page.

[271] Weller, M. (2011). *The Digital Scholar: How Technology is Transforming Academic Practice*. Bloomsbury USA.

[272] Weng, Z., Haque, N., Mudd, G. M., and Jowitt, S. M. (2016). Assessing the energy requirements and global warming potential of the production of rare earth elements. *Journal of Cleaner Production*, 139:1282 – 1297.

[273] Widdicks, K., Bates, O., Hazas, M., Friday, A., and Beresford, A. R. (2017). Demand around the clock: Time use and data demand of mobile devices in everyday life. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, CHI '17, pages 5361–5372, New York, NY, USA. ACM.

[274] Widmer, R., Oswald-Krapf, H., Sinha-Khetriwal, D., Schnellmann, M., and Böni, H. (2005). Global perspectives on e-waste. *Environmental Impact Assessment Review*, 25(5):436 – 458. Environmental and Social Impacts of Electronic Waste Recycling.

[275] Wilhelmsson, J. (2016). *Generation 64: How the Commodore 64 inspired a generation of Swedish gamers*. Bitmap Books.

[276] Williams, C. (2012). Commodore 64 at 30: computing for the masses. The Telegraph.

[277] Wong, C. S., Wu, S., Duzgoren-Aydin, N. S., Aydin, A., and Wong, M. H. (2007). Trace metal contamination of sediments in an e-waste processing village in china. *Environmental Pollution*, 145(2):434 – 442.

[278] Wurzel, R. K. and Connelly, J. (2010). *Introduction: European Union Political Leadership in International Climate Change Politics*. Routledge, New York, New York.

[279] Zheng, L., Wu, K., Li, Y., Qi, Z., Han, D., Zhang, B., Gu, C., Chen, G., Liu, J., Chen, S., Xu, X., and Huo, X. (2008). Blood lead and cadmium levels and relevant factors among children from an e-waste recycling town in china. *Environmental Research*, 108(1):15 – 20.

Appendix A

Publications and Outputs

A.1 Contributing publications and outputs

V. Thomas, C. Remy, and O. Bates. “The Limits of HCD: Reimagining the Anthropocentricity of ISO 9241-210” Proceedings of the third workshop on Computing within Limits, LIMITS ’17.
This workshop paper is referenced in the conclusion.

V. Thomas, M. Hazas, and R. B. Thomas. “Examining the repair of ’retro’ computing devices: a niche, persistent practice”. Submitted to TOCHI in March 2017.
This journal paper presents some of the analysis and findings included in Part I, Chapter 4

V. Thomas. “Negotiating and engaging with environmental public policy at different scales.” Chapter in forthcoming book Digital Technology and Sustainability: Acknowledging Paradox, Facing Conflict, and Embracing Disruption.
This book chapter presents some of the analysis and findings from Part II, Chapter 5.

V. Thomas, C. Remy, M. Hazas, and O. Bates. “HCI and Environmental Public Policy: Opportunities for Engagement” Proceedings of the Proceedings of the 35th Annual ACM Conference on Human Factors in Computing Systems, CHI ’17,
This conference paper presents some of the analysis and findings from Part II, Chapter 5.

V. Thomas. “Digital Technologies and Environmental Change.” A research and policy brief prepared for Global Affairs Canada’s International Policy Ideas Challenge. 2016. Available at: http://www.research. lancs.ac.uk/portal/files/126987017/GAC_PolicyBrief.pdf
This research brief informs the analysis and findings from Part II, Chapter 5.

V. Thomas, M. J. Brueggemann, and D. Feldman. "i am more than the sum of my parts: an e-waste design fiction." Proceedings of the EnviroInfo and ICT4S Conference 2015. doi:10.2991/ict4s-env-15.2015.7
This publication inspired some of Part II, Chapter 5, and some of the future work contained in the conclusion.

A.2 Additional publications and outputs

C. Remy, O. Bates, **V. Thomas**, and E. M. Huang. "The Limits of Evaluating Sustainability" Proceedings of the third workshop on Computing within Limits, LIMITS '17.

M. J. Brueggemann, A. Strohmayer, M. Marshall, N. Birbeck, and **V, Thomas**. "Reflexive practices for the future of design education: an exercise in ethno-empathy." Proceedings of the 12th European Academy of Design Conference, 2017. doi: forthcoming

D. Wang and **V, Thomas**. "What is open design for ethnography? An open discussion." Proceedings of the Cumulus Conference, 2016. doi: forthcoming

V. Thomas, D. Wang, L. Mullagh, N. Dunn. "Where's Wally? In search of citizen perspectives on the smart city." *Sustainability, 8*(3). Special Issue "Towards True Smart and Green Cities?" doi:10.3390/su8030207
This publication inspired some of Part III

O. Bates, **V. Thomas**, A. Friday, M. Hazas. "Sustainability by Design?: from micro-studies to macro-action." Submitted to the CHI2016 workshop on Design patterns, principles, and strategies for Sustainable HCI, 2016.

P. Abel, M. Fox, R. Potts, D. Hemment, C. Thomson, P. Gajdos, S. Li, A. D. Vazquez, R. Barraclough, G. Schliwa, J. Lindley, S. Turner, J. Devitt, J. MacDonald, A. Lee, C. Trueblood, D. Maxwell, H. Mehrpouya, M. Woods, V. Walsh, A. Moisy, G. Islamoglu, G. Sherriff, **V. Thomas**, L. Devitt, K. Jennings, C. Speed, F. Tynan-O'Mahony, V. Gebhardt, L. Trimble, R. Raikes, and K. Monsen. "Re-writing the city: negotiating and reflecting on data streams." Proceedings of the 2015 British HCI Conference. doi: 10.1145/2783446.2783562

M. Büscher, M. Liegl, and **V. Thomas**. Collective intelligence in crises. In Social Collective Intelligence, Springer International Publishing, 2015. doi:10.1007/978-3-319-08681-1_12

A.3 Community engagement

- ISS 2016 posters and CHI'17 HCIxBorders Symposium committee member
- Paper reviews for CHI 2016 and 2017, alt.chi 2017, DIS 2016 and 2017, and 13th IFIP 9.4 (2015)
- Workshop Chair for the International Fictional Conference on Design Fiction's Futures (2016)
- Co-organiser of a DEN graduate student workshop at Tiree Tech Wave 2016
- Co-organiser of a DEN graduate student workshop at the DEN Summer School of 2016
- Co-organiser of a DEN graduate student social event before FutureEverything 2016
- Presenter at Re:publica 2017, Edmonton NextGen PechaKucha 23, Oxford Humanitarian Innovation Conference 2014.
- Invited expert/contributor: European Town Hall Meeting on Brexit (Feb 2017); RCA roundtable on Transition Design and Redistributed Manufacturing (Dec 2016).
- Attendee of DEN summer schools 2015 and 2016; UBISS 2014; UCL summerLab Medellin 2014; CADE vacation school 2014.
- Organiser of countless events and talks for students and academics at HighWire and in Lancaster's School of Computing and Communications

A.4 Awards

- Best Paper, Honourable Mention at 35th Annual CHI Conference, 2017
- Global Affairs Canada "International Policy Ideas Challenge" Finalist, 2016
- Best Paper at 8th International Forum on Urbanism conference, 2015
- Best Project at the 5th International UBI Summer School, 2014

Appendix B

Semi-Structured Interview Guides

B.1 HCI Researcher Study

- How old are you? (offer ranges: <20; 20-29; 30-39; 40-49; 50-59; 60-69; 70-79; 80<)
- Whereabouts do you work?
- How long have you been an HCI researcher?
- What is your educational background?
- Are you based in a permanent team at your university?

Main questions:

- Could you walk me through a typical day at work?
- Could you walk me through what you did during one of your most cherished projects (one that you have either run or participated in)? (this is the most important question, so prompt for more information about the response. If they don't cover the following, make sure you ask about motivations for undertaking the project, people they worked with, how they prepared for the project, what they did with the materials during the project, and what they did after the project.)
- What do you like most about your job?
- What do you like least about your job?
- What motivates you to keep doing this type of work?

B.2 Retrocomputing Study

- How old are you? (offer ranges: <20; 20-29; 30-39; 40-49; 50-59; 60-69; 70-79; 80<)
- What is your occupation?
- Where do you live?
- Would you describe yourself as a computer enthusiast? Why/why not?
- Would you describe yourself as an avid gamer? Why/why not?

Heirloom/vintage computing systems (inventory/use questions):

- What vintage gaming and computer systems do you own?
- Do you use all of the systems that you own?
- How often do you use those systems?
- How long have you owned those systems?
- How did you acquire those systems?

Repair questions:

- Have you ever needed to repair the systems?
  - If yes, how did you repair them? (ie. Did you personally repair the systems or did you take them to a repair service?)
    - If personal repair: how did you repair the systems? How did you diagnose the problem? Where did you acquire the replacement parts? Where did you acquire the skills to do this? Did you have a local or web-based support person or group? Did you create any media after the repair (e.g. youtube guide or instructables guide)?
    - If repair service: how did you find the repair service? Why did you use a repair service? Did they meet your repair needs?
  - If yes, how often have you needed to repair the systems? When was the last time you repaired a system?
  - If yes, have you found some systems easier to repair than others?

  - If no, are you concerned about needing to repair the systems? How do you imagine you will approach their repair should they breakdown?

- What circumstances would make you consider (or go through with) discarding the systems?

Motivation questions:

- Why do you keep these systems?
- What motivates you to use the systems?
- What motivates you to repair the systems? (if applicable)
- What motivates you not to use the systems? (e.g. store the, discard them)
- What motivates you not to repair the systems? (if applicable)
- What role does privacy play in your use of the systems?
- What role does sustainability play in your use of the systems?
- What role does nostalgia play in your use of the systems?