Sustainable Interaction Design: Invention & Disposal, Renewal & Reuse

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ABSTRACT
This paper presents the perspective that sustainability can and should be a central focus of interaction design—a perspective that is termed *Sustainable Interaction Design* (SID). As a starting point for a *perspective of sustainability*, *design* is defined as *an act of choosing among or informing choices of future ways of being.* This perspective of sustainability is presented in terms of design values, methods, and reasoning. The paper proposes (i) a rubric for understanding the material effects of particular interaction design cases in terms of forms of use, reuse, and disposal, and (ii) several principles to guide SID. The paper illustrates—with particular examples of design critique for interactive products and appeals to secondary research—how two of these principles may be applied to move the effects of designs from less preferred forms of use to more preferred ones. Finally, a vision for incorporating sustainability into the research and practice of interaction design is described.

Author Keywords
Sustainability, design, interaction design.

ACM Classification Keywords
H5.m. [Information interfaces and presentation (e.g., HCI)]: Miscellaneous. J.7. [Computers in other systems]: Consumer products. K.1. [The Computer Industry]: Markets. K.4.m. [Computers and society]: Miscellaneous.

INTRODUCTION

In this paper, I claim that sustainability can and should be a central focus of interaction design—a perspective that I call *Sustainable Interaction Design* (SID). I propose several aspects of a framing for a research program and methodology germane to this way of thinking about interaction design—a way of thinking that is critical for our collective futures. The vision—design—for this future concerns defining sustainability as a core semantics for interaction design. As a starting point for a *perspective of sustainability*, I define *design* as *an act of choosing among or informing choices of future ways of being,* a definition which is inspired by several important design authors—principally by Tony Fry's [14] notion of *defuturing* in his book "A New Design Philosophy: An Introduction to Defuturing" and as well by Willis' [47] notion of *ontological designing*, which itself owes to Winograd & Flores' [49] "Understanding Computers and Cognition: A New Foundation for Design" as well as to Heidegger's [18] essay "The Question concerning technology". Alexander's [1] recent work on *structure-preserving transformations* is also an inspiration. This definition of design from the perspective of sustainability serves as a lens through which design values, design methods, and designs themselves may be evaluated, especially in the context of interaction design.

Sustainability as a notion of viable futures can be defined to include aspects of the environment, public health, social equality and justice, as well as other conditions and choices about humanity and the biosphere [14]. In what follows, the focus is primarily on environmental sustainability and the link between interactive technologies and the use of resources, both from the point of view of how interactive technologies can be used to promote more sustainable behaviors and—with more emphasis here—from the point of view of how sustainability can be applied as a critical lens to the design of interactive systems, themselves.

In addition to proposing this perspective of sustainability, I propose a rubric for understanding and assessing the material effects induced by particular interaction design cases in terms of forms of use, reuse, and disposal from the perspective of sustainability. The items of the rubric are *disposal, salvage, recycling, remanufacturing for reuse, reuse as is, achieving longevity of use, sharing for maximal use, achieving heirloom status, finding wholesome alternatives to use,* and *active repair of misuse*. The important claim is that software and hardware are intimately connected to a cycle of mutual obsolescence with implications for the environmental sustainability and other sustainability effects and modes of use enumerated by the rubric.

Several principles can serve as goals for SID of which two are discussed in detail in this paper, namely (i) *linking invention & disposal*—by which I mean the idea that any design of new objects or systems with embedded materials of information technologies is incomplete without a corresponding account of what will become of the objects or systems that are displaced or obsoleted by such inventions, (ii) *promoting renewal & reuse*—by which I mean the idea

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that the design of objects or systems with embedded materials of information technologies implies the need to first and foremost consider the possibilities for renewal & reuse of existing objects or systems from the perspective of sustainability.

There are three additional principles that I will describe in less detail here, but which have import for achieving the first two, namely (iii) *promoting quality & equality*—by which I mean the idea that the design of new objects or systems with embedded materials of information technologies implies the need to consider *quality* as a construct of affect and longevity and *quality* in the sense of anticipating means of renewal & reuse, thereby motivating the prolonged value of such objects or systems and providing *equality* of experience to new owners of such objects and systems whenever ownership transfers, (iv) *de-coupling ownership & identity*—by which I mean the idea that the virtual world has irrevocably changed the way in which ownership of information and in particular ownership of personal identity are constructed and secured and that alternative notions of ownership and identity have design implications for sharing materials, intellectual commons, and sense of self-hood which must be considered as part of sustainable design of interactions with digital artifice, and (v) *using natural models & reflection*—by which I mean the prospect that there may be an approach to interaction design—even by the design of its removal—that prompts sustainable relationships to nature and that SID begins with a reflection on this principle of making the world of the artificial more like the natural world with respect to sustainability. These principles are not intended to be exhaustive—rather, they represent an initial focus and an intuition about some of what is important in order to set sustainability as the focus in the context of interaction design.

Situating SID as a focus within HCI requires some reflection. The very title *Human-Computer Interaction* has embedded within it meanings which are problematic from the perspectives of sustainability—it is anthropocentric, and even if the anthropocentrism was not in-and-of-itself a condition of ontological blindness, the sense of human-centeredness in the HCI context is oftentimes construed as a notion of method in which engineering "needs and requirements" follow from cognitive models of "users," rather than a concern for human conditions, particular or global. There are notable exceptions to this "needs and requirements" construction of human-centeredness within the HCI literature, which include as only a partial list writings by Friedman and others [10-13], Kling & Starr [20], Nardi & O'Day [29], Muller & Wharton [28], and Winograd & Flores [49]. Writing about the larger importance of ethnography in HCI, Paul Dourish [8] provides the following insight: *"What matters is not simply what those implications* [for design needs and requirements] *are; what matters is why and how they were arrived at, and what kinds of intellectual (and moral and political) commitments they embody, and what kinds of models they reflect."*

It also needs to be said that the HCI community is one which has proved itself to be receptive to new ideas and multi-disciplinary discourse—*designerly perspective* is more and more available at CHI, beginning perhaps with one of the first such papers by Fallman [8]. Nonetheless, the skills associated with expertise in HCI are hard won and technical at their foundation, creating a context for the HCI community that oftentimes seems apart from other design disciplines and that oftentimes seems to see itself and to be seen by its clients as a service provider of product elements of "user" experience and usability. Both the difficulty of setting sustainability as a focus within such a landscape and the somewhat challenging prescription for actually doing so are expressed passionately for the case of the design disciplines in general by Tony Fry [14] as follows: *"Currently industry* […] *is still overwhelmingly deaf to those voices that speak of the complexity of un-sustainability, the poverty of current responses to it, the misplaced faith in technological solutions, the myopia of present political and corporate leadership and the extent of changes that are required if a psychology, culture and economy of sustainment are to ever arrive.*

This deafness also extends to the mass of the design community. In this situation, there are no passive or neutral positions. Service providers who timidly subordinate themselves to the will of clients who trade in the unsustainable are enemies of viable futures. This is not to say that designers should commit economic suicide—it is to say that they need to learn (a) how to design in a far more complex and critical frame, while developing a language of engagement with the ability to constitute dialogues of transformation with 'clients' or communities and (b) how to develop new and economically workable path finding and service practices."

Put another way, the challenge is to learn how to set sustainability as a focus of interaction design in a manner that can succeed by widely motivating the will for sustainable behaviors as part of an economically-viable *viable* future, rather than by expecting such effects to be solely the dominion of legislation and public policy. Fry's statement acknowledges the value tensions between sustainability goals and those of enterprise, while prescribing an ethical imperative for designers to confront such tensions with a "*language of engagement"* which advances the case for sustainability.

Nicolas Makelberge [25] has also written about what may be characterized as a sense of *ennui* surrounding the failure of technology-centered thought within HCI to explain the role of interaction design in an ontological sense of designing and being designed in the world. In Makelberge's writing, this sense is especially strong *apropos* of the notion within the HCI community of ubiquitous computing as an agenda of material improvement—an agenda which demands reflection

in terms of issues of quality of life: *"As the 'less evolved'* [Native American] *of the 18th century North America much better understood how his consumption impacted on his surrounding, we now 'more evolved' stand clueless. If he was in the need of meat, he had had to kill a buffalo. Today when we get a car, the global economy has taken us far from the real impact and consequences of our decision. The gasoline, the plastics, the rubber, the fabrics that go into making and maintaining a car is not derived from our backyards where we can see the direct consequences of our decision. They are derived from some place else, often poorer nations with little chance to raise their voice or organize themselves politically. It's often their backyard and therefore problem. Billions of people on this planet consume junk with no apparent clue on how it affects someone else's surroundings."*

In an editorial description of Makelberge's essay, Anne-Marie Willis [48] describes Makelberge's insights as originating "*from the inside of this* [HCI] *outside"*—where by *"outside"*, she means to include the notion that HCI as a discipline has not yet understood sustainability to be a central design ideal. This present paper is a *tableau* for working out the problems implied by these insights, in order to open the possibility that notions of sustainability can be adopted in a meaningful way—indeed, a sustainable way—by the larger *outside* community of informatics.

Notions of sustainability and design are common—nonetheless, there is little written specifically about sustainability and interaction design in the main corpus of the HCI literature—the Association for Computing Machinery's (ACM) digital library in particular—and concern for sustainability in the arena of interaction design is in an apparent infancy. Environmental sustainability has been identified as a human value that is *implicated* in system design in Friedman, Kahn, & Borning [10]. There is much that deals with values and value tensions, specifically *Value Sensitive Design (VSD)* by Friedman and others [10-13]. It is possible to consider SID to be situated as a concern within this established area of HCI. We might also include Kling & Star [19] as a contribution to the notion of values-oriented design of technologies. A workshop was held on this topic at the 1997 CHI conference [28]. Another workshop on the social implications of ubiquitous computing occurred at the 2005 CHI conference [6]. The DPPI conferences included work on this theme by Reed, Wang, & Blevis [37] and Woolley [50]. In Blevis et al. [4], environmental decision making is used as the content matter for investigating interactivity. As a sign of the importance of this perspective of sustainability and emergent interest in it, this claim has now been echoed in a proposed special interest group meeting at this conference [24] which references this paper as well as [2]. One of the reviewers of this paper provided the following very insightful summary statement of much of its spirit: *"sustainability* [should be] *more than just recycling, and indeed* [must become] *a cultural paradigm shift away from technology novelty and induced consumption, toward an aesthetic of well-cared-for systems."* That same reviewer suggested that understanding the role of technology in such ambitions for cultural change is key—an understanding which this paper modestly frames as important research for the larger community of HCI and interaction design.

In the context of design in general, sustainability has wider treatment. The journal *Design Philosophy Papers* is devoted to issues of sustainability and design. Tony Fry [14] introduces and defines notions of *defuturing*—by which he means that the unintended effects of design, even well-intentioned, can alter our collective futures in undesirable ways. He as well defines the terms *futuring, sustainability,* and *un-sustainability* as the basic tools for philosophical discourse about sustainable design. In his recent work, Christopher Alexander [1] describes the notion of *structure-preserving transformations*, by which he means the ideal of the designer to preserve old things in the construction of new ones, just as nature does—one of the examples he gives is that the fern that becomes a tree contains the original fern. Alexander's treatment of the relationship between nature and artifice is a counterpoint to Simon's [40] treatment of the topic. More generally, the need to understand design in a values-rich way is central to many design writers including Cross [7], Löwgren & Stolterman [23], Margolin [26,27], Nelson & Stolterman [30], Papanek [35], Schön [38], Stegall [41], and Thackara [42], and this list is by no means complete.

SUSTAINABLE INTERACTION DESIGN

In this section, SID is presented from the perspectives of a general framework for describing notions of design in terms of *design values, methods,* and *reasoning* [3]. As well, I propose some open research questions for SID.

Values

From the perspective of design values, *design* may be defined as *an act of choosing among or informing choices of future ways of being*. There are much more common notions of design values, which include all notions of what design can be construed to be about—from (a) the most common and banal view that design is about acts of decoration, to (b) the view that design is about the valuation of particular objects themselves, to (c) the view that design is about features and functions of objects, to (d) the view that design is about affordances of objects (see Norman [32] and Gibson [16]), to (e) the view that design is about affective aspects of objects (see Norman [31]), to (f) the view that design is about interactions between people and objects, to (g) the view that design is about interactions between people and environments, to (h) the view that design is about whole ecologies of people and environments (see Nardi [29]), to (i) the present view that design is about choices that lead to sustainable futures (after Fry [14]).

It would be politic to claim that all of these notions of design values are equally valid *and they are,* but they are not all equally vital. In Kumar et al. [21], an equation due to Graedel

and Allenby [17] is set in contemporary terms—that is from a global perspective

$$I = N \times P \times E$$

where the total impact, I, of energy consumption, material resource use, and waste production is defined as a product of the population size N, the Gross Domestic Product (GDP) per capita P, and the specific impact as a measure of eco-efficiency which may be understood as energy use per GDP per capita E.

Based on figures from the International Energy Association (IEA) and the Union of Concerned Scientists (UCS), Kumar et al. [21] make predictions that the earth's population N will increase by a factor of 2 to 10 billion by the year 2050, and that GDP per capita P will increase by a factor of 5, conservatively stated. Thus, in order only to do no more harm than we are already doing to the environment, we need to reduce energy use per capita E by a factor of 10. Kumar et al. [21] further point out that the improvement in efficiency in the use of energy over the last 100 years has only been a factor of 2.5, that faith in technology as usual cannot succeed, and that new thinking is critical to our survival.

For the scientific community, these predictions are not at all controversial. Thus, sustainability must be counted among the distinguished and primary design values in any context. At the very least, the goal of SID is to provide frameworks and discourse that enable interaction designers to reflect on sustainability as a design value and situate and balance notions of sustainability with respect to other design values.

Methods

From the perspective of design methods, one way to think about SID is as the notion that methods for interaction design need to integrate concern for potential effects on the environment, and for the sustainability of the behaviors induced by designed interactions. Sustainability need not be restricted only to the centrality of environmentalist concerns—for example, an hypothesis about the effects of interactive computer games on the prevalence of obesity (see [44], for example) is within the scope of SID and the prevalence of obesity is an example of an unsustainable behavior. A goal of SID is to suggest ways in which sustainability concerns can be integrated into existing design methods or new design methods in a manner that yields sustainable interaction design as a practice.

Methods expressed as belief in prescriptions for design processes are at the core of the research in HCI and software engineering. Löwgren & Stolterman [23]:c4 describe an inventory of such methods with an eye towards the limitations. The complexity of relationships between digital artifice and sustainability effects make the notion of methods as usual problematic for the cause of SID. Design methods for dealing with the complexity of SID would do well to include those common in other design disciplines, such as design critiques, design case studies, and reflective practices (see Cross [7], Fallman [9], and Schön [38]), at least in addition to general models of process as enumerated in HCI texts such as Preece, Rogers, & Sharp [36].

Reasoning

From the perspective of design reasoning, one way to think about SID is as the notion that representations and interpretations of interaction design should as well denote and account for the effects of a design on the environment and sustainable behaviors. I would begin such a discourse by proposing the following rubric for understanding and assessing particular interaction design cases in terms of forms of use, reuse, and disposal from the perspective of sustainability, ordered very approximately from greatest to least negative environmental impact:

1. **disposal**—does the design cause the disposal of physical material, directly or indirectly and even if the primary material of the design is digital material?
2. **salvage**—does the design enable the recovery of previously discarded physical material, directly or indirectly and even if the primary material of the design is digital material?
3. **recycling**—does the design make use of recycled physical materials or provide for the future recycling of physical materials, directly or indirectly and even if the primary material of the design is digital material?
4. **remanufacturing for reuse**—does the design provide for the renewal of physical material for reuse or updated use, directly or indirectly and even if the primary material of the design is digital material?
5. **reuse as is**—does the design provide for transfer of ownership, directly or indirectly and even if the primary material of the design is digital material?
6. **achieving longevity of use**—does the design allow for long term use of physical materials by a single owner without transfer of ownership, directly or indirectly and even if the primary material of the design is digital material?
7. **sharing for maximal use**—does the design allow for use of physical materials by many people as a construct of dynamic ownership, directly or indirectly and even if the primary material of the design is digital material?
8. **achieving heirloom status**—does the design create artifice of long-lived appeal that motivates preservation such that transfer of ownership preserves quality of experience, directly or indirectly and even if the primary material of the design is digital material? This notion of heirloom status is similar to Nelson & Stolterman's [30] description of "ensoulment".
9. **finding wholesome alternatives to use**—does the design eliminate the need for the use of physical resources, while still preserving or even ameliorating qualities of life in a manner that is sensitive to and scaffolds human motivations and desires?

10. **active repair of misuse**—is the design specifically targeted at repairing the harmful effects of unsustainable use, substituting sustainable use in its place?

The rubric above provides a mechanism for informal, heuristic reasoning about the sustainability outcomes of physical materials induced by interaction designs. Notions of *"Multi-Use"* and *"Zero Waste"* as described in Kumar et al. [21] map onto all but the first item of the rubric. More formal reasoning is also possible. As described in Kurk & McNamara [22]:22, the consulting firm PRe Consultants has devised a metric called ECO indicator 99 for the Dutch government which may be understood as a notion for formalizing reasoning about the environmental effects of a design, in general. While such metrics may seem overly reductive in some contexts, we might easily imagine an ECO index specifically for interaction design. I will suggest methods which appeal to such formalism in future work.

In [2], a paper which follows from this one, I give examples for each of the elements of the rubric, as well as distinguish between the use of the rubric from the perspective of *"design criticism—what is needed to understand and interpret present ways of being"*—as a complement to the perspective of *"critical design—what is needed to ensure that our actions lead to sustainable future ways of being."*

Open Research Questions

There are a number of research questions concerning SID that are appropriate. It is not possible to be exhaustive here. Also, some of these question imply the possibility for more formal techniques than some others. I divide the questions into two categories.

The first category includes questions concerning public policy, simulation & prediction, such as: (a) How can the effects of information technologies on unsustainable behaviors be measured? (b) How can the effects of harmful use of information technologies be predicted, or simulated? (c) What can be learned about SID *apropos* of sustainable behaviors from past experience? (d) What can be learned about SID *apropos* of sustainable behaviors from other societies? (e) How much damage both environmental and otherwise has already occurred? (f) Who is responsible for ensuring that design with the materials of technologies is directed towards sustainability?

The second category includes questions concerning motivating sustainable behaviors by means of sustainable interaction design, such as: (a) How can digital artifice be designed such that people will prefer sustainable behaviors to unsustainable ones? (b) How can the effects of invention be connected to the effects of disposal in the view of interaction designers and in the public view? (c) How can renewal & reuse of digital artifice be made to be more attractive than invention & disposal in the view of interaction designers and in the public view? (d) What would it take in the design of digital artifice—as opposed to dictates of public policy—to get people to prefer renewal & reuse to invention & disposal? (e) How can quality and equality of experience be used to promote longevity of digital artifice? (f) How can quality in the design of digital artifice be made available to everyone, promoting equality of experience and longevity? (g) How can we get people to want and demand sustainable design with the materials of technology? (h) How have digital technologies already transformed notions of ownership and identity, and what is the sustainable design response to the present condition? (i) Assuming that not everyone will be willing to give up the materialism that drives unsustainable behaviors, how can design influence more sustainable consumption and what are the tools that can allow designers to do so?

PRINCIPLES FOR DESIGNING ACCORDING TO THE PERSPECTIVE OF SUSTAINABILITY

The rubric for understanding particular interaction design cases in terms of forms of use, reuse, and disposal from the perspective of sustainability—*disposal, salvage, recycling, remanufacturing for reuse, reuse as is, achieving longevity of use, sharing for maximal use, achieving heirloom status, finding wholesome alternatives to use,* and *active repair of misuse*—is useful for understanding the environmental impact of interaction design in terms of use of physical materials and resources, however prompted by the use of digital materials. The principles presented in the introduction are general, informal rules of design for considering how the use of digital materials actually prompts the use of physical ones and motivates behaviors that affect sustainability one way or another as part of design process, specifically

(i) **linking invention & disposal—**is a principle that links *invention* as a cause of *disposal*,

(ii) **promoting renewal & reuse—**is a principle about the first-order design requirement for sustainability which includes several of the categories in the rubric above, namely *salvage, recycling, remanufacturing for reuse, reuse as is, and sharing for maximal use*,

which are the principles treated in this paper. There are three more principles for future report, all of which relate to finding ways to promote renewal & reuse over invention & disposal:

(iii) **promoting quality & equality—**is a principle about the second-order design requirement for sustainability concerning what is required to motivate *reuse as is, achieving longevity of use, sharing for maximal use,* and *achieving heirloom status,*

(iv) **de-coupling ownership & identity—**is a broadly construed principle about fashion, the commons, security & privacy, and sense of selfhood in the context of globally changing conditions for the construct of identity as these motivate relationships to the materials of consumption, especially with respect to the possibilities for *sharing for maximal use,*

(v) **using natural models & reflection—**is a principle about promoting imitation of use of resources in nature

and the design method for so doing, a theme which is also especially connected to *achieving longevity of use, sharing for maximal use, achieving heirloom status, finding wholesome alternatives to use,* and *active repair of misuse.*

These principles for designing according to the perspective of sustainability imply goals for moving the material effects of design from less desirable to more preferred ones. It is easier to state the kinds of behaviors we would like to achieve from the perspective of sustainability than it is to account for how such behaviors may be adequately motivated—to the point, Stegall [41] claims that *"the role of the designer in developing a sustainable society is not simply to create 'sustainable products,' but rather to envision products, processes, and services that encourage widespread sustainable behavior."* For Stegall, the intention on the part of designers to *"encourage positive constructive ways of life"* must be part of the design of artifice. Fry [14]:2,284 points out that intention in-and-of-itself is not enough, since unsustainable effects can oftentimes follow from the best of intentions.

In what follows, I describe in more detail the two initial principles with an eye towards understanding how interaction designers can evaluate and predict the effects of their craft on sustainable behaviors, providing some examples in the perspective of design criticism for each of the principles.

LINKING INVENTION & DISPOSAL

By *linking invention & disposal,* I mean the idea that any design of new objects or systems with embedded materials of information technologies is incomplete without a corresponding account of what will become of the objects or systems that are displaced or obsoleted by such inventions.

At first glance, if we think of software as a material of interaction design, then the principle of linking invention & disposal seems not to be a concern—no one will be worried about the environmental impact of replacing old bits with new ones and the disposal of the old bits seems not to be a concern for sustainability. This notion of regarding software as a material of design owes to a notion of digital artifacts as being composed from *materials without qualities* as described by Löwgren & Stolterman [23]. By *materials without qualities*, Löwgren & Stolterman mean simply that even though digital artifacts do not have physical qualities in the same sense as fabric and concrete, they may still be regarded as material. In Blevis, Lim, & Stolterman [3], the relation between Löwgren & Stolterman's notion of software as a material of design and the *values, methods,* and *reasoning* framework used to structure the section on SID above is described.

On further reflection, it is apparent that software is material that *prompts physical qualities* in the sense that it drives the demand for new hardware, and as such it causes pre-mature disposal of perfectly adequate physical materials through obsolescence—too often, *software* may be almost wholly defined as *that insidious material of digital artifice that causes the premature obsolescence of physical materials.* Newly invented hardware capabilities in turn prompt the invention of new software. To my knowledge, the data needed to understand the scope of this principle as an hypothesis does not exist—it would be an important undertaking to uncover such information in a systematic way. In any event, take as axiomatic and without controversy the notion that software is not *the* material of interaction design, but rather *a* material of interaction design and that software, hardware, and other materials of interactive technologies are all within the dominion of interaction design in general, SID in particular. Such a perspective is endorsed and without controversy within the HCI community, especially under the banners of *pervasive and ubiquitous computing* (see Weiser [45,46]) and *invisible computing* (see Norman [33]).

Importantly, Jain & Wullert [19] have argued for the responsibility of pervasive computing as a discipline to consider the environmental impacts of disposal and energy consumption of pervasive computing devices. One of the reviewers provided the insightful observation that *"the severity of this problem is unprecedented because none of the previous "revolutions" (e.g. industrial, etc.) faced the scale and growth-rate similar to this problem."*

There is a clearly documented problem with electronic trash, even if it is not easy to provide quantification of the link to software as a driver of the obsolescence of physical materials. The toxic composition of discarded computer electronics is well documented in Townsend et al. [43]. Writing in the journal "Environmental Health Perspectives", Charles Schmidt [39] reports that: *"Hungry for information technology but with a limited capacity to manufacture it, Africa has become the world's latest destination for obsolete electronic equipment. Much of this material is more or less functional and provided in good faith by well-meaning donors. But the brokers who arrange these exports often pad shipping containers with useless junk, essentially saddling African importers with electronic garbage."*

Bhuie et al. [5] report that whereas some 70% of cell phones are re-manufactured for reuse in the United States, most personal computers are discarded as re-manufacturing is not particularly viable from a marketplace point of view. In the US, the cost of upgrading an old personal computer is oftentimes considerably more than the cost of replacing it with a new one—a condition which almost certainly owes more to marketing practices than to actual costs of manufacture. The Hewlett Packard (HP) company does have a program that allows consumers and businesses to trade-in old equipment, even equipment that was not manufactured by HP. The depreciated trade-in allowance for the one year old HP laptop on which I am writing this article is only 20% of the original value according to the companies' web-site. The company accepts any old equipment for recycling—non HP equipment is accepted at the consumer's expense. It costs

Figure 1. The Apple iPod and the 1959 Braun TP1 radio module by Dieter Rams

$9.00 US plus shipping to recycle a laptop computer. The company claims to handle 3 million pounds of equipment per month, claiming to reduce such equipment to raw materials for the manufacture of new equipment. Apple Computer has a similar program, as does Dell, according to company web-sites.

While these programs are possibly laudable, the heart of the matter is much more complex than just providing an outlet for conscientious consumers to discard their old computing devices when they wish to acquire new ones. There are a lot of question to ask: What is driving this consumption? Why can't such devices be designed to be more easily upgraded to newer technologies? How many consumers will actually pay to responsibly dispose of old equipment?

From a designerly perspective of sustainability, the issue of how invention drives disposal means understanding why people want new things and looking for ways to get them to prefer the alternatives to such cycles of acquisition and disposal. One hopes that the companies will respond to such changes in preferences should they be achieved with new marketplace models, such as models that create incentives for renewal & reuse, rather than acquisition of new things and disposal of old ones, or models that create incentives for shared use. Modularity, upgrade-ability, and construction from enduring materials are some of the obvious ways in which this can be achieved—if companies are willing to imagine alternative models of commerce. Such preferences are a matter of fashion and design, rather than engineering and feature-driven marketing. For example, there are many mp3 players that preceded the Apple iPod, but Apple succeeded in turning the mp3 player into an item of fashion both through the design of form and through the design of systemic support in the guise of iTunes. A sustainability proposition in this case is that to be truly responsible from the perspective of sustainability, Apple needs to use its fashion and design talents to make it *chic* to want to own and keep an heirloom quality iPod, even if some of its components need to be updated from time to time and rather than making it fashionable to have the new and latest iPod. The hopeful corollary to this proposition is that if people begin to prefer

Figure 2. Street photography

long lasting digital products that can be updated rather than disposed, companies like Apple will respond with appropriate fashion, design, and marketing models, and other companies will follow.

The observation that the iPod looks to be inspired in form by the Dieter Rams 1959 design for the Braun TP1 radio (shown as thumbnails in Figure 1) is so pervasive that it is hard to know whom to credit. The comparison demonstrates that the invention on Apple's part is not so much in the product form, but rather in many other aspects of the design's context. One would have hoped that the digital nature of the media that the iPod houses would be hardware-preserving and as timeless as a quality radio. Sadly, the re-invention by Apple of its own product from time to time—from the original iPod to the mini to the nano—is a deliberately unsustainable act intent on driving consumption and with the clear side effect of premature disposal.

The material effects of digital photography are different than the material effects of digital music. As another—but not entirely comparable—case, Figure 2 is a photographic triptych of thumbnails that show an effect of digital invention as an instrument of disposal. The first thumbnail is the late Andreas Feininger's 1951 self portrait in which the icon of street photography—a Leica screw mount camera—has become one with the photographer's face, describing a harmony of photographer and tool. The second thumbnail is a famous portrait of the late Henri Cartier-Bresson holding a later Leica M-mount camera. The Leica cameras in both the first and second thumbnails are heirloom quality, professional objects. Many of these cameras are still in use, even in the digital age. The lenses made for these cameras still fit modern versions of the camera, including the long-awaited and unimaginably expensive digital version which has just come to market and which looks not very different than these earlier examples (Figure 3)—this backwards compatibility of such critical components as lenses is an act of sustainable design more typical of professional quality tools than consumer products. The third thumbnail shows the modern notion of a street camera—the cell phone camera. The ubiquity of this new form comes at the expense of

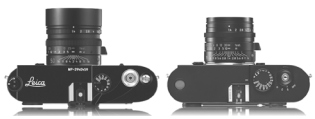

Figure 3. The Leica MP film camera (left) and the M8 digital camera (right)

Figure 4. The Garmin nüvi 350

quality both in terms of image quality and longevity of use, but ironically greatly increases the opportunities for everyday creation of street images by everyday people.

It is this kind of criticism of the particular cases like the iPod and the contrasts between the Leica and the cell phone camera that illustrates how the principle of linking invention & disposal can be applied. In the context of HCI and interaction design. Donald Norman—particularly in [33,34]—is known for this kind of design criticism. Nonetheless, the practice of design criticism of particular cases is not typical of HCI, which tends in an effort to be scientific to try to abstract interactivity in general from the use of interactivity in particular. Because of the complexities of understanding context, markets, fashion, and so on, this technique of focusing on particular design cases by means of design criticism is a useful method for SID that can be understood to be core design research.

PROMOTING RENEWAL & REUSE

By *promoting renewal & reuse*, I mean the idea that the design of objects or systems with embedded materials of information technologies implies the need to first and foremost consider the possibilities for renewal and reuse of existing objects or systems from the perspective of sustainability.

As with *linking invention & disposal*, one imagines at first glance that software as a material of bits makes renewal & reuse possible in ways that were not before possible—software updates do not directly imply the destruction of physical materials. Nonetheless, the same insights about the cycle of software requiring new hardware and hardware prompting new software apply. Especially with respect to the trend towards peoples' conceptions of computers as information appliances (see Norman [33]), the ideal of renewal and reuse by means of software revision seems more remote. As an example, newly introduced GPS navigation devices that come with all of the maps and mapping software pre-loaded (Figure 4) have displaced older models which required users to download the maps on an as needed basis or mapping applications targeted at PDAs. It may be possible that the appliance metaphor once in peoples' consciousness means that renewal by means of software updates is too onerous a process, since it is not part of the typical cognitive model of an appliance. This needs to be studied systematically. The appliance metaphor may invite a preference for invention & disposal over renewal & reuse.

It is possible to regard the GPS device of Figure 4 as little more than a non-essential, and environmentally harmful object of techno-fetishism. In the global scheme of things, there are many things that seem more important than creating demand for such devices by the affluent peoples of the world.

All such considerations notwithstanding, the particular Garmin nüvi 350 GPS device is a remarkably well-designed product from an interactivity point of view and a much better example of well-crafted interaction design than possibly any general purpose computing device. Because GPS devices vary considerably one-from-another, it is important and designerly to provide critiques of particular examples. It is possible to sketch a portion of a design critique of the Garmin nüvi 350 from a perspective of sustainability. Nothing is ever simple—this device has apparent properties that make it an environmental hazard as well as apparent properties that make it possibly contribute to sustainable behaviors. The possible **un-sustainability effects** include: (a) the distractions to the driver from cognitive overload create safety risks; (b) the device may be easily perceived as obsolete by many consumers as newer models are introduced; (c) the device must be connected to a computer with a DVD-ROM to be updated and many consumers may possibly just buy another newer unit rather than purchase updated maps; (d) this is not an essential device, except perhaps for those few who frequently travel in unfamiliar places; (e) the mp3 player is limited to SD storage card capacity, which is much less capacity than dedicated mp3 players like the iPod. The possible **sustainability effects** include: (a) the availability of directions, especially to goods and services *en route* can shorten driving times; (b) the device allows updating of older vehicles to include the navigation features of newer vehicles; (c) the device can be updated with newer maps; (d) the device is portable and useful for navigating at a destination when traveling by airplane, unlike dedicated factory installed vehicle navigation devices; (e) the mp3 player function may limit purchases of additional dedicated mp3 players.

One of the more compelling possible effects on the positive side is that the Garmin GPS can actually provide a means of renewal and modernization for older vehicles. The environmental benefits of renewing and reusing older vehicles may possibly outweigh the environmental benefits of substituting old vehicles with newer ones, even when the newer ones use cleaner technologies—the environmental costs of disposal and manufacturing need to be taken into account. Furthermore, if the means of renewal and modernization are available to consumers for some things and consumers come to demand a culture of renewal and reuse, perhaps manufacturers will concentrate on marketing those very same cleaner technologies as updates to existing vehicles rather than incentives for the purchase of the new and the disposal of the old.

Even if the primary effects of interactive technologies tend to drive disposal, rather than renewal & reuse, there are some notable examples of the use of technologies to improve sustainability practices or help repair the effects of technologies on sustainable behaviors. The web-site *www.freecycle.org* is one of a number of internet-enabled communities that provides a mechanism for people to give unwanted things away to others who might use them rather than discard such things. Here, the internet has the potential to facilitate reuse on a scale that was previously not possible. The Australian company Cartridge World is a world-wide

franchise that seeks to make it easy for people to refill inkjet printer cartridges rather than purchase new ones. The company USA Notebook.Com, Inc. is in the business of remanufacturing laptop computers and making them available for sale over the internet, providing a warranty to its customers. Compared to the social machinery of consumption created by computer manufacturers, these are small efforts that are nonetheless notable in their intentions.

As an issue of contemporary politics and market forces in general, renewal & reuse has little chance in the face of invention & disposal—but this may not always be so. As an issue of science, there are hopelessly too many variables to be able to determine the exact tradeoffs in environmental costs between renewal & reuse and invention & disposal in the general case—but it may be possible to do so in specific cases. As an issue of design, designers need to consider the possible positive and negative sustainability effects as part of the design of each and every interactive device—preferring renewal & reuse to invention & disposal whenever possible and as an instrument of positive change.

BEYOND INVENTION & DISPOSAL, RENEWAL & REUSE

It is not enough to hope that people will prefer renewal & reuse to invention & disposal—human nature must be taken into account. At least in the United States, people seem to have a strong preference for new things over old ones. There are aspects of style, status, and self-image that affect such preferences as much as issues of form and function. This seems to be even more true of information appliances than other products, since information appliances have particularly rapid depreciation and face early retirement from service due to frequent obsolescence. In other work, I am working with colleagues to conduct surveys in order to better understand just how valid is the notion that people prefer new things to old, especially in the case of information appliances. The principles for future discussion of quality & equality, ownership & identity, natural models & reflection are targeted at providing a key for how to make it easier for people to prefer renewal & reuse to invention & disposal, by trying to understand how old things and renewed things can be made to be perceived to be just as good or better than new ones.

If things are designed and constructed with sufficient quality and modularity, people may be inclined to look after them and selectively update them creating the effect of achieving longevity of use. Furthermore, quality things provide equality of ownership to those who may not be the first owner of such things. This is especially important not just as an issue of renewal & reuse by the affluent, but also as it concerns the conscientious redistribution of older technologies in global terms. In the US, 567 million new windows-based computers have been purchased since 1981 and nearly half (267M) of those machines have been purchased in the last 5 years, as interpreted from figures in an August 14, 2006 press release from the marketing research firm, Computer Industry Almanac, Inc. This means that the number of computers purchased new in the US in the last 5 years is equal to nearly 90% of the number of people who actually live in the US. The 567M figure represents slightly more than a third of worldwide sales. Such behavior is environmentally unsustainable, especially in the event that others adopt US patterns of consumption. The responsibility for *designing otherwise*—a term which owes to Fry [14]:266—rests with us.

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