Abstract
A review of the past decade of human-computer interaction relating to environmental issues identifies three discourses whose commitments and assumptions have consequences for the design of new interfaces and interactive systems: sustainable interaction design, re- visioning consumption and citizen sensing. It suggests two promising directions for future research: participatory design and infrastructure.

Keywords
Sustainability, design, discourse

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
To protect the nature that is all around us, we must think long and hard about the nature we carry around inside our heads. [10]

The field of human-computer interaction has seen a recent “burgeoning” [33] of work on the environment and particularly environmental sustainability: prototype systems, workshops, publications, special journal issues, and magazine articles. These projects address a dizzying array of technologies and contexts in response
to predicted dangers to humanity such as climate change, environmental pollution, and resource depletion. The goals of these projects include: intervention in purchasing/disposal cycles; decreasing resource consumption in use; enabling more effective pollution detection; and frameworks for understanding environmentally positive practices and values.

How we frame problems as "environmental" and then evaluate potential solutions has specific, concrete consequences for the products we design and policies we promote as designers, engineers, and educators. The repetition of "environmental" and "sustainable" as descriptions of various programs and projects may obscure significant differences in theoretical orientation, research methodology, and practical objectives. In particular, unacknowledged "ubiquitous ambiguity" in notions of "the environment" and "environmental information" deserve attention as destabilizing sources of misunderstandings between proponents of different discourses.

While thoughtful literature reviews (especially in [4] and [44]) inform this overview, there is a dearth of systematic, detailed overviews of "environmental HCI." This paper attempts to remedy that lack. Its purpose is not to highlight one "best" approach to environmental questions and answers. Rather, it compares three environmental discourses within HCI to delineate some categories within this flourishing field of research and suggest promising areas for future work.

**Discourses of the environment in HCI**

But what exactly is the "environment" that we are protecting? One conventional definition within computer science includes all physical phenomena, such as "the soil, the water, and the species in the world around us" [16].

Historical geographer William Cronon’s classic *Uncommon Ground* [10] details how environmentalism as an intellectual and political movement has derived considerable rhetorical power from an assertion of "natural" purity in the face of human society and its technological products. Yet as a site of human beliefs and activities, "nature" and "the environment" can encompass multiple and even contradictory meanings [27]. Definitions of "the environment" and nature, and even their assumed worth, vary dramatically over time [15] and space – even over the distance of a few miles [27]. Engaging with the history of "nature" as a material experience and intellectual concept considerably complicates the notion that there is some objective, inarguable "environment" that our actions affect. As Cronon writes,

"Nature" is not so nearly so natural as it seems. Instead, it is a profoundly human construction. This is not to say that the nonhuman world is somehow unreal...But the way we describe and understand that world is so entangled with our own values and assumptions that the two can never be fully separated. [10]

Given the complexity of even a seemingly simple concept such as "the environment," can we talk about a specifically "environmental HCI"? If environmental HCI exists, is it a singular field or many? This literature review seeks to answer that question through a discourse analysis of the past decade of research in environmentally motivated HCI.
Table 1 Discourse analysis inventory

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Why the past decade? Certainly, environmental information systems – systems that collect and manage information about physical phenomena – have been a consistently popular subject for research over the past forty years within computer science and environmental informatics [18]. Research on motivations for environmentally positive behaviors has also been popular within applied and environmental psychology [26][41]. But as some observers have noticed, a recent flurry of papers and events has perhaps created its own "hype" [33], keeping us from critically analyzing sets of inherited assumptions (but see [43] for one such analysis) about the potential scope and role of HCI.

A discourse is "a shared way of apprehending the world," produced rhetorically through "assumptions, judgments, and contentions that provide the basic terms for analysis, debates, agreements, and disagreements." [15] Discourses influence more than debates. In framing thought, they have concrete consequences for action.

A “discourse analysis” is the systematic surfacing and naming of those frameworks through close reading of documents [1]. It is an appealing lens for studying environmental agendas in HCI because HCI as a field is itself constituted by discourse: publications, panels, grant applications, workshops, special interest groups (SIGs) and even prototype documentation. It is also an appealing tool for organization because it prioritizes not just what is said, but also the types of assumptions and gaps in attention that can suggest novel directions for research.

This review analyzes a collection of 120 documents on the subject of human-computer interaction related to “nature,” “the environment,” or “sustainability” published mainly within computer science or by researchers associated with the CHI community. It begins with a 1998 study of appliance “eco-feedback” [31], and ends in June 2008 with a study of "getting to green." [9] As well as research papers intended for academic audiences, the collection includes documentation of design processes and research agendas designed for a broader audience: prototypes, visual documentation, and project websites. Of course, this collection has limitations. Most importantly, using the NSF database biases results towards the United States. However, international participation in conferences and journals should diversify the perspectives of authors.

The resulting corpus of documents (summarized in Table 1) resulted in the identification of three separate discourses: sustainable interaction design, re-visioning consumption, and citizen sensing.
Sustainable interaction design

Sustainable interaction design (SID) draws on green industrial design philosophy [40] to call for change in manufacturing, use, and disposal practices. But it targets not just manufacturing technique improvements but human behavioral changes (also noted in [30]) through persuasive technology [35] that influences individuals as end-users [17], [19] and designers [32]. SID advocates the agency and central role of designers in mitigating those “material effects” (but see [34]) of computationally intensive lifestyles and working towards less damaging “viable futures” [4].

SID projects typically do not address individuals constrained by material circumstances such as poverty, by deeply-held beliefs about the role of technology, or by powerful political institutions (see [4] for a discussion). The users of technology are imagined as consumers with leisure and power to choose within a free market of possessions, services, and ideals. Often, SID projects draw on theories of behavioral psychology to predict that consumers given new information will change their behavior. Groups of people are often envisaged as social networks — freely elected associations linked on Facebook or other social network websites [29]. From this perspective, one role of designers is to influence technology consumers with information that motivates better decision-making. Successful projects influence people to change their behavior, creating widespread change incrementally.

Notions of free choice are embodied in three main design directions:

- Systems that provide information relevant to the sustainability of products and services
- Visualizations of resource consumption ([20] has a thorough summary of this genre).
- Persuasive applications, such as games [2][29].

These design choices emerge logically from the assumptions described above. Visualizations of energy use can be aesthetically appealing ways to induce behavior change with situationally appropriate information. Games provide a built-in incentive – winning – to motivate immediate behavior changes and perhaps longterm behavior modification.

Often, the goal of SID projects is to give consumers information about what they buy and use at the moment of consumption. We can also see how the choice of interfaces reflects an emphasis on private consumption: personal possessions [34], appliance accessories [17], body-worn communication devices [22] and office lobby displays [17].

Notions of choice and human agency are also exemplified through the footprint as a recurring metaphor for humans’ relationship with the environment. The footprint, it has been argued (quoted in [6]),

is a good metaphor for our individual impact on the social or natural environment. It’s personal, tactile, organic, and immediately comprehensible.

Whether referring to a “carbon footprint” (or measure of carbon dioxide output) [11] or simply to the general “ecological footprint” of resource consumption [30], the footprint symbolizes a view of humans as powerful actors, and the Earth as a passive site of their imprints.
Sustainability\(^1\) is a powerful and influential new orientation towards the environment within HCI. Blevis' definitional manifesto [4] received a CHI Best Paper Award in 2007, and is (perhaps consequently) the most cited paper retrieved by searches for "sustainable design" and "environmental decision making" in ACM's Portal. Projects self-identified as "sustainable interaction design" or substantially following the rhetoric of Blevis' original paper comprised 95 of the 120 items reviewed.

**Re-visioning consumption**

The focus of projects within re-visioning consumption is the enactment beliefs about the natural environment. One NSF grant award abstract sums up this approach [38]:

> to highlight the aspects of everyday IT design which are predicated on industrialized orientations such as mass production and consumption of consumer goods.

Researchers working to “re-vision” new approaches information technology often try to specify “what exactly” they mean by environmental responsibility [44]. One common approach is studies of “marginal” [38] groups and behaviors that represent viable alternatives to resource-intensive technology behaviors.

Re-visioning consumption examines how humans perceive their relationships to the material aspects of the world – both the human-built environment and the “natural” features of water, dirt, air, plants, and animals. Often focusing on values [32], re-visioning consumption tends to de-prioritize recommendations for immediate, active solutions to perceived environmental problems in favor of engagement with the imagined landscapes of human beliefs and aspirations. Constituting 14 of the 120 items reviewed, it is distinctly a minority approach to environmental HCI.

Re-visioning consumption attends to “orientations” to consumption not only as personal decisions but also as responses to shared experiences. Instead of defining users by how they consume technology, re-visioning consumption studies tend to define users through their membership in groups in spatially defined communities [30][38] or households [44] with coherent sets of beliefs about the non-human world. Research participants are identified as people with a specific orientation or “value commitment” [32] to a conception of “nature” [3] [30] or “green values” [32]. These belief systems emerge in dialogue [3] over time with local landscapes (see [44] and [3] for exploration of two very different landscapes and groups) and relationships with other people.

Re-visionist work often contributes not design interventions but plausible visions of how technology practices embody feelings toward nature such as connection [35] or belonging [3]. The canonical product of this approach is not the prototype but the probe [3][33] or critical art installation [5] – an ambiguous, flexible, yet richly inspirational experience “meant to inspire and provoke questions rather than just answer them” [5].

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\(^{1}\) Ie, the International Symposium on Electronics and the Environment has changed its name to the International Symposium on Sustainable Systems and Technology.
Citizen sensing projects often represent outcomes as technopolitical tools rather than products. Participatory Urbanism’s website promises “an architecture of participation and democracy,” while Bratton and Jeremijenko call for “ecosystemic interfaces” [7]. Of course, the use of visualizations in political action is not new. In the 1960s, the Club of Rome sounded a call for urgent environmental action with creating data visualizations derived from digital environmental models [15]. But unlike these earlier agendas, citizen sensing emphasizes community-based, “participatory” nature of data collection and visualization.

Like SID, citizen sensing relies on individual agency. But unlike SID, for whom people as consumers leave damaging footprints upon the earth, citizen sensing imagines people as public actors who need highly localized, reliable information to protect themselves from pollution. One striking metaphor used to promote citizen sensing to the general public is that of exposure. Exposure has a double meaning. Obviously, it means a personal encounter with harmful pollution. Yet it also highlights how data visualization exposes otherwise invisible environmental conditions, transforming them into tools for activism. Unsurprisingly, the main design outcomes of citizen sensing (besides sensor platforms) are computer-generated pollution maps (Fig 3).

New directions
Having identified and critically analyzed the assumptions, goals, and technological outcomes of these different orientations to environmentalism in HCI,
I outline two relatively under-explored areas that suggest promising directions for future work.

**Participatory design**

Histories of environmental movements argue [10][15][27] that there can be no universal agreement on the identity and extent not just of "environmental problems" but even "nature" itself. Even seemingly objective phenomena come to be seen as important or meaningful through human processes of contestation and negotiation, sometimes resulting in temporary "strategic essentialism" (as discussed in [14]) that produces only a temporary accord. Designers, engineers, and research participants cannot assume discussions rest on common ground. Even within HCI, subtle differences in discursive assumptions and metaphors may produce very different material outcomes. Designing effective, appropriate, accepted interventions in everyday perceptions, behaviors, and decisions may mean treating how people perceive their relationship to the living non-human world as a primary question for research rather than as the taken-for-granted design rationale.

One valuable but under explored (with notable exceptions of [12] and [13]) methodology for understanding how people define and perceive environmental issues is participatory design (PD). By giving potential users power within the design process, PD can help empower potential users to reflect upon and creatively respond to their own unmet needs [13] in a complex, respectful dialogue with the makers of new technologies. It can also help designers attend to the political and ethical responsibility inherent in persuading others to change their behavior [12].

**Moving beyond human-centered computing**

The discourses of environmental design have tended to be human-centered. They study the behaviors, desires, and beliefs of individual humans (sometimes in groups), and design largely for privately owned, human-defined artifacts such as homes, office buildings, cars, and mobile devices. Yet as noted in Williams [43], the possibilities for materially sustainable lifestyles are bound up in politically sensitive, less "tractable" negotiations with corporate and governmental infrastructures and institutions. As a discipline, HCI need not only encompass individual interfaces between humans and computing systems; it can and should grapple with the institutional politics of transit, finance, building construction, and state regulation. Such a turn towards the political and the infrastructural may require different theoretical orientations and pragmatic alliances. Moving beyond human-scale spaces and human-centered computing experiences does not mean abandoning an ethical concern for human well-being or the appropriateness and usability of technical systems. Environmental information systems have long stimulated longterm interdisciplinary partnerships between scientists; perhaps a new brand of environmental HCI will stimulate longterm partnerships between designers, policy makers, community activists, and non-profits.

**Conclusion**

The multiplicity of "environmental" viewpoints in HCI suggests that we should not imagine "environmental HCI" or "sustainable interaction design" as a singular agenda. There are instead multiple orientations to the environment, to the lives of users, and to the role of designers in current HCI research.
Though their methodological stances and favored outcomes differ, these discourses are not necessarily antagonistic. Proponents of the different discourses co-organize scholarly forums and co-author papers. They share common ground: that humans cause and are in turn damaged by planetary-wide problems of pollution and resource depletion; and that designers, businesspeople, engineers, and scientists have a responsibility to both humans and the rest of the planet.

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Citations


