Toward an Ecological Sensibility: Tools for Evaluating Sustainable HCI

M. Six Silberman
Department of Informatics
University of California, Irvine
msilberm@uci.edu

Bill Tomlinson
Department of Informatics
University of California, Irvine
wmt@uci.edu

CHI 2010, April 10–15, 2010. Atlanta, Georgia, USA.
ACM 978-1-60558-930-5/10/04.

Abstract
We are developing evaluation tools that help sustainable HCI researchers to contribute to the overall project of achieving sustainability. In this paper we argue for broadening sustainable HCI evaluation beyond traditional HCI evaluation. We describe unintended environmental consequences largely overlooked thus far in sustainable HCI evaluation. We discuss three categories of tools—principles, heuristics, and indices—that could facilitate evaluation of sustainable HCI projects, mainly by operationalizing definitions of sustainability. We suggest that sustainable HCI research could become more relevant by developing evaluations that link to understandings of sustainability beyond HCI, and more 'scientific' by developing more systematic evaluations, while acknowledging that many ways of knowing play important roles in both sustainability and HCI. Our next steps include developing these evaluation tools and applying them to published research.

Keywords
Sustainability, design, ecology, evaluation, methods.

ACM Classification Keywords
K.4.2 Computers and society: social issues.

General Terms
Design, Human Factors, Measurement, Theory.

Sustainable HCI evaluation challenges

Evaluation in sustainable HCI research to date has focused on familiar questions in HCI evaluation: what do users do? when? how often? why? how do they feel about it? what do they know about what they are doing? how do they know? and so on. Sustainable HCI research has been concerned to understand how users *relate* to their technologies, and how this can inform the design of technologies which will facilitate more sustainable use practices (e.g., [1], [2],[3], [4], [5], [6], [7], [8], [9], and, outside HCI proper, [10]). Asking and answering these kinds of questions—about users and their rich and complex social, cultural, and technological contexts, understandings, goals, and meanings—is a strength of HCI research and its methods. It is linked to HCI's construction as a field about *design*. However a growing body of work within HCI and at its margins (e.g., [11], [12], [13], [14], [15], [16], and [17]) suggests a broader analytical scope for studies of 'sustainability'.

Sustainable HCI research often assumes simple proxies for sustainability: number of car trips; quantity of energy use; manner of device disposal; etc. This has been expedient and has allowed for the proliferation of sustainable HCI research. But ecological systems and social behavior evince complex dynamics, and well-intentioned interventions often lead to unexpected—and sometimes undesirable—consequences.

A recent insurance industry study, for example, concluded that US owners of hybrid cars drive on average 25% more than owners of non-hybrids [18]. If the average hybrid vehicle is less than 25% more fuel-efficient than the average non-hybrid, hybrid development and marketing may have led to a net increase in carbon dioxide emissions—and thus a net loss of sustainability—at least in the US.

More generally, the phenomenon of 'induced demand' is widely appreciated among economists and transportation planners. It describes a situation in which increased supply of a good or service—for example, the construction of new roads—leads to a growth in demand. Road construction often leads to more traffic, not less. To reduce traffic, do not build more roads.

This phenomenon also describes the driving habits of hybrid owners: increased efficiency leads to demand growth by expanding the supply of vehicle-miles available at a particular total cost. Demand growth can exceed gains from efficiency, leading to a net increase in gasoline consumption.

Environmental management is filled with related stories of unintended consequences. Consider one from Macquarie Island, southeast of Australia, reported this February in the *New York Times*:

In 1985, Australian scientists kicked off an ambitious plan: to kill off non-native cats that had been prowling the island's slopes[,] preying on native burrowing birds. Twenty-four years later, a team of scientists ... reports that the cat removal unexpectedly wreaked havoc on the island ecosystem. With the cats gone, the island's rabbits (also non-native) began to breed out of control, ravaging native plants and sending ripple effects throughout the ecosystem.

"Our findings show that it's important for scientists to study the whole ecosystem before doing eradication programs," said...a co-author of the paper. "There haven't been a lot of programs that take the entire system into account. You need to go into scenario mode: 'If we kill this animal, what other consequences are there going to be?'" [19]

We might call this preoccupation with consequences an 'ecological sensibility.' Introducing an ecological sensibility into sustainable HCI evaluation might involve broadening the evaluative scope to include effects on the objects of

typical sustainability assessments outside HCI—ecosystem health; air quality; continued availability of raw materials; climate stability; and so on—instead of using single proxies. By developing evaluations consistent with sustainability research outside HCI, sustainable HCI can demonstrate its contribution to the project of achieving sustainability. Additionally, such evaluation can help guide sustainable HCI research to maximize that contribution.

Tools for sustainability evaluation

In this section we describe three categories of tool for evaluating sustainable HCI projects for contributions to sustainability. The three categories—principles, heuristics, and indices—are not completely distinct and may 'bleed into' each other, but this is not a serious problem. The point is to show the ways in which the tools can be useful for sustainable HCI research, not to provide a definitive taxonomy. In each case, evaluation involves comparing project outcomes to a previously articulated definition of sustainability. Thus the categories refer mainly, but not exclusively, to definitions of sustainability or their various operationalizations. As discussed below, however, one area for sustainable HCI *evaluation* research lies in developing new principles, heuristics, and indices that operationalize both definitions of sustainability and other design objectives *and* preferences about the ways in which they interact.

Principles

Evaluation by principle involves comparing project outcomes to previously articulated principles for sustainability. Examples include the sustainable interaction design (SID) principles [9], Thackara's principles for design mindfulness [17], Holmberg et al.'s socio-ecological principles for a sustainable society [20], and the canonical Bruntdland definition of sustainable development [21]. Such principles tend to be simple, concise, logically appealing, and politically unobjectionable. Operationalizing them in the context of a particular evaluation however may involve substantial ambiguity, leaving considerable discretion to the evaluator. As definitions of sustainability, they rarely guide practitioners in balancing sustainability against other design objectives or in determining when sustainability is *not* a design objective. Generally, they tend not to facilitate comparative evaluation of designs or design methods, except in very simple ways (e.g., design A is sustainable, design B is not; or, at best, design A conforms to principles X and Y but not principle Z while design B conforms to Y and Z but not X). Once principles have been operationalized, particular designs are often simple to evaluate—but principles are often difficult to operationalize. When they are operationalized, they may lead to impractical design implications, making them of limited use in practice. Finally, sets of principles may conflict, leading to 'religious wars' with little empirical grounding and no principled resolution.

Heuristics

Evaluation by heuristic involves characterizing project outcomes by (a) simple indicator(s), or by change in value(s) of (an) indicator(s). Examples include number of car trips, quantity of energy use, and device longevity. Heuristics are often quantitative, but need not be; for example, manner of device disposal is a qualitative heuristic of interest in previous sustainable HCI research (e.g., [2]). Heuristics, like principles, tend to be simple and concise. They differ from principles in that they are by definition already operationalized. (One way to operationalize a principle is to derive a heuristic from it.) As such, heuristics can facilitate sophisticated comparative evaluation of designs and before-after evaluations of particular design interventions. Heuristics tend to be straightforward to evaluate—if the relevant data are available. Evaluators can

use multiple heuristics in a single evaluation to compose an implicit definition of sustainability, but generally these do not indicate the ways in which the multiple components of sustainability relate to one another, how sustainability relates to other design objectives, or when sustainability is not an objective. Widespread uptake of collaboratively developed heuristics can focus research on the problems deemed the most important in a particular field, but over-focus on (a) particular heuristic(s) may lead to inappropriate optimization and/or inattention to consequences not measured by the heuristic(s). As with principles, there is a danger of 'religious wars' between proponents of conflicting heuristics; or, if conflicting heuristics are derived from conflicting principles, contention may simply move from heuristics to principles.

Indices

Evaluation by index involves characterizing project outcomes by composite indicators. Examples include the Genuine Progress Indicator [22], the Happy Planet Index [23], the Environmental Performance Indicator [24], and the set of socio-ecological indicators devised by Azar et al. [25]. A sustainability index articulates a comprehensive, internally consistent, operationalizable definition of sustainability. As such, it indicates how different components of sustainability relate to one another. Like a heuristic, an index facilitates both comparative evaluation and before-after evaluation. Also like heuristics, they are straightforward to evaluate if the appropriate data are available. Unlike heuristics and principles, however, indices tend to be both complex and long. In practice, indices tend to be anything but straightforward to calculate. Many indices contain dozens of components, some of which require entire, independently-maintained simulations to compute. Despite this additional difficulty they do not resolve the risk of 'religious wars'; the amount of scholarly output that these can absorb is attested to by the voluminous debates around indices like the Gross Domestic Product, the Genuine Progress Indicator, and the ecological footprint. Nor do indices resolve the risks of over-optimization and inattention to consequences not measured or privileged by the index.

By virtue of their complexity, however, indices hold out the possibility of orienting and guiding research in such a way that it becomes both more rigorous and more effective. Following Sim et al.'s research on benchmarks in technical disciplines (especially software engineering) [26], we suggest that the sustainable HCI community could collaboratively define indices for evaluating sustainable HCI research.[1] Such indices could explicitly articulate existing knowledge about sustainability outside HCI with traditional priorities in HCI design and evaluation. In developing such an index, the sustainable HCI community would need to consider questions that have been underexamined thus far. For example: what are appropriate time frames for evaluation of sustainable HCI design interventions?[2] should sustainable HCI research and practice prioritize distributive justice as a design objective?[3] if so, how? how should sustainability or its derivative design objectives relate to other values or value-discovery methods articulated within HCI (e.g., in the value sensitive design literature, perhaps most recently [30])? These are questions worthy of urgent and serious study. *Even if no index can be agreed upon* that adequately embodies these complex concerns, the

[1] We use the term 'index' instead of 'benchmark' to follow Sim et al.'s [26] definition of the latter term, which includes a motivating comparison, a task sample, and performance measures. In many sustainable HCI cases there may be no 'task sample', so 'sustainable HCI benchmark' may be an inappropriate term.

[2] See [27] and [28] for a discussion of the importance of time frames in sustainability evaluation and planning.

[3] See [29] for a discussion of sustainability as opportunity, operationalized by a quantitative notion of distributive intergenerational and intragenerational justice.

discussion and collaborative transdisciplinary study that such a project would require if taken seriously may help to strengthen sustainable HCI's ability to contribute meaningfully and verifiably to sustainability. Put another way: for Sim et al. [26], a benchmark operationalizes a scientific paradigm within a technical discipline or community. It may be that 'sustainability'—and even approaches to sustainability useful in HCI—exceeds any single, internally consistent paradigm. The process of arriving at this discovery is nonetheless likely to entail complex, intense, rigorous, and transdisciplinary engagements that will raise the rigor, practical efficacy, and responsibility of sustainable HCI research.

Recommendations and next steps

If sustainable HCI as a community is to contribute to the overall project of sustainability, it should take up the question of sustainability evaluation. One approach involves what we have called 'the ecological sensibility,' a concern for unexpected consequences of design intervention outside the traditional scope of evaluation.

Sim et al. [26] argue that collaborative development and uptake of benchmarks allows a technical discipline to "become more scientific." Development and uptake of indices may allow sustainable HCI research to become more scientific. if sustainable HCI is to become more scientific, it should take up the question of systematic sustainability evaluation. It is not at all obvious that sustainable HCI research *should* become more scientific (as opposed, for example, to 'designerly'), or that 'science' must always denote practices involving systematicity or quantification. We do not argue this flavor of evaluation should be favored exclusively in sustainable HCI research; rather, it should be considered as one approach among many.

We have not discussed here the utility or rigor of particular principles, heuristics, or indices, or applied them to existing systems or methods in published work, design practice, or commercial circulation. This has allowed us to explore these tools conceptually. The next step in the research program implied here is to develop specific tools—principles, heuristics, and indices—for sustainable HCI evaluation, and to apply them to systems and methods in published HCI research and to designed technological systems and products in general. These tools and the evaluations they are used to produce should bridge understandings of sustainability outside HCI with existing criteria and design objectives within HCI. The evaluations, the rationale behind them, and detailed accounts of evaluation *methods* should be made widely available. An iterative research practice in which the evaluation of actual systems informs the development of evaluative tools is appropriate; in turn, these evaluations can inform design methods and practice in the production of more sustainable designs and practices as well as more robust, meaningful, and useful definitions of sustainability in practice.

Acknowledgments

The Bren School of Information and Computer Sciences at UC Irvine, the California Institute for Telecommunications and Information Technology, and the Alfred P. Sloan Foundation supported this research. We thank our anonymous reviewers for their helpful contributions.

References

[1] Hanks, K., et al. Sustainable millennials. *Proc. CHI '08*: 333-342.

[2] Huang, E. and K. Truong. Breaking the disposable technology paradigm. *Proc. CHI '09*: 323-332.

[3] Paulos, E., et al. Ubiquitous sustainability: citizen science and activism. Workshop, *UbiComp '08*.

[4] Woodruff, A., et al. A bright green perspective on sustainable choices. *Proc. CHI '08*: 313-322.

[5] Xiao, J. and J. Fan, 2009. PrintMarmoset. *Proc. CHI '09*: 109-112.

[6] Froehlich, J., et al. UbiGreen. *Proc. CHI '09*: 1043-1052.

[7] Chetty, M., et al. It's not easy being green. *Proc. CHI '09*: 1033-1042.

[8] Tomlinson, B. *Greening Through IT*. MIT Press, 2010.

[9] Blevis, E., 2007. Sustainable interaction design. *Proc. CHI '07*: 503-512.

[10] Sterling, B. *Shaping Things*. MIT Press, 2005.

[11] Nathan, L. P., et al. Envisioning systemic effects on persons and society throughout interactive system design. *Proc. DIS '08*. 10 pp.

[12] Nathan, L., et al. Information system design as catalyst. *Interactions* **16**(4): 6-11.

[13] Dourish, P. Print this paper, kill a tree: environmental sustainability as a research topic for HCI. UCI Lab. Ubiq. Comp. & Interaction Tech. Report, 2009.

[14] Goodman, E. Three environmental discourses in HCI. *Proc. CHI '09*: 2535-2544.

[15] Williams, A. Infrastructure and sustainable ubicomp. Workshop paper, *UbiComp '07*.

[16] Stegall, N. Designing for sustainability. *Design Issues* **22**(2): 56-63, 2006.

[17] Thackara, J. *In The Bubble*. MIT Press, 2005.

[18] Quality Planning Corporation. Hybrids: is a little of the green rubbing off? www.qualityplanning.com/index.cfm?event=showNews&newsId=46&displayType=page, 2009.

[19] Svoboda, E. The unintended consequences of changing nature's balance. *New York Times*, 16 February 2009. nytimes.com/2009/02/17/science/17isla.html.

[20] Holmberg, J., et al. Socio-ecological principles for a sustainable society. In R. Costanza et al., eds., *Getting Down to Earth: Practical Applications of Ecological Economics*: 17-48. Island Press, 1996.

[21] Brundtland, G., et al. *Our Common Future*. Oxford, 1987.

[22] Talberth, J., et al. *The Genuine Progress Indicator 2006*. Redefining Progress.

[23] Abdallah, S., et al. *The (un)Happy Planet Index 2.0*. New Economics Foundation, 2009.

[24] Esty, D. C., et al. *2008 Environmental Performance Index*. Yale Ctr. Envtl. Law and Policy.

[25] Azar, C., et al. Socio-ecological indicators for sustainability. *Ecol. Econ.* **18**(2): 89-112, 1996.

[26] Sim, S. E., et al. Using benchmarking to advance research. *Proc. ICSE '03*: 74-83.

[27] Costanza, R. and B. C. Patten. Defining and predicting sustainability. *Ecol. Econ.* **15**(3): 193-196, 1995.

[28] Dasgupta, P. Discounting climate change. *J. Risk and Uncertainty* **37**(2): 141-169, 2008.

[29] Howarth, R. E. Sustainability as opportunity. *Land Economics* **73**(4): 569-579, 1997.

[30] Le Dantec, C. A., et al. Values as lived experience. *Proc. CHI '09*: 1141-1150.