Self-Obviating Systems and their Application to Sustainability

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Abstract
Most research in computing and information science reinforces the premise that information and communications technology (ICT) can be productively applied even more broadly than it is at present. A recent thread of research in sustainable HCI, however, has focused on the possibility that there are many situations where less ICT, not more, may be desirable. We envision an adaptation of this premise, where the goal is not just to consciously omit or remove ICT systems, but rather to create systems explicitly designed to make themselves superfluous through their use. Such a system—one in which the successful operation of the system in the short term renders it superfluous in the long term—could be called a “self-obviating system”. We present a case study in the sustainable food domain for a context in which self-obviating systems could be useful, and a typology of self-obviating systems that could be relevant to other domains. Self-obviating systems could be an important part of a sustainable future, and could be applied more broadly in ICT design.
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1 Introduction

Information and communications technology (ICT) systems are powerful enablers of industrial civilizations around the world. However, these industrial civilizations are not currently on a sustainable trajectory. ICT systems are pushing industrial civilizations ever faster toward non-trivial limits in resource availability (e.g., fossil fuels, phosphorus) and other looming problems (e.g., global climatic disruption, ocean acidification, biodiversity loss). In addition, the ICT systems themselves are directly responsible for problematic resource usage (e.g., coltan) and waste production (e.g., e-waste). An unstated premise of most current ICT research and engineering is that the spread of ICT into ever more domains is, on balance, a good thing. This paper is based on the idea that it is not.

An important question in the study of sustainability is whether or not human civilizations will be able to “turn the ship” and adopt sustainable ways of living before global change causes profound hardship around the world. Unfortunately, we may not address the question of long-term sustainability until problematic effects are already unavoidable. Therefore, there is reasonable concern in the sustainability science community that a shift is needed from mitigation (that is, reducing the severity of change) to adaptation (that is, coming to terms with unavoidable change) (Holdren 2011).

Because of the mismatch between human and environmental horizons (Tomlinson 2010), sustainability at a global level may be intractably complex. Short-term problems may continue to trump long-term problems, and any surpluses that could be used to address long-term problems may be channeled into more growth. If global sustainability is not viable (or, if there is even any question of its viability), local sustainability may be a more effective strategy (Heinberg 2003; McKibben 2007). Even though there will continue to be economies of scale and other forces pushing toward larger-scale infrastructures, tractable sustainability may need to occur at a local scale.

Local sustainability is already under consideration within various different communities. It is central to groups interested in self-sufficiency and simple, sustainable living (Håkansson et al. 2012). We envision local sustainability as existing primarily at the level of sustainable communities involving no more than a few hundred people. The broad goal of this work is to enable local sustainability.

While an appealing prospect, local sustainability is not necessarily easily achieved. Even for those who are ideologically committed, significant barriers to entry prevent people from engaging in local sustainability. Steep learning curves, lack of social support, and lack of access to materials all stand in the way of efforts to build sustainable communities. In Section 2 we introduce preliminary findings of a permaculture course case study to discuss a range of barriers to entry for engaging in local sustainability.

These challenges draw attention to a potential tension in the relationship between ICT and sustainability. On the one hand, modern ICT systems for computer-supported learning, social networking, online resource sharing, and other goals are well suited to addressing many of the technical and social difficulties facing local sustainability (e.g., Ho and Metcalfe 2009; Knezek et al. 2010; Pasquini et al. 2014). On the other hand, modern ICT devices are typically not a viable part of a fully self-sufficient community, since they are constructed of materials that are not available in many regions of the world (Raghavan and Hasan 2012), they have relatively short lifespans of operation, and they are difficult to repair (cf. Tomlinson et al. 2012; Jackson, Pompe, and Krieshok 2012). We need a way to *reconcile this apparent mismatch* between the conflicting goals of being locally sustainable and being supported by ICT.

We propose that this mismatch may be resolved by building ICT systems that help bootstrap new ways of living, and in the process render themselves (and future ICT systems that might replace them) superfluous. This suggestion draws on a recent trend in sustainable HCI (Blevis 2007; DiSalvo et al. 2010; Knowles et al. 2014) suggesting that designing for the absence or elimination of technology may represent a valuable approach (Ross and Tomlinson 2011; Pierce 2012; Baumer and Silberman 2011). This paper seeks to contribute to this trend by envisioning ICT systems that facilitate their own phased exit from various human contexts. On their way out, however, ICT systems can help people adopt more self-sufficient and sustainable lifestyles. We call these forms of ICT “self-obviating systems.” A self-obviating system is one in which the successful operation of the system in the short term renders it superfluous in the long term. Currently, some existing systems fall loosely into this category, but by engaging with the concept more explicitly designers may be able improve how their systems self-obviate. This paper explores the concept of self-obviating systems, describes in detail one case study demonstrating the potential utility of such systems, and maps out a design space for these systems. While this paper uses sustainability as a domain in which to explicate and demonstrate the value of self-obviating systems, we suggest the concept may be broadly applicable across many areas of ICT design.

2 Related Work

Self-obviating systems are related to a variety of existing concepts from computing research and other domains. In particular, self-obviating systems represent a confluence of work from two related areas in HCI: designing for the absence of technology, and empirical studies of technology non-use.

2.1 Designing (for) Technological Absence

HCI researchers often study particular situations, environments, or communities in search of opportunities for technological intervention, i.e., implications for design (Dourish 2006). Baumer and Silberman (2011) suggest there may be value in considering the possibility that some situations may not call for technological intervention. That is, they suggest valuing the implication not to design technology. Going a step further, Pierce (2012) suggests the notion of “undesign,” the intentional negation of technology via technology design. Pierce and Paulos (2014) take a related approach in their exploration of counterfunctional objects. Eliminating some aspect of an object’s expected functionality--e.g., removing a camera’s shutter button and making the camera take photos at random intervals--opens up new design possibilities that would not have been available with a fully functional version. This approach relates also to zensign (Tatar et al. 2008), the notion that the features omitted from a system’s design are just as important as, if not more important than, the features included. Self-obviating systems also relate to the idea of “natural obsolesence” (Boettiger et al. 2012), in which “transitional interventions” cease to be relevant once their purpose has been served, but with a more explicit focus on the intentional design of the obviation process.

Self-obviating systems walk a line between these designed absences of technology and more traditional approaches to technology design. On the one hand, self-obviating systems do in fact represent a technological design intervention in a particular situation. On the other hand, such a system is an intentionally short-term intervention that, when successful, ultimately removes itself.

2.2 Technology non-use

HCI researchers have demonstrated increasing interesting in technology non-use (e.g., Satchell and Dourish 2009; Baumer et al. 2013; Ames 2013; Lampe, Vitak, and Ellison 2013; Schoenebeck 2014), building on an established line of work in STS and the sociology of technology (e.g., Wyatt 2003; Selwyn 2003, 2005; Uotinen 2003; Kline 2003).

This prior work plays two important roles here. First, it provides a valuable conceptual vocabulary, as some elements or aspects of non-use that may be important to consider in the context of self-obviating systems. For example, Wyatt (2003) emphasizes volitionality: is a person(s) a non-user(s) of their own accord or due to factors beyond their control (access, infrastructure, socioeconomic status, etc.)? Satchell and Dourish (2009) refer to such non-volitional non-use as “disenfranchisement.”

Second, it helps us push back on the prevailing user-oriented logics of (ICT) design (Redström 2006). Some work on non-use has pointed to the ways that user vs. non-user is not a strict dichotomy or even necessarily a single-dimensional spectrum (Satchell and Dourish 2009; Baumer et al. 2013; Wyatt 2003). Doing so suggests that “the user” is not a single, monolithic entity but warrants unpacking and further examination (cf. Cooper and Bowers 1995; Woolgar 1991).

Designing self-obviating systems contributes to this endeavor. Most technology is designed around encouraging people to adopt the technology, that is, to become users. Designing instead around eventual abandonment of the technology, that is, around people becoming non-users, opens up numerous design opportunities. This paper focuses on such opportunities within sustainable HCI, but designing self-obviating systems may prove a beneficial approach in a variety of application domains.

2.3 Other Related Concepts

Some similarities can be seen between self-obviating systems and “gateway” technologies (Schwanda et al. 2011). A study of the Wii Fit exercise system found that numerous users eventually abandoned the technology, but this abandonment did not represent failure. The users did not cease to exercise regularly but rather moved on to other forms of exercise--running outdoors, attending a gym, playing team sports--such that the Wii Fit became unnecessary for them. While Schwanda et al. (2011) use this finding to argue for rethinking the evaluation of persuasive technologies, we argue here that such concepts can also usefully inform design.

Self-obviating systems can also be likened to Non-Profit Organizations (NPO) that put themselves out of business. In contrast to NPOs that address intractable problems such as HIV, sea level rise, etc., NPOs that put themselves out of business address important but manageable problems and achieve their end goal. An example NPO, Malaria No More, is winding down because they are reaching their end goal, having reduced the occurrence of malaria by distributing bed netting in areas where malaria is worst (Strom 2011). Malaria No More is like a self-obviating system that is deployed to provide tools to a population to address a problem. Once the tools are in place, like the bed nets, the self-obviating system is no longer necessary and can be eliminated.

For many decades consumer products have been designed according to the policy of planned obsolescence, in which products are made to become artificially obsolete or non-functional before they otherwise would. This design policy has only become more pervasive with the advent of computing technology, which becomes obsolete quickly for many reasons, including heavier software footprints, cheap electronics, and fashionable industrial design. On the surface, a self-obviating system is similar to a system exhibiting planned obsolescence; the key difference, however, is in the aftermath of its ceasing to be used. A system built for planned obsolescence is one whose functionality disappears as soon as the system does; that is, one must acquire a new system of the same type to replace its functionality. A self-obviating system, on the other hand, is one that need not be replaced by a system of the same type when it goes into disuse.

Environmental scientist Amory Lovins proposed the ideas of the “negawatt” (a measure of energy saved) (Lovins 1989) and “negatechnology” (the act of removing a problematic technology) (Lovins 2003). These ideas informed the conceptualization of “negabehaviors” (the act of ceasing a problematic behavioral pattern) (Ross and Tomlinson 2011). Each of these concepts focuses on the inversion of some common way of thinking. Similarly, self-obviating systems would seek to invert the premise of ubiquitous computing; rather than enabling technology to "vanish into the background" (Weiser 1991), the goal is to foreground the role of the computer, and empower people to take over its functionality.

3 Background - Understanding Barriers to Entry for Pursuing Local Sustainability

This section presents a case study of a context in which a self-obviating system could be of use. The case study demonstrates the broad range of barriers to entry preventing students enrolled in a local permaculture design course (i.e., people ideologically on board with local sustainability) from pursuing local sustainability. This case study draws from ethnographic fieldwork conducted by the second author in the Spring of 2014. We highlight the students' attempts to utilize ICT to overcome barriers, their voiced wishes for specific ICT solutions, and offer our opinions of unrealized ways ICT could help. Finally, we discuss how the presence of ICT has the potential to hinder local sustainability efforts and even present new barriers to entry. Together, the short-term benefits of ICT, and the long-term concerns regarding that same ICT, point to the appropriateness of a self-obviating system in this context.

3.1 Permaculture and the PDC

Those who identify themselves as permaculturists ("Permies" in the lexicon of the culture) are members of a subculture engaging in local sustainability. Thus, in the context of this paper, they are an appropriate group for analyzing barriers to entry. Permaculture is an ecological design methodology used in sustainable homesteading and livelihood practices (Mollison 1988). This design methodology emphasizes principles that support local sustainability such as minimizing external inputs by utilizing onsite resources and returning waste back into the system as a resource (Holmgren 2002). The permaculture methodology and ethics include social concerns, such as emphasizing fair share (i.e., setting limits to consumption and redistributing surplus) and people care (i.e., looking after self, kin, and community) (ibid.). Local currencies, community resource and education centers, community composting programs, and local seed banks are manifestations of permaculture social ethics supporting local sustainability. Furthermore, other local sustainability movements such as transition towns and ecovillages often utilize permaculture principles, ethics, and techniques.

To explore barriers to entry for engaging in local sustainability, a Permaculture Design Course (PDC) at an ecologically-oriented community center in San Juan Capistrano, CA was selected as a field site. The course totaled 72 hours of instruction over three months. The PDC was taught by experts in permaculture methods both at the community center and at various off-site locations in Orange County, CA. Instruction involved numerous hands-on activities and culminated in out-of-class group projects where the students had to create a permaculture design for a client. The course included 16 students recruited from all over Orange County via flyers, word of mouth, email lists, etc. Students held a variety of occupations (e.g., incoming and alumnus Peace Corps volunteer, conservation biologist, landscape designer, nurse, retail employee, student, homemaker, advertisement designer, ICT consultant, volunteers and staff at the community center). Because this was only the second PDC taught at the community center, the course's logistics and activities evolved as changes were made on the fly. Rather than produce experts in sustainable agriculture and community design, the PDC aimed to give students a high-level understanding of what permaculture is and how to engage in permaculture design in a way best suited to their interests and skill set.

This work primarily employed participant observation and semi-structured interviews. The second author took part in the bulk of the discussions and activities during the course while generating field notes, as well as interviewed five students at the end of the course. The fourth author engaged in the course as a full participant, and engaged in post-class reflections with the second author. Observations primarily focused on questions that students asked to further their understanding about the course content, barriers to entry that the researcher observed or students explicitly described, and resources and materials students referenced or used in their projects. Supplementary materials were also collected and analyzed, including course handouts and photographs of in-class and final project design activities. These data were analyzed using a grounded theory approach with a specific eye toward information challenges that might be addressable via ICT systems.

3.2 Barriers to Entry

Students in the course were invested in and committed to the idea of permaculture and had a significant financial or work study investment in learning permaculture design. Nonetheless, students faced significant barriers to entry that made it difficult to engage in permaculture design.

Time was a fundamental barrier preventing engagement in local sustainability. Though invested in learning permaculture design, students frequently reported time constraints with work or social and familial events. In the course setting, time restraints were manifested as absence from or abbreviated presence in class, scant participation in out-of-class design projects, and opting out of suggested reading. In personal pursuit of sustainable practices, lack of time pushes the ideal of living and/or working sustainably from the now into a future when they have more time. The shortage of time was primarily caused by prioritization of other commitments (e.g., work, household duties), but many reported various stages of the learning and design processes to be overwhelmingly complex and time consuming. The overwhelming and time consuming nature of these processes were strongly linked to informational challenges.

We found that students faced many informational and educational challenges over the course of the PDC. One such challenge was the expectation for students to create actionable site designs while lacking the tacit knowledge of an expert. “I don’t feel like I can tell someone what to do when I’m still learning,” said one student about the group design project at the end of the course. At times, mastering the information was such a significant challenge that students began to lose confidence in their ability to do the project: “you just blame [your flawed design] on yourself instead of trying to fix the problem because you don't even know where to begin.” Lacking self-confidence when preparing to enter a professional industry is not unusual and can be successfully addressed via problem-based learning capstone courses in educational settings (e.g., Dunlap 2005). However, these students reported lack of self-confidence at the end of the course indicating that engaging in the project did not help them become confident in their skill. This may indicate that the students engage with the project prematurely, that is before basic skills and theory have been learned (Durel 1993).

To complete their project, students had access to an abundance of informational resources via books, blogs, online videos, and podcasts. However, students found it difficult to determine which resources were best to help them whichever challenge they faced. Complete information of design elements (e.g., water catchment system, organic waste management, etc.) were rarely found from a single information resource, and searching for the missing pieces proved to be time consuming. The same was true for a complete profile of a plant’s properties; students were scraping multiple databases and written materials to get the information necessary for determining which plants to include in their design. In the final project presentations no group was able to provide a comprehensive plant list leaving their design high level (i.e., an area for natives, an area for shade loving plants, etc.) and unable to be implemented. One student described her experience of creating complete plant profiles: “It was like I had fallen into the pit of Google, going in circles only to come out hours later having forgot what it was I was initially searching for.” Consulting with experts (e.g., a course instructor or staff member at the community center) was the most direct way for students to find salient solutions for their challenges, but they noted how scarce of a resource expert consultation was and found it was not a consistently available solution. Other information challenges students faced were adjustment to new terminology and lack of region specific information (e.g., details of permaculture concepts are dependent on climatic conditions).

3.3 How ICT can Help or Hinder Permaculture Education

In the previous section we demonstrated that, even though the students were ideologically committed, significant barriers to entry prevented them from engaging in local sustainability, largely in terms of information challenges. Modern ICT systems are well suited to address these informational and learning challenges the permaculture design students faced. Students and instructors postulated ICT-based solutions for some of their information problems. For example, in response to the plethora of unindexed information resources, a group of four students discussed the possibility of an online “card catalog” for permaculture books, magazines, handouts, and other print material that would allow a person to search for topics and keywords. Realizing that this was difficult to do as some of the material pre-dates electronic formats, they suggested that members of the community work to create a summary of contents with a keyword bank.

For other challenges, students applied existing ICT tools. For example, one student realized that the pen, paper, and trace paper design paradigm employed in class was limited in experimental placement of design elements (e.g., water catchment systems, plants, grow boxes, compost piles, etc.). He utilized Google SketchUp for a modular design experience, easily moving design elements into new arrangements in effort to optimize the design. Further, he found the library of open source models easier to customize than generating sketches and felt that the final presentation of the design was aesthetically superior to one that he would have drawn.

Based on our personal experience in permaculture design, our conversations with other students and instructors, and building upon the student's use of SketchUp for a modular design experience, we believe an instructional computer-aided design tool specific for permaculture design would foster the learning process and help novices create actionable site designs. The computer-aided design tool we envision would require a back-end comprehensive plant database, thus reducing cognitive load by eliminating the need to search many resources to construct complete plant profiles. In addition to having a searchable plant database, the tool could suggest a range of plants given environmental conditions provided by the user, thus helping a novice become familiar with which plants are capable of thriving in or useful to particular conditions. A tool like this one would enable experimental placement of design elements, offer a granular look into plant relationships to ensure the most stable design, and provide instructional components to guide the user through the design process.

Given the many barriers to entry a permaculture design student faces, it would be feasible for an ICT system to be developed that solves the challenge. However, doing so would largely undermine the effort of learning how to live sustainably. Take for example our envisioned instructional computer-aided design tool for developing actionable site design. ICTs can enhance the transfer and creation of new tacit knowledge (Roberts 2000). By going through the process of creating a design with input on promising pairings and placement of plants, students are given the opportunity to create tacit knowledge of how plants in the design react with each other and other environmental conditions. If, instead of requiring a user to go through the design process, a system could be build to automate the design, the opportunity to create tacit knowledge is removed (Roberts 2000). While an automated design tool will help the recipient of the design live more sustainably, potentially grow their own food, etc., they may not form the requisite tacit knowledge to design future systems once the automated design tool becomes unavailable. At a larger scale, such ICT systems run the risk of contributing to a de-skilling of permies, effectively drawing attention away from engagement with the materiality of formulating and implementing permaculture designs.

We propose that self-obviating ICT systems can be built to address barriers to entry for engaging with local sustainability, but in the process should render themselves superfluous, thereby ensuring that the community remains self-sufficient. In the case of the instructional computer-aided design tool, if the tool is phased out of existence, the users of the tool still maintain the knowledge of the system. Thus, the sociotechnical system would reap the benefits of ICT in the short term, but not become reliant on it over a longer time scale.

4 Typology of Self-Obviating Systems

Self-obviating systems represent a subset of those systems designed to operate for some finite duration, rather than for indefinite use. Within that group, there are at least two classes -- planned-obsolete systems and self-obviating systems (see distinction in the Related Work section above). We offer several dimensions to describe the space of possible self-obviating systems.

4.1 Static vs. Dynamic

A static self-obviating system is one in which the system's mode of operation remains the same throughout its lifespan, but its use or use context changes. A dynamic self-obviating system is one in which the system changes its mode of operation or behavior over time, with the changes tending towards self-obviation.

Drawing on the permaculture domain, a simple plant identification aid could be an example of a static self-obviating system. At first, the aid provides significant value to a user in the form of, for example, expert identification of plant photos. Over time, however, the user learns and needs the system less and less; eventually, when the user is able to identify the plants on their own, the plant identification aid is unnecessary.

A dynamic example would be a plant identification aid that gradually phased out its functionality, for example, by showing the plant's full information on the first several viewings of that plant, then giving the user a brief quiz on some key characteristics of the plant before showing the full information (encouraging them to draw on their own knowledge), and gradually raising the barrier to use until users relied fully on their own knowledge.

While we view the distinction between static and dynamic as useful in understanding such systems, the distinction itself is false in the limit -- all systems eventually fail or degrade in some way, and thus all self-obviating systems, and indeed nearly all ICT systems, in the long run, are dynamic. Thus we might refine our definition of dynamic self-obviating systems in this context to mean those systems whose dynamism is planned or specified in advance, likely with some design intention. For example, as a system degrades over time, if designed with self-obviation in mind, the components or features could degrade gracefully, in a way that eases the transition towards dis-use of the system.

4.2 Timed vs. Interactive

If a system is to be dynamically obviated by design, there are two possible ways that the obviation could occur. First, it could happen on a predetermined schedule. For example, it operates fully for the first month, at a reduced level for a second month, and not at all in the third and following months. An example could be an instructional aid for a permaculture design tool. Early in the course students would depend on the aid as it introduces fundamental concepts and principles. Then the aid would reduce instruction only offering assistance with new content that coincides with the course. Finally, the aid would fade out the instructional material for a final project assessment.

However, computational power allows for more elegant solutions to the process of obviation. For example, the support provided by the system could degrade as the user demonstrates efficacy in operating without it. Consider an alternative instructional aid for a permaculture design tool to be used independent of a course. Instead of the aid reducing instruction on schedule with the course, the aid would reduce instruction as the user succeeds in completing certain tasks requiring particular skills before moving on to other parts of the material.

4.3 Optional vs. Mandatory

Wyatt (2003) draws an important distinction in the volitionality of technology non-use. In her typology, *resisters* and *rejecters* voluntarily forgo the use of a technology, while the *excluded* and the *expelled* are, against their will, prevented from using a technology.

A similar distinction may be made in designing self-obviating systems. On the one hand, a system may be designed to encourage reflection on the use of the technology itself in such a way as to discourage future use. Consider again the instructional aid for a permaculture design tool. An early instructional component would encourage reflection on the waste streams created by the technologies they use and the systems they create. In this case, the user would, eventually, voluntarily forgo the use of the system. On the other hand, a system may impose constraints or limits on its own use. In this case, the user would ultimately be prevented from continuing to use the system even if s/he wanted to. Consider again the instructional aid for a permaculture design tool that self-obviates in a way that is synchronized to a particular Permaculture Design Course schedule. The aid mandatorily self-obviates for the final project so that the user is forced to engage in the design activity based on only what they have learned.

Together, these dimensions offer a way to conceptualize the space of self-obviating systems.

5 Conclusion

This paper describes the concept of self-obviating systems, and provides a case study for a context in which self-obviating systems could be of use. We envision self-obviating systems as being an important part of a phased reduction in the ubiquity of ICT systems in human civilizations. While ICT systems are exceptionally powerful, they are also deeply entangled with contemporary industrial infrastructures, and reliance on them leaves us open to the possibility of our quality of life being compromised if those infrastructures begin to fail. ICT systems also have non-trivial environmental costs. We are not proposing that ICT systems are not valuable; rather, we are suggesting that the prevailing vision of ubiquitous computing may lack sufficient awareness of the actual and potential drawbacks of ubiquitous reliance on computing. We see self-obviating systems as a potential way to reap the benefits of how powerful and effective ICT systems are, while simultaneously easing them out of the critical path in many human systems.

6 References

Ames, M. G. (2013). Managing Mobile Multitasking: The Culture of iPhones on Stanford Campus. In Proc CSCW (pp. 1487–1498). San Antonio, TX.

Baumer, E. P. S., Adams, P., Khovanskaya, V., Liao, T., Smith, M., Sosik, V. S., & Williams, K. (2013). Limiting, Leaving, and (re)Lapsing: A Survey of Facebook Non-use Practices and Experiences. In Proc CHI (pp. 3257–3266). Paris.

Baumer, E. P. S., 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). ACM, New York, NY, USA, 2271-2274. DOI=10.1145/1978942.1979275 http://doi.acm.org/10.1145/1978942.1979275

Blevis, E. (2007). Sustainable interaction design: invention & disposal, renewal & reuse. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '07). ACM, New York, NY, USA, 503-512. DOI=10.1145/1240624.1240705 http://doi.acm.org/10.1145/1240624.1240705

Boettiger, S., Toyama, K., and Abed, R. (2012). Natural obsolescence of village phone. In Proceedings of the Fifth International Conference on Information and Communication Technologies and Development (ICTD '12). ACM, New York, NY, USA, 221-229. DOI=10.1145/2160673.2160702 http://doi.acm.org/10.1145/2160673.2160702

Cooper, G., & Bowers, J. (1995). Representing the User: Notes on the Disciplinary Rhetoric of HCI. In P. J. Thomas (Ed.), The social and interactional dimensions of human-computer interfaces (pp. 48–66). Cambridge: Cambridge University Press.

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). ACM, New York, NY, USA, 1975-1984. DOI=10.1145/1753326.1753625 http://doi.acm.org/10.1145/1753326.1753625

Dourish, P. (2006). Implications for design. In *Proc CHI* (pp. 541–550). Montréal, Québec, Canada: ACM Press.

Dunlap, J. C. (2005). Problem-based learning and self-efficacy: How a capstone course prepares students for a profession. Educational Technology Research and Development, 53(1), 65-83.

Durel, R. J. (1993). The capstone course: A rite of passage. Teaching Sociology, 223-225.

Ferguson, R.S., Lovell, S.T. (2014). Understanding permaculture: Design, movement, practice, worldview. *Agronomy for Sustainable Development*. In press.

Håkansson, M., Leshed, G., Blevis, E., Nathan, L., and Mann, S. (2012). Simple, sustainable living. In *CHI '12 Extended Abstracts on Human Factors in Computing Systems* (CHI EA '12). ACM, New York, NY, USA, 2795-2798. DOI=10.1145/2212776.2212723 http://doi.acm.org/10.1145/2212776.2212723

Heinberg, R. (2005). *The party's over: oil, war and the fate of industrial societies*. Clairview books.

Ho, S. M. and Metcalf, C. F. (2009). Life-Cycle Thinking: What can ICT do to be green? In: *Proceedings of iConference 2009*.

Holdren, J. (2011). National Academies. Symposium on Science, Innovation, and Partnerships for Sustainability Solutions. 2012. http://sites.nationalacademies.org/PGA/sustainability/SustainabilitySymposium/PGA_069360.

Holmgren, D. (2002). *Principles & Pathways beyond Sustanability* (p. 36). Holmgren Design Services.

Jackson, S. J., Pompe, A., & Krieshok, G. (2012). Repair Worlds: Maintenance, Repair, and ICT for Development in Rural Namibia. In Proc CSCW. Bellevue, WA.

Kline, R. (2003). Resisting Consumer Technology in Rural America: The Telephone and Electrification. In N. Oudshoorn & T. Pinch (Eds.), How Users Matter: The Co-construction of Users and Technology (pp. 51–66). Cambridge, MA: MICT Press.

Knezek, G., Christensen, R., Tyler-Wood, T., Lim, O., Neaville, W. (2010). Going Green with ICT: A Study of Energy Consumption by Home and School Information Technology Systems in the College of Information at the University of North Texas. In: *Proceedings of iConference 2010.*

Knowles, B., Blair, L., Coulton, P., and Lochrie, M. (2014). Rethinking plan A for sustainable HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '14). ACM, New York, NY, USA, 3593-3596. DOI=10.1145/2556288.2557311 http://doi.acm.org/10.1145/2556288.2557311

Lampe, C., Vitak, J., & Ellison, N. (2013). Users and Nonusers: Interactions between Levels of Facebook Adoption and Social Capital. In Proc CSCW (pp. 809–819). Baltimore, MD.

Lovins, A. (1989), The Negawatt Revolution: Solving the CO2 Problem, Green Energy Conference. http://www.ccnr.org/amory.html

Lovins, A. (2003). Some Missing Elements of Sustainable Development. Digital Vision Fellows, Stanford University. Retrieved from: http://www.rmi.org/Knowledge-Center/Library/S03-12_MissingElementsSustainableDevelopment 9/1/14.

McKibben, B. (2007). *Deep economy: The wealth of communities and the durable future*. Macmillan.

Mollison, B. (1988). *Permaculture: A Designers' Manual*. Tagari Publications.

Pasquini, L., Miller, A., Moynihan, F., McLeod, P. (2014). Community Systems, Sensor Monitoring, and the Internet of Things: A Case Study about Feed Denton Community Compost. In: *Proceedings of iConference 2014.*

Pierce, J. (2012). Undesigning technology: considering the negation of design by design. In*Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '12). ACM, New York, NY, USA, 957-966. DOI=10.1145/2207676.2208540 http://doi.acm.org/10.1145/2207676.2208540

Pierce, J. and Paulos, E. (2014). Some variations on a counterfunctional digital camera. In*Proceedings of the 2014 conference on Designing interactive systems* (DIS '14). ACM, New York, NY, USA, 131-140. DOI=10.1145/2598510.2602968 http://doi.acm.org/10.1145/2598510.2602968

Raghavan, B. and Hasan, S. (2012). Macroscopically Sustainable Networking: An Internet Quine. ICSI Technical Report, September 2012.

Redström, J. (2006). Towards user design? On the shift from object to user as the subject of design. *Design Studies*, 27(2), 123–139.

Roberts, J. (2000) From Know-how to Show-how? Questioning the Role of Information and Communication Technologies in Knowledge Transfer, Technology Analysis & Strategic Management, 12:4, 429-443, DOI: 10.1080/713698499

Ross, J. and B. Tomlinson (2011). Negabehaviors and environmental sustainability. *Journal of Sustainability Education* 2.

Satchell, C., & Dourish, P. (2009). Beyond the user: use and non-use in HCI. In Proc OZCHI (pp. 9–16). Melbourne, Australia: ACM.

Schoenebeck, S. Y. (2014). Giving up Twitter for Lent: How and Why We Take Breaks from Social Media. In Proc CHI (pp. 773–782). Toronto, ON. doi:10.1145/2556288.2556983

Schwanda, V., Ibara, S., Reynolds, L., & Cosley, D. (2011). Side Effects and “Gateway” Tools: Advocating a Broader Look at Evaluating Persuasive Systems. In Proc CHI (pp. 345–348). Vancouver, BC.

Selwyn, N. (2003). Apart from technology: understanding people’s non-use of information and communication technologies in everyday life. Technology in Society, 25(1), 99–116. doi:10.1016/S0160-791X(02)00062-3

Strom, S. (2011). Mission Accomplished, Nonprofits Go Out of Business. New York Times, 4/1/2011. Retrieved from: http://www.nytimes.com/2011/04/02/business/02charity.html?pagewanted=all&_r=1&

Tatar, D., Lee, J.-S., & Alaloula, N. (2008). Playground games: a design strategy for supporting and understanding coordinated activity. In Proc DIS (pp. 68–77). Cape Town, South Africa: ACM. doi:10.1145/1394445.1394453

Tomlinson, B. (2010). *Greening Through ICT: Information Technology for Environmental Sustainability*. MICT Press.

Tomlinson, B., M. S. Silberman, D. Patterson, Y. Pan, E. Blevis. (2012). Collapse Informatics: Augmenting the Sustainability & ICT4D Discourse in HCI. in *ACM Conference on Human Factors in Computing Systems (CHI 2012)*. (Austin, TX.)

Uotinen, J. (2003). Involvement in (the Information) Society - The Joensuu Community Resource Centre Netcafé. New Media & Society, 5(3), 335–356. doi:10.1177/14614448030053003

Weiser, M. (1991). The computer for the 21st century. Scientific American (1991) 94-104.

Woolgar, S. (1991). Configuring the user: the case of usability trials. In J. Law (Ed.), A Sociology of Monsters: Essays on Power, Technology and Domination (pp. 58–99). London: Routledge.

Wyatt, S. (2003). Non-Users Also Matter: The Construction of Users and Non-Users of the Internet. In N. Oudshoorn & T. Pinch (Eds.), How Users Matter: The Co-construction of Users and Technology (pp. 67–79). Cambridge, MA: MICT Press.