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Technology with the Environment in Mind

Green Homeowners as Lead Adopters: Sustainable Living and Green Computing

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ABSTRACT

In this paper, we explore opportunities for green computing, drawing on our ethnographic study of 35 green households in the United States. We begin by discussing recent shifts in Western environmentalism and the growth of green consumerism. We then explore green social networking processes and how these relate to perceptions of corporations, openness to new technological solutions, and our participants' perceptions of computing devices. We conclude with a framework of strategies for green computing technologies that is based on our analysis.

INTRODUCTION

The dramatic importance of environmental issues has permeated the awareness of consumers, regulatory bodies, OEMs, and others over the past few years. This awareness of environmental issues and global climate change has reached an inflection point with the potential to impact Intel's products, brand, and operations. Intel has already taken significant actions such as reducing emissions from its Fabs, playing a formative role in initiatives such as the Green Grid [1] and Climate Savers [2], and pursuing energy-efficient products. Many additional opportunities lie ahead for "green" (environmentally conscious) computing.

In this paper, we discuss emerging trends in environmental action and how these relate to green computing technologies. Our analysis draws on an ethnographic study of 35 households in the United States, as well as expert interviews and secondary sources. Although green home owners are clearly a distinct and unique population, in many ways they are at the forefront of personal environmental action, and they offer valuable insights into how consumers perceive technologies in terms of sustainability and green values. We explored questions such as our participants' motivations for environmentalism, their openness to new

technological solutions from corporations, and their perceptions of computing devices in relation to green values.

METHOD

In addition to surveys, focus groups, and other market research, Intel gains insight into the daily practices and everyday behaviors of consumers through ethnographic research. This typically involves visiting with people in their homes, workplaces, and other locations with the objective of developing a deep understanding of the values, beliefs, and worldviews that inform their perspective of technology in their lives. Methods usually include informal interviews, participatory exercises (such as collaboratively mapping the home and asking how participants interact with various areas of it; or working with an image-association card deck), home tours, and participant observation.

The ethnographic data from this research (video footage, photographs, interview transcripts, artifacts such as annotated maps, and other relevant materials) are then analyzed, and the findings are used to identify opportunities for our computing platforms to enable experiences that consumers value. This process typically involves refining a series of user experience models (or usages) that are designed to best tailor technological capabilities to the lives and priorities of consumers.

For this study, we visited households whose occupants made significant changes to their homes and behaviors in order to be more environmentally responsible. From simple changes that reduce water consumption to the installation of photovoltaic systems or the use of recycled and salvaged materials, the home has become the vehicle for expressing environmental values for many people in the United States and beyond. This study set out to gain a deep understanding of the domestic practices, values, and priorities that shape these decisions and to determine the role technology plays within them.

We chose to locate this phase of the study (October 2006 to February 2007) in the United States, in large part because the rate of energy consumption in proportion to population makes the U.S. a clear candidate for the development of new technologies that help improve energy efficiency. As the world's largest single energy consumer, the United States is also the largest emitter of carbon dioxide, accounting for 23% of energy-related carbon emissions worldwide [3]. Much of this can be attributed to home energy usage, which can be broken down accordingly: heating/cooling (44%), lighting/appliances (33%), water heating (14%), and refrigeration (9%) [4].

As for selecting regions for this study, www.sustainlane.us recently published (2006) a sustainability ranking of cities, in which Portland, OR; San Francisco, CA; and Seattle, WA consistently rank at the top in all categories (renewable energy use, alternative fuel use, food availability, tap water quality, air quality, walkability, park space, and roadway congestion). In terms of progressive energy and climate change policy, Portland, San Francisco, and Seattle were tied for first place, followed by Los Angeles and Albuquerque. Our selection of metro areas for this study roughly follows this ranking:

- Portland, OR (5 households)
- Bend, OR (3 households)
- San Francisco Bay Area, CA (7 households)
- Los Angeles, CA (8 households)
- Santa Barbara, CA (2 households)
- Albuquerque, NM (7 households)
- Taos, NM (3 households)

In these places, we sought participants who expressed commitment to improving the environment by building or retrofitting home functions that minimize negative (and enhance positive) effects on the ecosystem in which the home is situated. In addition, we sought participants who represented a range of diverse living conditions and perspectives on sustainable domestic praxis.

Our analysis is informed by data from these participants, additional interviews we conducted with domain experts, and a critical examination of secondary sources about environmentalism.

SOCIAL CHANGES IN ENVIRONMENTALISM

To set the stage for our research, it is important to consider the broader context of environmentalism.

Beginning in the late 1980s and early 1990s [5, 6], environmentalism in the Western world began to change from a counterculture movement with a focus on saving endangered species and preserving the integrity of their ecosystems to a more holistic approach that began to integrate social, economic, and political considerations into ecology. This shift was accompanied by changes in terminology as well and is probably best represented by the increasingly common usage of the term "sustainability."

In keeping with this more holistic perspective, our participants' motivations for taking environmental action were wide ranging: they included everything from religious values to a desire to save on home energy bills to new forms of patriotism that focus on reducing dependence on foreign oil. In a recent report, Euromonitor [7] cites four primary drivers for sustainable behavior that may explain some of the rapid growth of interest and action in this area, especially among those who have not traditionally self-identified as environmentalists. These include motivators such as saving money by saving energy, a desire for a healthy home, freedom from guilt associated with purchasing environmentally-damaging products from ethically compromised companies, and an appreciation for "unspoiled nature." Janet's story below (in her own words) is evidence of a wide range of motivations, and it illustrates how reasons to take environmental action are not necessarily altruistic, or even always "green" (note that participants' names have been changed in order to protect anonymity):

Janet: Motherhood was really what got me on this. There is nothing like having children to plug you into the future and it so happened that when I came to California in '66 I felt as though I was coming home although I had never been here before. And I think one of the reasons that it felt that way is because I was able to reconnect to nature here in a way that I hadn't on the east coast for many years. And so I joined many environmental organizations and their newsletters and magazines provided me with my environmental education. And so in the 70s I was already aware of some of the environmental problems that were kind of lurking in the wings waiting to make their entrance on stage before mainstream media picked it up at all.

And so as I learned more and more about that, I became really concerned about my children's future and the future of all of life on Earth and that is what started me on my quest was, you know, I came to realize that it is our modern urban lifestyle except for the military which does do a lot of environmental junk damage. It is true. But other than the military, one can trace back virtually all of

our environmental problems to our modern urban lifestyle which is that was me. You know. I was living it. And so it was both empowering and overwhelming. I decided to go with the empowering.

And so I started to just look into, well, how can I change my lifestyle so that it is not so destructive to the environment but is less destructive and maybe even in some ways can help to support three generations of a healthy environment within an urban setting. That was the big challenge of it because the resources that I had for these systems were magazines like *Mother Earth News* and *Organic Gardening* that were targeting really rural folk.

But as I read them and then I read it in my environmental magazines about the problems, I began to put the two together and realize well here I have a front yard and a back yard. There are a lot of these strategies that are described in...*Organic Gardening* magazine and *Mother Earth News* that I can implement right here just having a front and back yard. So that's what started me. I have a perfect little mini cosmos here to use as my lab to see if I can create a lifestyle that doesn't destroy the environment, you know. So that's what started me off. My children and my environment. So I don't have any formal training, although when I started my front yard I did take some courses in horticulture and native plants and landscape design and things like that to give me some skills that I didn't have.

As these more integrated views began to spread, some previously held positions within environmentalism began to be questioned and challenged. In particular, a notable shift away from critiques of technology began to take place, and a new optimism arose that technology and design could provide solutions to environmental challenges. Wikipedia describes this phenomenon (sometimes labeled "bright green environmentalism") accordingly:

"Bright green environmentalism aims for a society that relies on new technology and improved design to achieve gains in ecological sustainability without reducing (indeed, increasing) the potential for economic growth. Its proponents tend to be particularly enthusiastic about green energy, hybrid automobiles, efficient manufacturing systems and bio and nanotechnologies, [and] are supportive of dense urban settlements. 'One-planet living' is a frequently heard buzz-phrase.

Their ideas can be contrasted with what they consider traditional environmentalism: pessimistic, return-to-primitivism, unattractive, 'dark green' ideas that depend on a reduction in human numbers or a relinquishment of technology to reduce humanity's impact on the Earth's ecosphere."

Together, bright green environmentalism and the increasingly holistic view of the environment have set the stage for an expanded understanding of environmentalism in the Western world. It is here that the media—sparked in large part by rising energy costs, an unstable oil supply associated with conflict in the Middle East, major climate events such as Hurricane Katrina, and Al Gore's clear depiction of the causes and consequences of global climate change in *An Inconvenient Truth*—gripped the public imagination with an appeal far broader than 1960s counterculture-based environmentalism. As a consequence, people began to identify ways in which they personally could take environmental action without necessarily adhering strictly to the traditional strategies of protest and political action. Some called it the birth of green consumerism.

GROWTH OF GREEN CONSUMERISM

Many of the drivers for environmental action seem to extrapolate well to the general population in the developed world, and there are some clear indicators that green consumerism as a new form of environmental action is taking root in substantive ways. In terms of economics, it is hard to ignore the shifts in policy and practice that have taken place in corporate America over the past five years or so. For example, Wal-Mart's "Sustainability 360" program now evaluates suppliers based on progress toward sustainability benchmarks in areas such as energy efficiency, durability, package size, materials that help reduce the use of hazardous substances, the ability to upgrade, and recycling possibilities. Likewise, Home Depot's Eco Options Program highlights "green" products for consumers who are looking for sustainable options in home projects. Further evidence can be found in the fields of architecture and design, where green building and design standards are rapidly becoming the norm. The U.S. Green Building Council has recently extended its Leadership in Energy and Environmental Design (LEED) standards into residential structures, and some local real estate Web sites (see Portland's MLS [8]) now include green features such as solar electricity or water reclamation as value-added features of a home. In design, a quick glimpse at popular blogs such as www.core77.com will illustrate how sustainability has come to the forefront in that profession. Similarly, interest in green entrepreneurship is spreading across the country (and the world), as evidenced by the rapidly growing popularity of green networking efforts such as Green Drinks gatherings

(www.greendrinks.org), and the new flush of venture capital investment in alternative energy in the Silicon Valley [9, 10].

These corporate and entrepreneurial efforts offer potential benefits such as higher product margins, increased market share, and positive consumer perception of a company's corporate social responsibility. According to a 2006 Mintel Research study [11], the green marketplace is now estimated at somewhere between \$300-500 billion a year. The same study showed that there are approximately 35 million Americans who regularly buy green products, and that 77% of consumers changed their purchasing habits due to a company's green image. Marketing statistics from many different industries support this. Green homes, for example, are estimated to cost between 2 to 5% more to construct, but are valued at 10 to 15% more in the marketplace [12]. Likewise, organic dairy products are priced typically 15 to 20% more than conventional ones, and organic meats are often priced two to three times more than traditional meat [13]. In terms of technology in particular, we see increasing consumer interest in energy conservation, as well as growing expectations that consumer technologies should enable consumers' personal wellness in ways that are both sustainable and ethical.

While these statistics are certainly promising, it is also important to note that consumer valuations of technology also include a history of expectations that inform perceptions of technology products in unique ways. For example, a recent study by Saphores *et al.* found that most consumers "are willing to pay only a 1% premium for 'greener' CEDs" [14]. Part of this may be attributed to the fact that "consumers expect manufacturers to innovate to make their products more environmentally friendly without significantly increasing their prices as they may be accustomed to the falling prices and constant progress that characterizes electronics manufacturing" [14]. Even so, the study concludes that "[w]orldwide, the trend is toward environmentally friendly electronics manufacturing," and green attributes can play a role in consumer preference for one device over another even when they do not command a premium price.

Participants in our study expressed optimism that corporations and other organizations could provide valuable solutions or environmentally friendly options, but they were also deeply concerned that the growing awareness and popularity of green values would increasingly result in unethical attempts to overstate claims of environmental responsibility by corporations and other businesses. Participants were highly sensitized to such "green-washing," and were strongly negative

about products that were positioned as green but were in fact only partially or superficially green.

GREEN NETWORKING

Most social scientists are likely to agree that all of the attention, interest, excitement, and investment around environmentalism does not necessarily constitute a community. Some posit that community can be approached as a value [15], comprised of qualities such as solidarity, commitment, mutuality, reciprocity, and trust [16, 17]. More functionalist approaches see 'community' as constituent of two related components: 1) that the members of a group have something in common with each other; and 2) that the thing held in common distinguishes them in a significant way from the members of other possible groups [18]. Using these definitions as a guide, the concept of community necessarily involves an exclusionary act, in which the benefits of belonging to a particular group are denied in some way to non-members. In addition to this exclusionary position, shared expectations about the way people should behave 'in-group'—and how well integrated these behaviors are within conceptions of identity for its members—are also critical to understanding whether or not a group understands itself as a community.

For the participants in our study, it is difficult to argue that they collectively constitute a community. Beginning with Cohen's exclusionary principle of community, some participants in our study pointed to varying levels of commitment to sustainable building and living in which they tended to position themselves. This did not typically translate to exclusionary behavior, however. For example, Edward, an architect in the Bay area, is quick to point out that although he feels many other architects fall short in green building, he doesn't want to "disqualify them."

Allison: Are there any green architects in—in the area that you [interact with] or...?

Edward: Yeah, there are a few.

Allison: Yeah?

Edward: Yeah. But I have to say—I mean, you know, everybody tries to be green and I don't want to, you know, um disqualify them or anything. I mean, I guess everybody's doing their best, right?

This inclusive sentiment is often accompanied by a remarkable enthusiasm for sharing information and different perspectives on sustainable living.

Whether intentional or not, our participants' drive and enthusiasm to share knowledge and (in some cases) facilitate the somewhat viral spread of interest in sustainable living into the 'mainstream' would seem to indicate an inherent resistance to forming a 'community'

as defined by the social sciences. This could be interpreted as an effort to avoid the ghetto-ization of sustainable living and to steer ‘earth-friendly’ practices in directions that were out of reach for 1960s counterculture-based environmentalism. In other words, if mainstreaming is the goal, it doesn’t do you much good to form a clique.

Our research revealed a number of patterns within which participants tended to communicate about green home construction, remodeling, and related forms of sustainable living. These patterns typically begin with processes of learning by networking with others who have already taken similar action. For instance, Jerry and Kylie cite how a solar conference proved to be a particularly informative venue for them:

Allison: So, where do you find out how stuff works?

Jerry: Lots and lots and lots and lots of reading and I think our biggest, most interesting eye opener in the past year was we went to a big solar fair called SolWest...

In all, it was a great technology event as far as being able to sit down with the people and talk about problems and solving this and going to seminars and that kind of thing. It was a huge eye opener for why this technology is being accepted across the board. There were 280 or 300 visitors to SolWest. And like I told people at the solar home party after this whole thing was over, I said, “If you guys want to go somewhere and see an interesting cross-section, go to SolWest.” There were like 280 visitors at SolWest and you could probably find 200 different reasons why people were interested in solar power.

Likewise, the Web tends to play a critical role in green networking. Here, Janet talks about how her non-profit environmental organization benefits from online communications:

Jay: Does the Internet play an increasing role in the [non-profit’s] networking?

Janet: Well it does. Increasingly people come to the tour having found us on the net and then they tend...they will become members. Not everyone who comes on a tour joins, but a proportion of them do and that does build the network.

Instances like these—where synergy between online networks and traditional organizations builds momentum and reaches new audiences—are increasingly common. In fact, authors like Bill McKibben see the Internet as a key facilitator of a new kind of environmental action:

“In days of yore, if you were concerned about, say, global warming, you might write a letter to your congressman. You might research the presidential candidates to figure out which one was most aggressive about climate change, and then you might mail him a check. But the chance to work together with people around the country on a common cause was mostly reserved for ‘organizations’—for environmental groups, say, with big buildings in Washington, calendars and boards of directors.

In the Internet Age, though, new models emerge...a certain kind of organizing no longer requires years of groundwork. It requires a good idea and a well-written e-mail...The fight against global warming requires all kinds of technology—solar panels and windmills, but also servers and routers” [19].

In addition to new forms of alliance-building, the Web also provides opportunities for participatory environmentalism in which blogs, forums, mailing lists, social networking sites, and other Web venues increasingly serve as platforms where individuals can personalize their own forms of environmentalism. The breadth and depth of environmentally-focused blogs alone (c.f., www.bestgreenblogs.com/) bears witness to the fact that there is a great deal of interest in varying forms of personal expression in this area.

Our research also revealed personalized forms of environmentalism in which the home itself is used as a vehicle for “green” expression. For many of our research participants, street protests or sit-ins aren’t realistic options for expressing their concern about global climate change or other environmental issues. However, modifying a home to be more sustainable offers immediate personal gratification coupled with a tangible demonstration of environmental values. And, like other forms of expression, home modifications are also increasingly tied to the Web and the resources it offers.

These forms of individual expression align well with the historical tradition of North Americans’ understanding of nature and environmentalism, and the relationship of these to North America’s frontier-oriented history. These beliefs begin with the assumption that individual action (often enabled through networks) is the most direct way to affect change. Silveira puts it in terms of entitlement:

“...the notion of Nature itself is laden with religious and moral overtones. From early on, American frontier ideology has equated the settling of the frontier with the rise of America’s vigorous and independent democracy. Whether it be the right of a child to grow up without the increased

risk of getting asthma from poor air quality, or the right of indigenous populations to fish in ancestral fishing grounds without increased risks of cancer from toxins in the fish, rights rhetoric can be used by environmentalists to both personalize and broaden the appeal of their message.” [20]

Beyond Silveira’s notion of environmentalism linked to entitlement, we found that our research participants also practice many other forms of expression that reflect a unique intersection between environmental priorities and North American values closely tied to the historical and cultural landscape of the United States. Perhaps most commonly, we witnessed a sense of optimism that is suggestive of the utopian narratives that describe the nation’s settlement.

For example, our participants’ critiques of the ‘mainstream’ often engage utopian imaginaries that are reminiscent of the nation’s founding narratives, in which immigrants fleeing various forms of oppression from (historically European) cultural establishments find a place to start over, and in the process re-invent themselves. Although this latter narrative typically overlooks some of the tragedies that befell Native Americans in the process, it also includes an appreciation of the environment that is firmly rooted in the mythical and visual interpretations of the American West, where some of the country’s most widely renowned early environmentalists (Emerson, Thoreau, Muir, Roosevelt, Leopold, etc.) found their inspiration.

PERCEPTIONS OF COMPUTING DEVICES

Having situated our research in terms of social shifts in environmentalism, green consumerism, the increasing importance of social networking, and the historical referents these phenomena exhibit, we now turn to a more specific consideration of technologies in the lives of our research participants. Many participants in this study expended tremendous effort and funds to behave in environmentally responsible ways and to make environmentally responsible purchasing decisions. They frequently performed sophisticated and complex analyses to determine their preferred course of action, often drawing on many facts and heuristics to make decisions about transportation, home energy use, water use, food purchases, etc. [21]. However, they had invested significantly less energy in considering the environmental impacts of computing devices and consumer electronics, and their analyses were much less sophisticated in this area relative to others.

Susan lives in affordable rental housing in the Los Angeles area. Susan recently purchased her first new car. Prior to the purchase, she and her friends did research and performed detailed calculations about the expense of a hybrid car versus a conventional gas-powered car. Susan and her friends ultimately concluded that, over the life of the car, it would cost Susan \$2000 more to have a hybrid car rather than a conventional gas-powered car. Susan decided that it was worth it to her to spend \$2000 extra to do what was right for the environment. She purchased the hybrid car and was very proud of her decision. We asked Susan what considerations will go into her next computer purchase. She said she usually just considers the speed of the computer—she wouldn’t know how to think about the purchasing decision for a computer in an environmental way, she just doesn’t have that knowledge.

In some cases, participants appeared to draw simple analogies from other areas to try to reason about environmentally responsible behaviors and purchasing decisions for computing devices and consumer electronics. For example, one participant spoke at length about packaging and the amount of styrofoam in the packing box as a dominant concern in her purchasing decisions for stereos and other similar devices. In addition, participants often had a sense that they should recycle electronic products, although their understanding of the recycling process and potential environmental impacts of different recycling options seemed extremely limited when compared with the complex issues raised in publications such as Grossman’s *High Tech Trash* [22]. Even participants who were quite technical did not have as much knowledge as one might expect about issues such as the recycling of electronic products.

Participants also often had a strong inclination to keep computers turned off and to have as few electronic devices as possible (in keeping with conservationist heuristics). Participants often optimized energy use of their computers by shutting them down entirely when they were going to be away from their computers for even short periods of time. Some participants were very concerned about “phantom loads” (energy that is consumed by devices when they are off or in stand-by mode). A common strategy for addressing phantom loads was to plug devices into a surge protector and then cut off power to the devices when they were not in use by turning off the surge protector. This suggests some opportunities for device design—features such as fast wake-up or other energy management functions would plainly be appealing to this audience, although careful consideration would have to be given to the energy consumption of the device while in stand-by mode.

Many participants evidenced a pragmatic attitude toward computing devices, expressing that computers had poor environmental qualities but that they were necessary or that their use of the computer was an overall benefit to the environment because they were using it to promote green causes.

Cory: We both use computers every day in our jobs... We use them as tools. And so even though we know they're toxic, we know there's all sorts of things in them that aren't sustainable, they help us do our work, which is promoting sustainability, so we move on.

In addition to being used for green-related work such as designing green buildings or running a green business, computers were very commonly used as a resource for searching the Internet for information about green living and green purchasing.

Adam: [The water reclamation system] is all automated, it is all mechanically automated.

Jay: How did you find out about that?

Adam: Let's see, there was a Web site that I was researching—when I was researching the systems I came across this product. It's manufactured in...the Midwest and there is a lot more water harvesting in the agricultural region in Texas and so forth, and they use it more for irrigation, but they come up with these little devices. It's fun to apply it here.

Christopher: For one thing, in and of itself [the Web is] more sustainable than having people mail you stuff all the time. Catalogs and whatever... And I view it as being more current. You can find the latest information. You can find more impartial information. You don't have to wait for a brochure from a company who's trying to sell you something to send you this brochure. You can get more original research off the Web if you search carefully. And you can look up things about, you know, lifecycle analysis on different materials and so on, like that.

Overall, while computers were seen as a useful tool for green work-related activities, the purchasing choice and day-to-day operation of the computing devices themselves was seen as a somewhat marginal issue from a green perspective. One possible explanation as to why participants had a relative lack of awareness or interest in this area is that the historic counterculture roots of environmentalism did not embrace electronic devices. Therefore, early proponents of environmentally responsible activities may not have reflected in detail on electronic devices, in contrast to their more sophisticated

consideration and dissemination of information in regard to (for example) food. As awareness of environmental issues has reached a wider audience, this early anti-technology bias may have left a gap in knowledge and education. We believe this gap may present an opportunity for education and (re)positioning of computing devices and electronics relative to environmental concerns.

STRATEGIES FOR GREEN COMPUTING

Technology is understood to have a complex relationship with environmental issues. As discussed above, while traditional environmentalism argued for a reduction in technology, more recent environmental perspectives tend to recognize positive opportunities for simultaneous advances in environmental responsibility, quality of life, and economic growth. Accordingly, while computing technology can be viewed as "part of the problem" via issues such as e-waste and energy consumption, computing technology can simultaneously be viewed as "part of the solution" by enabling better use of resources in a wide range of domains (e.g., telecommuting, optimized route planning for fleets of trucks, smart buildings). These two perspectives correlate with two broad categories of an overall green strategy for computing technology:

Minimize: Minimize computing technology's contribution to the problem in both products and operations, e.g., through novel energy-efficient products, product design for reuse, reduced use of materials, recycling, etc.

Enable: Maximize computing technology's contribution to the solution by enabling green applications of computing technology, e.g., green design, smart buildings, dematerialization, etc.

Inspired by the actions and attitudes of our participants as well as by our review of secondary research materials, we have developed a framework of opportunities for green actions in these categories. This framework appears in Table 1.

Table 1: Strategies to (1) *Minimize* harmful environmental impacts of products and operations, and (2) *Enable* green behavior through computing

<i>Minimize</i>	<i>Reduce</i>	<i>Optimize X (optimizations to use strictly less of X, or increase the efficiency of X)</i> Examples: Reduce emissions from manufacturing, turn off lights, use energy efficient devices
	<i>Reconstitute</i>	<i>Replace X with Y (generally game-changing or more radical innovations)</i> Examples: solar panels, biodegradable packaging, hybrid cars, eco-friendly household products
	<i>Reuse</i>	<i>Reuse X as X</i> Examples: extend useful life of objects
	<i>Recycle</i>	<i>Extract materials from X</i> Examples: extract gold, e-recycling, composting
	<i>Reparation</i>	<i>Compensate for X by also doing Y</i> Examples: carbon offsets
	<i>Re-think</i>	<i>Reconsider or increase awareness (indirectly prompt Reduce/Reconstitute/Reuse/Recycle/Reparation)</i> Examples: make new policy, education, eco-labeling, Energy Star
<i>Enable</i>	<i>Design and Invent</i>	<i>Use computing technology to design and/or invent green objects and green processes</i> Examples: design green buildings, invent sources of renewable energy, design fuel-efficient aircraft
	<i>Optimize and Automate</i>	<i>Use computing technology to calculate and/or execute optimizations in real-world systems</i> Examples: efficient route planning for delivery trucks, smart buildings, smart agriculture, smart appliances
	<i>Minimize Miles</i>	<i>Use computing technology to support remote activities to minimize travel of people and goods</i> Examples: telecommuting, teleconferencing, online purchasing
	<i>Monitor and Model</i>	<i>Use computing technology to monitor and model the state of the environment</i> Examples: environmental quality sensing, climate modeling
	<i>Operate and Sell</i>	<i>Use computing technology to sell green goods or services, or run a green non-profit or business</i> Examples: solar panel installers, carbon offset vendors
	<i>Educate and Persuade</i>	<i>Use computing technology to promote green behavior and share information locally and globally</i> Examples: green blogs, citizen action tools, ambient displays of energy use, personal digital coach for green behaviors

First, Table 1 lists green strategies to minimize harmful outputs and the use of resources: Reduce, Reconstitute, Reuse, Recycle, Reparation, and Re-think. These strategies underlie a wide range of environmentally responsible behaviors. To illustrate the generality of these principles we include examples of both actions that might be taken by a technology company (e.g., reducing

emissions) as well as actions that might be taken by people in their daily lives (e.g., turning off the lights).

Second, Table 1 lists strategies to enable green processes, products, and actions: Design and Invent, Optimize and Automate, Minimize Miles, Monitor and Model, Operate and Sell, and Educate and Persuade. In the descriptions

and examples in the table, we focus in particular on how information and communication technologies can enable each of these strategies. Note that these Enable strategies implicitly enact Minimize strategies. For example, a green building can be designed to reduce energy use, reuse water, etc.

To date, the bright green perspective has tended to emphasize areas such as alternative energy sources and transportation. However, computing technology has much to offer in this arena as well. A comprehensive strategy for green computing will both Minimize and Enable, by making computing technologies that are themselves environmentally conscious and by deploying technologies to meet environmental challenges. Many of these directions are already being pursued, and many exciting opportunities lie ahead.

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