Greening through IT

Information Technology for Environmental Sustainability

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1 Introduction to Green IT

Kerala, a state in the southwestern part of India, has a substantial fishing industry, directly employing more than a million people. Sardines are one of the main species that the commercial fishers catch. Starting in the late 1990s, mobile phone service became available in Kerala. The fishers gradually began using the phones to find customers in need of their catch and coordinate sales. In previous years, 5 to 8 percent of the daily catch of sardines was wasted, with sellers sometimes unable to find buyers. With the introduction of mobile phones, this waste was eliminated completely, as the fishers and the buyers dynamically streamlined their markets. The fishers' profits increased, consumer prices declined, and fewer sardines went to waste unnecessarily (Jensen, 2007).

Utility companies and research laboratories around the world are working to develop and install smart electricity and gas meters in millions of households and businesses. These meters are designed to support real-time energy pricing and enable households and businesses to optimize their usage. For example, various energy-intensive activities such as running a clothes dryer could be scheduled at times when electricity demand is low. These meters will simultaneously save money for consumers and allow the utility providers to deliver energy more efficiently.

On July 14, 2007, a group of fifty-seven naked bicyclists took to the streets of Seattle, Washington. This event was one of many such rides in cities across the globe as part of the "World Naked Bike Ride." The organization's Web page offers the following credo: "We face automobile traffic with our naked bodies as the best way of defending our dignity and exposing the unique dangers faced by cyclists and pedestrians as well as the negative consequences we all face due to dependence on oil, and other forms of non-renewable energy" (WorldNakedBikeRide.com, 2007). Rather than relying on paper brochures or other traditional media, the organization used the World Wide Web, email, and other information technologies to support the planning, coordination, and deployment of events around the world. In the online wiki, a comment for the Seattle event reads: "Great weather, 3 arrested" (NakedWiki.org, 2008).

The above examples illustrate just a few of the many ways in which environmental issues and information technology (IT) are beginning to interact.[1] From Cisco's use of telepresence to reduce corporate travel (Hsieh, 2009) to the large-scale migration of computing processes to places where energy is available (Hopper & Rice, 2008), instances of IT systems having an environmental impact are emerging across a wide range of domains. This book seeks to provide a framework for thinking about IT systems that address environmental topics. By doing so, it aims to help people work more effectively, both individually and together, to address the numerous environmental concerns currently facing the planet.

The Field of Green IT

Over the last several years, the term "Green IT" has begun to be used to describe a field at the juncture of two trends. The first trend involves the growing concern about environmental issues across many human communities. For example, a *Newsweek* poll in August 2007 found that 61 percent of adults in the United States said they had personally taken "steps to reduce [their] own energy consumption because of concerns related to climate change and global warming" (Polling Report, 2008). A survey of 49,243 teens from around the world revealed that 74 percent of them "believe that global warming is a serious problem and are more concerned about it than any other issue including drugs, violence or war" (Greenpeace, 2007). As further evidence, the film *An Inconvenient Truth* won the 2007 Academy Award for best documentary feature, and Al Gore shared the 2007 Nobel Peace Prize with the UN Intergovernmental Panel on Climate Change "for their efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change" (Nobel Foundation, 2008). These and many other recent cultural phenomena reflect a growing awareness of the impact that humans and our activities have on the world. The term "Green" has become connected with this sense of awareness; the word choice is based on the primary color of plant leaves and reflects a concern for the ecosystems in which humans exist.

The second trend involves IT—the use of digital tools and techniques for manipulating information, and the social phenomena that surround these systems. (Actually, two acronyms, IT and ICT, could apply here. As noted above, IT stands for information technology and is broadly known across a range of public audiences. ICT stands for information and communications technology; this more explicitly inclusive term is used in certain fields of academia and a range of government/economic contexts. To make the content of this book broadly accessible, the acronym IT is used throughout.)

IT is growing at a rapid rate; as an example, while mobile phones were relatively rare a decade ago, now more than half the world's people have them (Reuters, 2007). There are many different forms of IT, in terms of both the information systems that exist—such as software packages, databases, and networks—and the devices that people and institutions use to access these systems—such as notebook computers, servers, mobile phones, and personal digital assistants. Humans inhabit the growing information ecologies that result from this abundance of devices and systems (Nardi & O'Day, 1999). The rapid adoption of IT is transforming societies around the world, affecting many different aspects of human life from communication between individuals to the workings of international politics.

Green IT brings together these two areas, environmental issues and IT, and explores the ways in which they connect to each other. In particular, it examines the opportunities for IT to address issues related to the global ecosystem. The rapid growth and acceptance of IT worldwide suggests that this area may be a fruitful one in which to seek possibilities for environmental change, building on other transformative societal effects already underway. Andy Hopper (2008), professor of computer technology and head of the computer laboratory at the University of Cambridge, states the case succinctly: "Computing is a crucial weapon in our armoury for ensuring the future of the planet" (p. 1).

It is important to note that not all facets of IT are environmentally favorable. Computation is beginning to occupy a nontrivial amount of the power consumption around the world, and electronic waste (e-waste) is a fast-growing concern. In addition, the culture of disposability implied by the rapid innovation and turnover rate in computational technologies is deeply problematic. According to a report by the Gartner research firm, the IT sector emits CO_2 at a rate approximately equivalent to that of the airline industry (Mingay, 2007). This rate is growing rapidly, especially in the mobile computing area. Nevertheless, according to *Smart 2020*, a report by the Climate Group (2008) on behalf of the Global e-Sustainability Initiative, the potential positive environmental benefits enabled by IT are five times as great as the environmental footprint of IT itself. Given the inherent complexity of environmental issues and the inefficient ways humans currently live, innovations in IT across many aspects of society can have a strongly positive net environmental impact.

The environmental opportunities presented by IT systems are both external and internal to the IT field itself. Externally, Green IT can have an effect on areas from economics (von Weizsäcker, Lovins, & Lovins, 1998) to ecological monitoring (Szewczyk et al., 2004) to the details of people's everyday lifestyles (Mankoff, Matthews, Fussell, & Johnson, 2007; Woodruff, Hasbrouck, & Augustin, 2008). Internally, Green IT can help reduce the impact of e-waste (Grossman, 2006; Hightower, Smith, Sonnenfeld, & Pellow, 2006), enable sustainable interaction design (Blevis, 2007), and decrease energy consumption by computational systems (Markoff, 2006). While the term "Green IT" is sometimes used to refer solely to the ways in which the IT industry itself can become more sustainable, in this book Green IT involves any IT that helps to make any aspect of society greener, including IT itself. The title of this book, *Greening through IT*, seeks to capture this focus on the use of IT across many different sectors, rather than concentrating just on its own impact.

The ultimate goal of this text is to help humans and the ecosystems in which we live achieve a state of sustainability. Various definitions have been offered for the term “sustainability”; for example, Ismail Serageldin (2006) offered a human-centric definition, stating that “sustainability is giving future generations as many opportunities as, if not more than, we have had ourselves.” For the purposes of this book, sustainability is a characteristic of a system—in this case, the global ecosystem—in which all defining processes, such as the maintenance of biodiversity (including *Homo sapiens*) at a high quality of life, are able to continue indefinitely. A sustainable system can be juxtaposed with one in which limitations on the availability of resources, overproduction of waste, or other factors will eventually cause the system to collapse.

Other useful terms have been put forward to describe related concepts. “Resilience” has been defined as “the capacity of a system to absorb disturbance and reorganize while undergoing change so as to still retain essentially the same function, structure, identity, and feedbacks” (Walker, Holling, Carpenter, & Kinzig, 2004, p. 1). Aldo Leopold (1966) offers a more general term, “right,” suggesting: “A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise” (p. 262). Because of its existing association with an array of ongoing international efforts, the term “sustainability” will be used to represent this suite of concepts throughout this text.

Abundant scientific evidence—for example, the findings in the IPCC’s (2007b) Climate Change 2007 report—suggests that humanity is not currently living in a sustainable way. Fortunately, people around the world are increasingly becoming aware of environmental issues and taking action to address them. Despite this growing engagement, we need to ramp up the intensity of these efforts in order to avoid profound and potentially catastrophic global change. The coming chapters explore the critical role that IT can play in this undertaking. For the past several millennia, technology has multiplied the rate at which humans brought about the current environmental concerns; by broadening humans’ horizons of time, space, and complexity, Green IT can provide a multiplier effect on our ability to resolve those same environmental issues in the future.

Environmental Issues Operate on Broad Scales of Time, Space, and Complexity

Humans and all other organisms require certain characteristics of our habitats to remain within certain parameters in order for us to survive. If our body temperature goes too far from 98.6°F, if we do not receive air, food, or water for a certain period of time, or if many other conditions are not met, we cannot continue to exist. Throughout this text, the term “environmental” will refer to the collection of topics that relate to the nonhuman physical and biological context in which humans live, and on which we rely for our continued existence.

The key problem in the way humans understand and act on environmental issues is one of scale. Environmental issues tend to occur on broad scales of time, space, and complexity compared to the typical scope of human concerns. These differences are particularly apparent in domains such as population, resource use, waste production, and species extinction. Regarding the first of these areas, the world population is approximately 6.7 billion people and has been increasing rapidly, doubling within the last forty years. People inhabit over 190 countries, speak thousands of languages, and live in cities with millions of inhabitants. Within this century, the world population is likely to grow to over 9 billion (United Nations, 2004).

People are exhausting natural resources, many of which regenerate slowly through nonhuman processes, on a global scale; nevertheless, we do not adequately address the restoration of these resources. For example, humans consume oil and other petroleum products at a rapid rate, but these resources only come into existence naturally via geologically long periods of compression and heating. “Peak oil” is the term given to the point at which worldwide petroleum production will reach its maximum level; this point is seen as occurring within the next few decades, if it has not already happened (U.S. Government Accountability Office, 2007). Peak oil indicates the dramatic imbalance between the time scales of petroleum formation and exploitation.

As another example of humanity’s vigorous resource use, consider that half the world’s forests, which once covered 48 percent of Earth’s surface, have disappeared during human history (NRDC.org, 2004). The loss of these forests has a variety of effects, such as reducing the planet’s ability to convert CO_2 to breathable O_2 and eliminating the habitats of many biological species. Beyond the impacts we can already see, the long-term environmental effects of human civilization’s current actions will take decades or centuries to emerge fully. Therefore, it is likely that increasing environmental degradation as a result of human resource consumption will be with us for a long time.

In the process of using these resources, humans produce large amounts of waste as well. For example, in 2005, the world produced over 28 billion metric tons of CO_2 from the consumption of fossil fuels (U.S. Environmental Protection Agency, 2007); CO_2 is one of the greenhouse gases (GHG) largely responsible for global climatic disruption. (John Holdren [2008], Barack Obama’s science and technology adviser, prefers the term "global climatic disruption" to "global warming.") According to the Intergovernmental Panel on Climate Change (IPCC, 2007b), "Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations" (p. 10).

Global climatic disruption is the most famous problematic result of this waste production, but there are many others. According to the U.S. Environmental Protection Agency (2008a), the United States produces 230 billion kilograms of municipal solid waste per year, or more than 2 kilograms per person per day. In 2006, people around the world consumed 47 billion gallons of bottled water; the United States had the highest per capita consumption of bottled water, at more than 29 gallons per person that year (BottledWater.org, 2006). Only 31 percent of these bottles were recycled; the others ended up in landfills or other locations (U.S. Environmental Protection Agency, 2007). Taken together, these unsustainable habits represent a major issue that needs to be addressed. Nevertheless, the impacts of these choices are rarely immediately apparent, but instead unfold over long periods of time, at great distances away, and in a variety of indirect ways.

The drastic increase in worldwide species extinctions over the last several hundred years also suggests that we are not on a sustainable trajectory. According to a report by the Secretariat of the Convention on Biological Diversity (2006), a treaty signed by 150 world government leaders at the 1992 Rio Earth Summit, "Species are going extinct at rates 1,000 times the background rates typical of Earth's past." This trend is sometimes referred to as the "Sixth Extinction" (Leakey & Lewin, 1996)—the sixth major extinction event since the beginning of life on Earth, and the most severe since the extinction of the dinosaurs sixty-five million years ago. The ecological factors that underlie each species' extinction are complex; taken together, the complexity involved in the extinction of thirty to fifty thousand species per year (Leakey & Lewin, 1996; Olson, 2005) is difficult to grasp.

The extinction of species is significant not just for whatever inherent value one might place on the species themselves. Additionally, the sustainable survival of humans is more likely if there are many different kinds of life in existence. Diversity offers robustness in the face of perturbation. Diverse ecosystems are able to absorb and adapt to change more easily than homogeneous ecosystems. There are numerous examples of the fragility of monocultures (i.e., large tracts of the same crop), such as the potato blight that caused the Great Irish Famine in the mid-nineteenth century, and the spread of the boll weevil across cotton farms in the southeastern United States in the early twentieth century. Humans are part of the ecological complexity of Earth. While the world may be made temporarily more amenable to humans by the dedication of large areas of land to corn, palms, and cows, our tendency to exploit a few species on large scales leads to the extinction of many others, and thereby threatens the stability of the global ecosystem as a whole.

The environmental issues currently facing the planet are substantial. Nevertheless, people, governments, and other human institutions often choose to attend to other, more immediate, local, or accessible concerns, rather than addressing any of the above problems with vigor.

Humans Operate on Narrow Scales of Time, Space, and Complexity

In the above brief account of some of the world's environmental issues, I used a common shorthand in discussions of scale: whenever I used an adjective like "large," "slow," or "big," I assumed that the reader would understand that I meant each of these terms "from a human perspective." The amount of CO_2 humans produce is not large when compared to the mass of the Sun. The process of forest regeneration is not slow when compared to continental drift. The extinction of a single species is not complex compared to the evolution of all life. Nevertheless, to a person trying to make sense of these issues, the scales involved are larger than those we typically confront. Environmental issues tend to occur on much broader scales than humans are skilled at comprehending.

Human anatomy, physiology, and behavior evolved to deal with a certain set of problems that recurred frequently in our ancestors' lives. They looked for food and water; they avoided danger; they sought opportunities for reproduction; and they cared for their children. All of these interactions usually happened on what I will refer to as "human scales" of time, space, and complexity. Individual humans rarely worried about gathering food a thousand years after their deaths. They did not concern themselves with a boulder bounding down a mountain in a different continent; they worried about the ones over their heads. And in helping their children learn and grow, they taught them about the world they would encounter every day, so that they too might live well.

As humans developed more and more complex societies, moving to unprecedented forms of communication, memory, and collective action, cultural factors began to broaden their horizons. People developed rules and laws to enable them to plan further into the future and live together at larger scales. They told stories about their past encounters so their social partners could learn from their experience without needing to suffer any negative outcomes themselves. They developed governments and corporations so that they could together reap the benefits of broader-scale activity. Economic innovations such as discount rates enabled them to formalize the way value changes over time. City walls and political borders helped humans understand the limits of their physical domains. Organizational hierarchies and division of labor let people manage the growing complexity of their lives.

Human scales of time, space, and complexity are broad, from some perspectives. Our lives are long when compared to those of ants; our bodies are big when compared to bacteria; and our ability to comprehend is vast when compared to that of a macaque. Nevertheless, the topic of this book is environmental change, and the relative narrowness of human comprehension and action when compared to the scale of the world's environmental concerns is a critical factor in our ability to respond effectively. "Business as usual"—that is, continuing along current trajectories of population, resource consumption, waste production, and global impact—with our current horizons of time, space, and complexity, is not sustainable.

Human institutions such as corporations and governments have many of the same characteristics that people have, but on somewhat different scales of time, space, and complexity. In fact, many are explicitly organized to help leverage the benefits of broader scales of operation. For example, Ronald Coase (1937) won the 1991 Nobel Prize for Economics based on his paper "The Nature of the Firm," which shows how reduced transaction costs enable firms to outperform individuals operating as independent contractors in a free market; this reduction in complexity helps a firm succeed in business more effectively than a collection of individuals. Similarly, governments help smooth out problems that might be caused by individuals acting out of pure self-interest without regulation. Governments thus allow people to operate with longer time horizons and move across larger areas of space with an expectation of consistent interactions with each other.

At the same time, corporations, governments, and other institutions still primarily serve human-scale interests. Corporations are tasked with enhancing shareholder value. The U.S. Constitution begins: "We the People of the United States, in Order to form a more perfect Union, establish Justice, insure domestic Tranquility, provide for the common defence, promote the general Welfare, and secure the Blessings of Liberty to ourselves and our Posterity, do ordain and establish this Constitution for the United States of America" (archives.gov, 2009). This document is ultimately a human-centered text, and as such reflects human scales of time, space, and complexity. Human institutions, seeking to leverage opportunities to act with broader horizons to serve human needs, often lie somewhere between the scale of individual humans and that of environmental concerns.

IT Compresses Time, Space, and Complexity

Technology, our ability to work with tools and develop techniques for manipulating our environment to better serve our liking, developed alongside human communities and has a long history of extending our reach. We invented agricultural implements, rapid transportation systems, and powerful weapons. Technology has provided a "force multiplier" in many domains of human experience, letting us act with greater impact for less effort. Through the technologies we have developed, humans have made our own horizons broader, crossing oceans, forming multinational organizations, and watching light arrive from long-dead stars.

IT in particular has proved to be effective at broadening our horizons, or seen another way, compressing time, space, and complexity. IT compresses time in many ways—for example, by storing abundant information for later retrieval, letting us model the past and predict the future, and enabling the synchronization of many different human activities. IT compresses space by allowing us to communicate over great distances, browse maps of the entire world, and transport goods and people around the globe. IT compresses complexity by augmenting our memories, allowing devices to perform repetitive calculations, and establishing agreed-on standards for the cooperation of devices and people. Across human history, IT systems have been critical in broadening the scales on which humans operate. We need systems that broaden our understanding and ability to take action across broad ranges of time, space, and complexity; framed another way, we need compression algorithms that shrink global environmental problems to human-comprehensible scales.

In terms of human institutions rather than just individuals, IT helps bridge gaps in scale as well. IT has been used to provide more comprehensible information to individuals about a variety of institution-scale phenomena, from stock prices to electricity rates to election results. IT also allows institutions to act more effectively based on expert opinions and analyses predicated on computational simulation, modeling, and visualization. IT has the potential to extend both of these connections, bridging from human scales to institutional ones, and institutional scales to environmental ones, thereby indirectly enabling individuals to impact environmental concerns via the mediation of institutions.

Green IT Bridges from Human Scales to Environmental Scales

Technology and IT have not always worked to the benefit of environmental sustainability. In fact, quite the contrary: technological innovations have allowed us to farm, burn, mine, fish, drive, reproduce, and buy to the detriment of many environmental concerns. From these problems, though, arise numerous opportunities for people to make the way we live more sustainable. Helping people and institutions discover, understand, and act on these and other environmental possibilities is the primary goal of Green IT.

By helping spread information about environmental issues, and enabling humans and our organizations to share best practices for addressing them, Green IT can hopefully assist in mitigating the global problems that appear to be looming in our future. Many examples of explicitly environmental IT systems already exist—from smart energy grids to systems that optimize hybrid car engines (Kleimaier & Schröder, 2004) to the Earthday Network's Ecological Footprint Quiz (Earthday.net, 2008). In addition there are many IT systems that have been developed for nonenvironmental reasons, but that have implicit environmental impacts, such as GPS systems and online mapping software, which lead to more efficient travel and therefore reduced CO_2 emissions. This book draws on existing examples of systems whenever possible, in order to ground the discussion in real-world applications. Green IT also shows promise as an area in which future developments will enable new ways of living and working together. In this spirit, the book presents ideas for novel innovations in the field of Green IT.

The ways in which IT can benefit environmental issues take a variety of forms. One axis along which these innovations may be arrayed is from "personal" to "institutional." Personal IT systems enable individuals and small groups to broaden the horizons of time, space, and complexity with which they think and act, thereby enabling them to respond more effectively to a range of environmental concerns (see figure 1.1a). Institutional IT systems have a similar effect, but broaden the horizons of understanding and action for corporations, governments, nongovernmental organizations (NGOs), universities, and other large-scale organizations (see figure 1.1b). These two forms of Green IT are mutually reinforcing.

Personal

Green IT can help individuals participate in many different ways to address the world's current environmental concerns. For instance, it can provide information that encourages people to exert more effort in this direction. This form of participation can be simple—for example, reading a post on an environmental Web site about walking up the stairs instead of taking the elevator—or more dramatic—such as selling one's car, and then using a bicycle or a car-sharing system such as Zipcar instead.

IT can also improve the efficiency with which we enact our daily lives. Using a Garmin Nuvi GPS navigation device to take a more optimal route among several chores

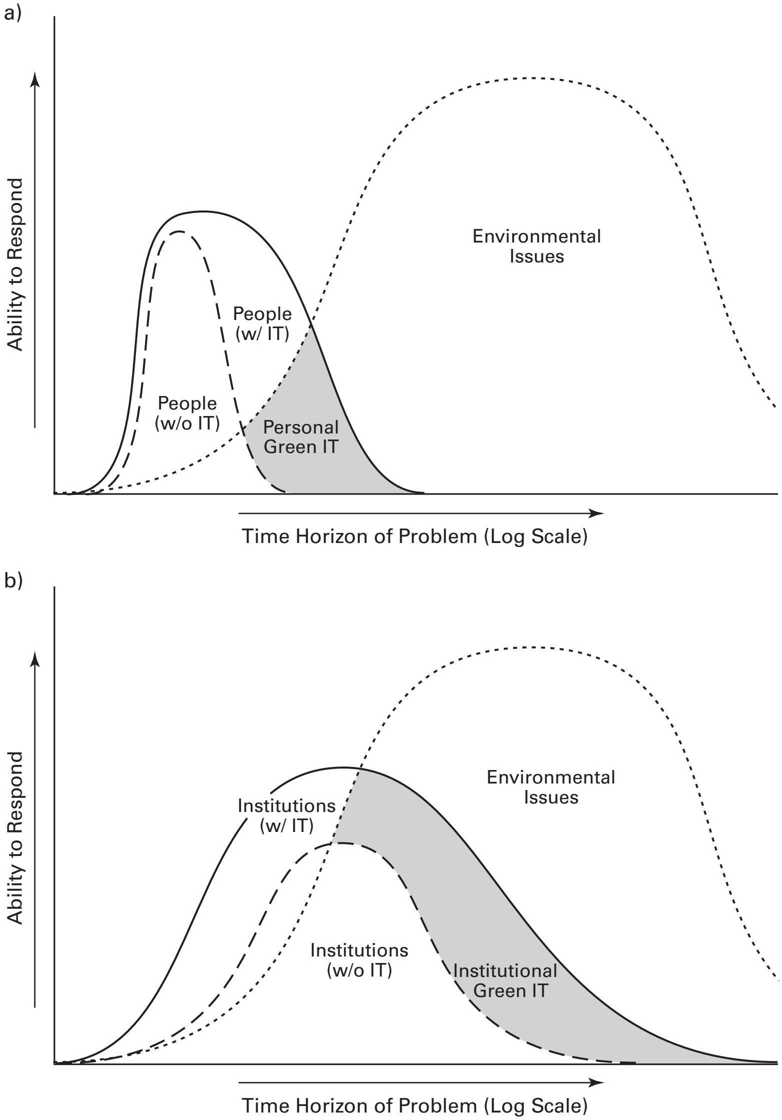

Figure 1.1
IT extends the ability of people (a) and institutions (b) to respond to environmental issues.

in an afternoon or hosting a business meeting via teleconference rather than flying people in from other countries are examples of more efficient practices that are more environmentally conscious as well. While there may be accompanying problems with these and other innovations, such as the loss of serendipity in driving and reduced benefits of face-to-face interaction, we are reaching a point where environmental concerns should weigh heavily in the choices we make.

Furthermore, Green IT can provide opportunities to address environmental issues through improved collaboration. For example, CouchSurfing.com allows people to plan trips where they stay in someone's house rather than a hotel. In addition to reducing the environmental impact for the trip, it also helps enable a social reward through the connections and possible friendships established among like-minded individuals. This and many other online systems help groups of people organize themselves and find strength in numbers for environmental goals. Earlier in this chapter, I mentioned a poll suggesting that 61 percent of U.S. adults have taken steps to reduce their energy consumption due to global warming. Put another way, 39 percent of U.S. adults have not taken any steps at all to reduce their energy consumption. If sustainability is the goal, there is still a long way to go. Understanding the mechanisms by which Green IT can lower the bar for participation and increase the rewards that come from greater effort could be an important contribution to a sustainable future.

Institutional

Beyond the actions of individuals, there are abundant ways that Green IT can contribute through corporate, governmental, and other institutional efforts. Green IT innovations can extend the scale with which human institutions support the movement toward global sustainability.

One of the primary institutional contributions of Green IT is through improved infrastructures. Smart energy grids enable more efficient power utilization. Improved transportation systems reduce fuel use while optimizing the movement of people, objects, and materials around the world. More effective waste management systems can facilitate more comprehensive recycling and salvaging of useful materials after their initial usage is complete.

Green IT can also improve large-scale planning and policy decisions. IT is helping scientists and other experts develop an understanding of many real-world phenomena—a critical factor in making informed, far-reaching decisions. Visualization and modeling techniques can help policymakers understand scientific factors and likely outcomes more fully, thereby allowing for more informed decisions. E-government systems can involve the populace more effectively in policymaking, providing citizens with information about why decisions are made, and encouraging them to participate in community- or worldwide efforts.

Institutional action through Green IT also has the potential to enable individuals to live more sustainably on a large scale. It is often difficult to make environmentally sensitive choices when those choices are discouraged by law or lack of infrastructure. Understanding the ways in which human institutions can provide individuals with environmental options is crucial to the goal of achieving global sustainability.

It is important to note that there is fluidity between personal and institutional Green IT innovations. For example, the smart energy meters mentioned at the beginning of this chapter allow individuals to monitor their consumption habits and institutions to analyze usage across millions of households, both of which help humanity live more sustainably. While there is not a clear distinction, personal and institutional forms of Green IT address different scales of time, space, and complexity. These efforts are complementary; if some of the personal Green IT innovations allow people to take environmental actions in domains previously under the aegis of institutions, it now frees up those institutions, which operate under constraints of available time and energy, to focus on broader environmental issues.

An Extended Human-Centered Approach

This book is grounded in the field of human-centered computing (HCC), and takes a human-centered approach to the Green IT field. HCC focuses on humans as the most important element in the development of computing systems. Moving beyond narrowly scoped HCC, however, *Greening through IT* presents an extended view of human-centeredness, looking at how computing can situate human civilizations at the locus of responsibility for environmental issues, and enable individuals and groups to act to resolve these issues. This human-centered approach is distinct from anthropocentrism and is not meant to downplay the significance of the survival of other species; rather, it sees humans as the species with the greatest potential to orchestrate a coherent response to the world's current environmental problems, and therefore the most expedient path to addressing those issues.

HCC arose from a response by computing professionals and researchers to an earlier state of computing. During its first few decades, computing resources were scarce, and hence humans were expected to take a great deal of effort to organize and customize content intended for computers prior to its being input into the machine. From large stacks of punch cards to complex command-line systems, interfaces to computers were complex and unintuitive. In the last several decades, though, as computing power has become more abundant and less limiting, there has been a move toward increased human usability in computing. Humans began to have more active roles in human-computer systems (Bannon, 1992), and to be included in the process of designing interfaces. As computers have reached a mass market, designing interfaces for ease of use rather than just computational efficiency has become increasingly important to the computing industry.

HCC continues to be a growing field, with programs at the U.S. National Science Foundation (NSF), the U.S. National Aeronautics and Space Administration, and several major research universities. NSF offers the following definition of the area:

> [HCC] research encompasses a rich panoply of diverse themes in Computer Science and IT, all of which are united by the common thread that human beings, whether as individuals, teams, organizations or societies, assume participatory and integral roles throughout all stages of IT development and use. People design new technologies; people, in teams and organizations, at school and at home, use them; people anticipate and enjoy their benefits; and they learn about the outcomes of use (whether anticipated or not) and translate that knowledge into the next generation of systems. At the same time, new information technologies and human societies co-evolve, transforming each other in the process. As a consequence, the design of IT must be sensitive to human values and preferences. (U.S. National Science Foundation, 2006b)

A human-centered approach leads to several benefits. It produces computing systems that allow people to work more effectively and play more enjoyably. It develops interfaces that mesh smoothly with people's abilities and desires. It allows for communication and collaboration on previously unheard-of levels. Through these and other advantages, a human-centered approach contributes to greater human happiness.

Extending the focus of HCC to consider factors on a broader set of horizons than the usual scope of individual humans provides the central structure around which this book is organized. This "extended human-centered computing" (EHCC) perspective provides a way of understanding the potential for Green IT. This view discards the notion that the immediate gratification of human desires is an unconquerable problem for the world's ecosystems.

A broader set of horizons for HCC is necessary if the world's environmental concerns are to be addressed effectively. There is already some awareness in the research community of this need. For example, NSF includes "broader impacts" as one of its key evaluation criteria for grant making. Yang Li and James Landay (2008) offer that their theoretical framework "uses a larger unit (long-term, high-level activities such as staying fit) for analysis and design than simple tasks (such as using a treadmill), which have been the focus of traditional approaches." Similarly, as mentioned previously, Eli Blevis's (2007) focus on sustainable interaction design seeks to give computing systems greater longevity in a variety of ways. The "value-sensitive design" approach put forward by Batya Friedman and her colleagues posits a need to "broaden the goals and criteria for judging the quality of information systems to include those that advance human values" (Friedman & Freier, 2005, p. 371). Value scenarios (Nathan, Klasnja, & Friedman, 2007) can help support long-term thinking about important design problems. Many other research projects focusing on broad-horizon environmental issues will be discussed throughout this text. Focusing on the impact of IT systems a century or millennium from now, or on a worldwide scale, may seem impractical, given people's predilections for thinking of our own immediate, local issues first. Certain ways of thinking about computing, however, may help shift the focus in order to serve the same goals as a human-centered perspective with a broad horizon in time, space, or complexity.

The human-centered approach taken here also embraces human institutions such as corporations, universities, governments, and other organizations. These institutions were formed by humans and are staffed by humans; as such, they often reflect a human-centered approach. They tend to have broader horizons than individuals; however, they tend to focus on problems facing groups of people. In order for most institutions to deal effectively with environmental concerns, they too need to broaden their horizons still further in time, space, and complexity. While my research over the past several years has tended to focus on personal Green IT, and therefore many of the examples throughout this book are from that domain, the core principle of this text—that IT can help make connections between human-scale action and broader environmental concerns—applies to human institutions as well as individuals.

Broadening Time

While NSF's vision for HCC does include some attention to human values such as environmental sustainability and social justice, and thus has some connection to broad-scale undertakings, there is a pervasive rhetoric associated with HCC that leads to short-term satisfaction of human users' needs and desires. I use "short-term" here in the economic sense, as in short-term capital gains, rather than in the cognitive science sense, as in short-term memory. Unless otherwise specified, I will use "short-term" to mean hours, days, weeks, or months, and "long-term" to mean years, decades, centuries, and millennia.

Relatively short-term human satisfaction has been a primary focus for much HCC-related scholarship. For example, citing Mark Weiser's seminal article, "The Computer for the 21st Century," Li and Landay (2008) summarize a prevailing view within the research community as follows: "Ubiquitous computing (ubicomp) promises to support our everyday activities by weaving computing power into the fabric of everyday life." (p. 1303). Even the term "human-centered computing" (rather than "humanity-centered computing," "world-centered computing," or many other possible choices) suggests a focus on the interests of an individual person.

A concentration on narrowly scoped human centeredness makes sense when the development of computing is seen in the context of human cognitive evolution. Humans are exceedingly skilled at thinking about scales of time that reflect our own needs for survival and reproduction. On the evolutionary landscape in which we evolved, our ancestors could neither gather information effectively on global or millennial scales, nor act effectively on them. Except for our ability to use technology, which is good for all sorts of things, human brains are not particularly well suited for comprehending or acting on broad-scale phenomena. Technology, though, has an established tradition of helping us deal with scales of time beyond those in our comfort zone. IT in particular, with its ability to collect, analyze, and store vast bodies of data with a high degree of precision, support communication and collaboration across time and space, and interact with people and control devices, is appropriate for supporting human efforts to understand broad issues and coordinate effective responses.

A focus on short-term human usability and support in computing also makes sense given the computing field's history of interfaces that required humans to alter their behavior profoundly to accommodate machines' needs. Moreover, there is nothing inherently wrong with attending to the short-term needs and desires of users. In fact, if their short-term needs and desires are not attended to, users will frequently abandon a system. However, a key issue here is that it is insufficient to concentrate *only* on short-term issues. Computing researchers and professionals need to look at long-term issues as well.

Making it more socially acceptable to think about issues on a longer time scale could help. People are capable of delayed gratification—that is, making decisions that are costly in the short term but beneficial in the long term. Savings accounts, dieting, and university educations could all be seen as examples of this phenomenon. Because of differences in how people perceive the value of present benefits versus the value of benefits in the future, individuals may disagree on the most effective use of current effort and resources. The ability to postpone the satisfaction of current desires in order to protect against global climate disruption and other environmental concerns is nonetheless a crucial element of the process of fostering Green IT.

Broadening Space

In addition to helping us think with a thousand-year time window or longer, Green IT can also help enable scaling of our impact across the spatial dimension. In order to address the world's environmental problems, we will need to work together across the globe to find suitable resolutions. Invariably, different individuals and organizations will bring different experiences, opportunities, and expectations to the discussion. Enabling disparate groups to work together is one of the most important goals that can facilitate sustainability on a large scale.

A global perspective is critical to addressing sustainability effectively. A distinction often made in discussions of international themes involves the separation between the "developed world" and the "developing world." This second term implies a movement toward a higher quality of life and likely greater environmental impact. Perhaps a separation into "more resource-intensive nations" and "less resource-intensive nations," which would create a distinction along somewhat different lines, would be more useful to the current discussion.

It is crucial that people in nations that are currently less resource intensive become engaged with the process of achieving environmental sustainability. For example, over the last twenty-five years, China has accounted for 80 percent of the increase in industrial energy demand (International Energy Agency, 2007); enabling the Chinese and other nations to continue to improve their standard of living without repeating the environmental mistakes of previously industrialized countries is an essential piece of a global sustainability effort. This stance is not intended to align with the hypocritical perspective that suggests that it was acceptable in the past for industrialized nations to pollute on their way to a high quality of life, but that it is not acceptable now for countries aspiring to that same quality of life. Rather, the goal is to help find ways that less resource-intensive nations can achieve a high quality of life for their citizens that is less costly and more sustainable because it takes advantage of recent discoveries and innovations.

One of the advantages that most of the less resource-intensive nations have with regard to sustainability is a lack of entrenched infrastructure that perpetuates environmentally harmful behavior. People in many of these countries are receiving their first introduction to computers through mobile phones rather than desktop computers. If there were to be sustainable systems that could be viable on a large scale, it may be that nations in the process of establishing a modern infrastructure could lead nations with entrenched legacy systems. This phenomenon, known as leapfrogging, can potentially be a catalyst for transformations in the way that the world's civilizations approach environmental concerns.

An ongoing question in the internationalization of the world is to what extent homogenization is a good thing. Certainly, a great deal of standardization has occurred as the world's civilizations have come into closer contact with each other. From passport systems to TCP/IP networking protocols, nations have come to agree on certain ways of facilitating communication and commerce. Digital tools have played a key role in the development of global communication protocols. One might postulate that the homogenization of the world's civilizations might simplify some of the processes of environmental sustainability.

As will be discussed in chapter 2, however, monoculture leaves a farm open to catastrophic failure, while diversity breeds robustness. Although it may be marginally more efficient to have all civilizations work the same way, embracing the differences among cultures will help to develop a global system that is sustainable and robust, and perhaps better able to survive changing circumstances.

The global human rights movement provides a good case study of an effort to enable global cooperation without trying to force unnecessary standardization. The United Nations has long upheld the Universal Declaration of Human Rights (UN General Assembly, 1948), listing rights to freedom, education, and other topics seen as universally due to all humans. This declaration provides a framework for understanding how governments ought to act toward their citizens.

Environmental issues and human rights are closely connected. It is hard to convince people to care about a rain forest fifty years in the future when their children are hungry right now. There is also an inverse correlation between the education level of women and their fertility rate (Akmam, 2002); in this light, the work being done to increase levels of education, in particular among women, may be among the efforts with the longest reach in terms of both environmental and humanitarian effects by slowing the growth of the world's human population. These efforts could work in concert with projects to reduce our per capita footprint to reduce humanity's overall environmental footprint.

In addition to the conceptual relationship between human rights and environmental issues, there is also a similarity in terms of the practical action that is taken, and the way IT factors into that process. For example, in the wake of the 2004 Asian tsunami, over US$7 billion in aid came in from around the world (bbc.co.uk, 2005), with the World Food Programme providing food to 1.2 million people (wfp.org, 2008). Coordinating a response on this scale required the use of many different forms of IT working in concert. Furthermore, since that time, significant effort has gone into the development of early warning systems and other technologies that might mitigate humanitarian crises and coordinate responses to them. Drawing on this and other examples of the rapid mobilization of global resources in a period of just a few months provides an example of how humanity might someday respond to a worsening of the world's environmental issues.

Several major international documents explicitly connect environmental issues to human rights, offering a human-centered view on the topic of environmental sustainability. For instance, the UN Millennium Declaration includes the following section, under the heading "Protecting Our Common Environment":

21. We must spare no effort to free all of humanity, and above all our children and grandchildren, from the threat of living on a planet irredeemably spoilt by human activities, and whose resources would no longer be sufficient for their needs.

22. We reaffirm our support for the principles of sustainable development, including those set out in Agenda 21, agreed upon at the United Nations Conference on Environment and Development.

23. We resolve therefore to adopt in all our environmental actions a new ethic of conservation and stewardship an s first steps, we resolve:

- To make every effort to ensure the entry into force of the Kyoto Protocol, preferably by the tenth anniversary of the United Nations Conference on Environment and Development in 2002, and to embark on the required reduction in emissions of greenhouse gases.
- To intensify our collective efforts for the management, conservation and sustainable development of all types of forests.
- To press for the full implementation of the Convention on Biological Diversity and the Convention to Combat Desertification in those Countries Experiencing Serious Drought and/or Desertification, particularly in Africa.
- To stop the unsustainable exploitation of water resources by developing water management strategies at the regional, national and local levels, which promote both equitable access and adequate supplies.
- To intensify cooperation to reduce the number and effects of natural and manmade disasters.
- To ensure free access to information on the human genome sequence. (UN General Assembly, 2000)

The Millennium Ecosystem Assessment conducted by the UN Environment Programme (2005) sought to "assess the consequences of ecosystem change for human well-being and the scientific basis for action needed to enhance the conservation and sustainable use of those systems and their contribution to human well-being." This assessment involved a number of reports aimed at documenting the current state and trends in the world's ecosystems, then analyzing these data, and offering recommendations about ways for the United Nations and other organizations to take action. One of the "Key Messages" in the summary report stated that "even today's technology and knowledge can reduce considerably the human impact on ecosystems. They are unlikely to be deployed fully, however, until ecosystem services cease to be perceived as free and limitless, and their full value is taken into account" (Millennium Ecosystem Assessment Board, 2005).

Achieving global sustainability will require the collective expertise and participation of people around the world. With a set of common principles underlying the global sustainability effort and IT-enabled coordination across cultures, it may be possible to maintain the cultural diversity that abounds throughout the world while still collaborating on common environmental goals. The ideas presented here may be helpful in establishing the role of IT in facilitating cooperation among different individuals, and by extension among different cultures, around environmental themes.

While environmental issues are affecting all civilizations, many of the examples used in this book relate to people and institutions in the industrialized nations, including those in North America, Western Europe, Japan, and Australia. There are a number of reasons for this focus. First, residents of industrialized nations use a great deal more natural resources per capita and produce more waste per capita than residents of nonindustrialized nations (Diamond, 2008). The industrialized nations, and in particular the United States, have the worst environmental track records of any countries. Second, since many people in the nonindustrialized world are striving to achieve a standard of living like that found in the industrialized one, this focus on current industrialized nations may also provide a test bed for sustainability work that may later be applied more effectively and with greater participation in nonindustrialized nations. By exploring sustainability via the industrialized nations first, this book not only pursues the most striking cases of resource use but may also offer models for sustainable lifestyles that can be deployed elsewhere around the world.

Broadening Complexity

The third main area in which Green IT can broaden horizons is with regard to complexity. There are many different forms of complexity, and Green IT can help with many of them. The two that are most related to the coordinated response of humans to environmental concerns are social and disciplinary complexity.

Social Complexity

In a number of different ways, Green IT can help us work at greater degrees of social complexity. Scaling up social complexity can enable people to take action not just as individuals but also via larger groups and social structures. This scaling can cover anything from small groups of friends to local communities to complex international social networks. One of the great values of computational systems is their ability to scale; online social networks provide for a much greater degree of fluidity and speed in forming like-minded groups.

Among the challenges in managing the social complexity of environmental concerns is the need to pass down innovations from generation to generation. Herein lies the value of attitudes toward sustainability and environmental education; while infrastructural advances can help us live lives with a lower impact, it is critical that future generations embrace sustainability as a lifestyle in order for humanity to survive in the long term. Sustainability is more process than product; it is not simply a matter of fixing the problem and then returning to business as usual. We need a dramatic shift in our approach to living in the world. This shift will produce a great deal of complex changes in human social and cultural systems. It may occur through attitude change, but some aspects are deeply entrenched in human cultures, so adoption may only fully occur in younger generations.

Social complexity also involves the organizations that people have created to facilitate living and working together. Corporations and governments act as proxies for people; just as individuals need to lengthen our time horizons, our conglomerates need to do so as well.

It is interesting to note that participatory culture enabled by the Internet is beginning to blur the boundary between individuals and institutions. It may be that a strong presentation of this dichotomy is becoming less necessary as traditional barriers to group action are lowered. IT support for collective action can be a powerful force for helping people enact change by decreasing the complexity of working together at a global scale.

All cultures contend with the need to consider longer-term issues. The Haudenosaunee (Iroquois) people's seventh-generation philosophy states that decisions should be made with an awareness of their impact on people seven generations from now (SixNations.org, 2007). This philosophy was adopted by the leading brand of green cleaning products, Seventh Generation, Inc. The ability to plan ahead, conceiving of likely futures as well as potential alternates, is perhaps the key attribute that differentiates humans from other animals. Embracing this ability, and allowing people and our technologies to help plan for long-term sustainability, is the core focus of Green IT.

Disciplinary Complexity

In addition to cooperation around the globe, Green IT involves collaboration across numerous intellectual disciplines. Green IT is a relatively young field that draws on many existing ideas and theoretical frameworks. It harvests technological innovations from computer science, information science, human-computer interaction, interactive media, and electrical engineering. It incorporates broad motivations and goals from ecology, economics, and environmental studies. Various Green IT projects have also utilized ideas from anthropology, psychology, sociology, education, art, music, theater, science and technology studies, and numerous other fields.

It is important to distinguish the topic of Green IT from one of its nearest conceptual neighbors: environmental technology. Environmental technology explores ways in which the environmental sciences can be applied to conserve natural resources and mitigate human impacts on the world. Green IT focuses on how IT can serve these and related goals. Of particular interest in the field of Green IT are the personal and social elements—the ways in which people can be enabled to enact lifestyle changes to live in more environmentally sound ways. In addition, as will be discussed later, certain aspects of the theoretical underpinnings of IT lend themselves to environmentally preferable lifestyles and thus make it an ideal platform for sustainable change.

Value of This Approach

The EHCC approach described earlier—focused on broadening people's horizons in time, space, and complexity—has several key values. These benefits primarily relate to the development of technologies and the sociotechnical systems in which they are embedded, but ultimately must lead to an improvement in the world's environmental condition in order to have true value.

First, EHCC can provide a structure for analyzing potential responses to particular environmental problems. Designers can engage in thought experiments regarding the ways people have contributed to certain issues, and how we might be enabled through technology to mitigate or reverse our effects. Potential questions include: What is the time/space/complexity scale of the environmental problem? What is the scale of usual human responses to this problem? How can IT narrow the gap between these two scales?

Second, with particular existing technological innovations, the EHCC approach can provide guidance in evaluating and refining the system to allow it to have greater Green impact. By analyzing the ways in which systems alter people's horizons, this approach may help discover direct or indirect environmental impacts of IT systems that were not originally designed to be Green. With systems that are intentionally designed to be Green, an analysis of how they affect people's scales of time, space, and complexity may help to assess each system's success and overall impact.

Finally, EHCC can be used to compare different technologies and help provide an organizing structure. By arranging systems in a taxonomy based on whether they extend people's horizons of time, space, and/or complexity, and the degree to which they do so, it may be possible to find gaps in the taxonomy that point to fertile space for Green innovation.

Structure

Through both theoretical discussions and an examination of specific cases, this book seeks to provide a way of thinking about Green IT. Chapter 2 offers an overview of the broad environmental concerns currently facing the planet. This chapter presents in detail humanity's resource use, waste production, and other effects on the world, and frames the opportunities for IT to make a contribution. Chapter 3 discusses the characteristics of the human audiences for Green IT, looking in particular at how humans and our societies frequently think and act in narrow ways. Chapter 4 focuses on technology in general, IT specifically, and the sociotechnical systems that arise from them, and considers how they can broaden our horizons of time, space, and complexity. Chapter 5 provides a survey of a broad range of Green IT innovations to offer a sense of the diverse ways IT is impacting environmental issues. Chapters 6–8 discusses three specific areas of Green IT in more detail—environmental education, tools for personal change, and systems that support community action—each of which supplies a unique perspective from which to understand Green IT as a field. In each of these chapters, the analyses are framed around the details of specific projects undertaken by my research group. Taken together, considerations of these three projects help to fill in the contours of the EHCC approach to Green IT. To conclude, chapter 9 explains the way in which Green IT can help us transition from the unsustainable present to a more sustainable future. All of these chapters present an array of existing examples of Green IT projects, in order to provide a sense of the breadth of topics involved in this field.

Methodology

Chapters 6–8 of the book include in-depth descriptions of three social Green IT projects—titled EcoRaft, Trackulous, and GreenScanner—that were created by my research group. EcoRaft is an interactive museum exhibit designed to help children learn principles of restoration ecology. Trackulous is a suite of Web-based tools that assist people in tracking, analyzing, and sharing information about their own environmental impact and other personal data. GreenScanner is a system designed for desktops and mobile devices to help people engage in environmentally preferable purchasing by accessing community-generated environmental impact reviews about consumer products. These projects were created using an iterative design methodology, discussed below, and contributed to the development of the EHCC perspective described previously.

Many varying definitions of design have been suggested by researchers and practitioners over the last several decades. In this text, I will use Herbert Simon's (1996) definition that design is the process of "devis[ing] courses of action aimed at changing existing situations into preferred ones" (p. 111). The use of a design methodology helps ground the book in the practical challenges and opportunities presented by real-world IT systems. The theoretical concepts presented here are derived from ongoing efforts to create working systems.

Iterative design, in particular, offers a way of understanding the context of the use and potential benefits of a system more fully. It utilizes a cyclic process of prototyping and evaluation, with each new prototype being informed by the evaluation of the previous version. The process of coming to understand the possibilities and constraints of the system helps flesh out the set of issues that are most important. In many areas of design, including the design of IT systems, iteration is necessary to produce a high-quality end result. As Web usability consultant Jakob Nielsen (1993) suggests, "Because even the best usability experts cannot design perfect user interfaces in a single attempt, interface designers should build a usability-engineering life cycle around the concept of iteration" (p.32).

In each of these three projects, an interdisciplinary team of designers, engineers, artists, and content domain experts worked together to develop each successive prototype. By bringing together experts from a range of backgrounds, the developers sought to avoid the various problems often encountered by homogeneous teams. For example, in the EcoRaft project (chapter 6), having several ecologists on the team helped ensure that virtual creatures inhabiting the interactive simulation of a Costa Rican rain forest exhibited plausible behavioral patterns and interactions. Had this team been composed only of engineers and artists, the virtual ecosystems would have lacked the veracity that the ecologists could help provide.

For the evaluation of each successive prototype, the research teams used mixed methods to assess the viability and impact of the system on its intended audience. The teams employed both qualitative and quantitative methods at each stage, tailoring the evaluation methodology to the particular needs of each project. With the education-focused EcoRaft project, qualitative methods including semistructured interviews and passive observation were used to assess the user experience and learning objectives. With the Trackulous project, designed to enable people to track their personal habits and behavior, quantitative methods such as an analysis of usage patterns from server logs provided the primary source of information, augmented by a design critique by a skilled user-experience expert. With GreenScanner, the community-based environmental impact review project, server logs as well as online surveys were used to assess the usage and impact of the system.

The audiences that interacted with the various prototypes of each project were selected to represent the target population for the final system. With EcoRaft, the creators exhibited the installation at a regional science museum, and brought in groups of children from the local area to test it at several points. Trackulous was distributed via the Facebook social network and other online mechanisms. With GreenScanner, a press release was sent to a variety of environmental and nonenvironmental news sources as a way of gathering a broad user group through which to evaluate the project.

The iterative design methodology described above facilitated the development of each of these projects, helping the group's research address a range of sustainability issues. In later chapters, these projects are described in greater detail and are each connected to the EHCC perspective. Each project is explicitly analyzed to examine how it contributes to the lengthening of people's time horizon for thinking about environmental issues and the ways in which it situates people at the center of this suite of concerns. This methodology provides an adaptable lens through which to examine the breadth of topics that collectively make up the field of Green IT.

Scope of This Work

The challenge of moving humanity toward sustainability is vastly complex; no one text will be able to cover all aspects of this effort. Therefore, this book seeks to address one small part of the broad set of topics that must be integrated to enable sustainable civilizations. IT is a powerful piece of the sustainability puzzle because it offers a multiplier effect on many sociotechnical systems operating around the world. There are many other factors, however, that must contribute to this goal as well.

There are some deep questions related to cause and effect that underlie the issue of global sustainability. For example, Gus Speth (2008), dean of the School of Forestry & Environmental Studies at Yale University and a global leader in preventing environmental degradation, argues that capitalism, with its emphasis on growth and short-term perspectives, lies at the heart of the world's unsustainability. Rob Watson (2009), who founded the LEED green building rating system, echoes this premise: "The timescales on which markets and nature work are several orders of magnitude off, and most markets and economists continue to labor under the delusion that capital is infinitely substitutable for everything else, including 'ecosystem services.'" Other scholars—for example, Russell Hopfenberg (2003), have maintained that the agricultural revolution may underlie the problem. Researchers from vastly different disciplines, from biochemistry (Elliott & O'Connor, 2007) to public policy (Mazmanian, 2009), all have critical contributions to make in the effort to help humanity live more sustainably.

It is important to explore all of these topics in order to know how best to proceed toward sustainability on a global level; nevertheless, in-depth examinations are beyond the scope of this document. Regardless of the outcome of these and other key debates, it is likely that IT will play a significant role in the solution. IT is not tied to specific food-gathering processes or sociopolitical structures; the concepts presented here can make a contribution in any of the global scenarios that unfold.

Central Argument

Green IT is a growing field that seeks to understand the ways in which IT and environmental issues interact. It takes an interdisciplinary approach, drawing on disciplines from computer science to ecology to economics. There are many projects already in existence in this area, and many more are likely to be developed in the coming years. This book seeks to provide a structure for understanding this field, focusing on the interactions that Green IT systems encourage between humans and the world around us.

The core argument is this:

- Humans are facing significant environmental issues that occur over long time scales, large distances, and great degrees of complexity.
- Unassisted, humans are not well equipped to deal with problems on these scales of time, space, and complexity.
- Throughout history, technological innovations have enabled human cultures to deal with broader suites of problems than we would otherwise be able to address.
- IT specifically involves tools and techniques for dealing with vast bodies of information across wide ranges of time, space, and complexity, and is thus well suited for addressing environmental concerns.

By enabling innovations in infrastructure, education, personal change, community involvement, and many other domains, Green IT can help people live more sustainable lives. This shift need not be instantaneous; rather, we can seek to transition smoothly from current ways of living to more sustainable ones. Green IT systems can assist with all stages of this transition. Once humanity is living sustainably, perhaps we can begin to repair some of the global problems we have caused, restoring endangered ecosystems and threatened species.

The goal of Green IT is to help people make a difference, and change our world to be more in accord with the way we would like it to be. The naked cyclists in Seattle have one unique way of making a difference. In addition to high-profile demonstrations, though, there are thousands of ways, large and small, that people and institutions can participate in a movement toward environmental sustainability. By helping people and organizations discover approaches to changing our world and working together to accomplish sustainable goals, Green IT is enabling a certain part of human consciousness that looks out for others, looks out for animals and plants, and in the long run looks out for our children and ourselves. This text seeks to help us understand the ways in which Green IT has had an impact already, and the ways in which it could have an even greater impact in the future. By contributing to an understanding of the social and technological mechanisms by which Green IT contributes to sustainable living, *Greening through IT* may itself make a greater contribution than the environmental cost of the paper on which it is printed. I hope it will.