MIS Quarterly

ISSUES AND OPINIONS

INFORMATION SYSTEMS AND ENVIRONMENTALLY SUSTAINABLE DEVELOPMENT: ENERGY INFORMATICS AND NEW DIRECTIONS FOR THE IS COMMUNITY[1]

By: **Richard T. Watson**
Department of MIS
University of Georgia
Atlanta, GA 30602-6273
U.S.A.
rwatson@terry.uga.edu

Marie-Claude Boudreau
Department of MIS
University of Georgia
Atlanta, GA 30602-6273
U.S.A.
mcboudre@terry.uga.edu

Adela J. Chen
Department of MIS
University of Georgia
Atlanta, GA 30602-6273
U.S.A.
chenjw@uga.edu

Abstract

While many corporations and Information Systems units recognize that environmental sustainability is an urgent problem to address, the IS academic community has been slow to acknowledge the problem and take action. We propose ways for the IS community to engage in the development of environmentally sustainable business practices. Specifically, as IS researchers, educators, journal editors, and association leaders, we need to demonstrate how the transformative power of IS can be leveraged to create an ecologically sustainable society. In this Issues and Opinions piece, we advocate a research agenda to establish a new subfield of energy informatics, which applies information systems thinking and skills to increase energy efficiency. We also articulate how IS scholars can incorporate environmental sustainability as an underlying foundation in their teaching, and how IS leaders can embrace environmental sustainability in their core principles and foster changes that reduce the environmental impact of our community.

Keywords: Environmental sustainability, energy informatics, IS community

An Ignored Challenge

Environmentally sustainable development is the foremost concern identified by a worldwide United Nations survey of the issues dominating the future. As the report observed, "never before has world opinion been so united on a single goal as it is on achieving sustainable development" (Amy Lovins cited on p. 12 of Glenn and Gordon 1998). This concern has trickled down to industry, and many business leaders are embracing environmental sustainability in their corporate vision (Esty and Winston 2006). IS leaders took heed, and CIOs recently singled out "Green IT" as the most important strategic technology for 2008 (Thibodeau 2007). It is expected that the Green IT service market will reach nearly $5 billion by 2013 (Mines 2008). Such a prediction acknowledges the central role of information systems, given its cross-

[1]Carol Saunders was the accepting senior editor for this paper.

functional view of the entire organization and ability to understand, change, and reinvent business processes to better support sustainable practices. Whereas world opinion, corporations, and IS units are united in their acknowledgment of the problem, the IS academic community seems largely ignorant of the challenge of sustainable development, with a few exceptions (e.g., Avital et al. 2007). The IS academic community cannot afford to be a bystander in tackling environmental sustainable development, along with its partner, global climate change. It is to this community that we direct this "Issues and Opinions" piece, so as to enhance the sensitivity of IS scholars to the urgency of the environmental sustainability challenge and to propose ways for the IS community to engage substantively.

The argument for our involvement in promoting environmental sustainability is compelling. Information systems have been the greatest force for productivity improvement in the last half century. We have spent much time researching how information systems are designed, developed, adopted, used, diffused, maintained, and retired. We have been inspired by practice and have influenced it through our research and teaching. Currently, many organizations have an opportunity to tackle sustainable development while improving productivity, reducing costs, and enhancing profitability. Their poor environmental practices result in many forms of waste; unused resources, energy inefficiency, noise, friction, and emissions are all waste products that subtract from economic efficiency. Such poor environmental practices, we argue, could be improved by Green IS[2] initiatives. It is our responsibility, as IS scholars, to dedicate some of our research efforts to better understand (in terms of description, explanation, and prediction) the role of IS in tackling environmental sustainability. Similarly, through our teaching, our students should have a greater awareness of the potential of IS in relationship to the environmental sustainability challenge. Finally, our IS academic community also includes journal editors and association leaders whose actions can be very consequential. We, as IS researchers, educators, journal editors, and association leaders, cannot simply sit on the sidelines of the greatest challenge of human civilization; we need to show leadership in applying the transformative power of IS to create an environmentally sustainable society.

[2]In the practitioner literature, much of the current attention is devoted to "Green IT." We argue that this exclusive focus on information technologies is too narrow and should be extended to information systems, which we define as an integrated and cooperating set of people, processes, software, and information technologies to support individual, organizational, or societal goals. To the commonly used Green IT expression, we thus prefer the more encompassing Green IS one, as it incorporates a greater variety of possible initiatives to support sustainable business processes. Clearly, Green IS is inclusive of Green IT.

In this "Issues and Opinions" piece, we focus primarily on the research opportunities because that is where we can make the greatest contribution to sustainability. First, we propose a framework and discuss research questions that should be embraced by IS scholars. Because the root cause of global warming is fossil fuel consumption (Hoffert et al. 2002), we advocate a research agenda to establish the subfield of energy informatics. Second, we articulate how IS scholars can incorporate environmental sustainability as an underlying foundation in their teaching. Third, we turn to our IS leaders, embodied in our journal editors and association representatives, and advocate for them to embrace environmental sustainability in their core principles and foster changes toward it. In conclusion, we offer a set of action items that the IS academic community should carry out.

Green IS in Our Research: Energy Informatics

In line with our information biased *Weltanschauung*, we take an IS focus to solving global warming and creating a sustainable society, whereas other scholars might take an engineering perspective. The wedges model (Pacala and Socolow 2004), for example, is coauthored by an engineering scholar and many of the proposed wedges to reduce global warming, not surprisingly, are engineering solutions. Alternatively, we see the problem as a lack of information to enable and motivate economic and behaviorally driven solutions. Thus, an information system is at the heart of the framework (Figure 1) we present to stimulate IS research to address environmental sustainability. We propose that we need to develop a new subfield of IS, **energy informatics**, that recognizes the role that IS can play in reducing energy consumption, and thus CO_2 emissions.[3] Our core idea can be expressed quite concisely:

$$\text{Energy} + \text{Information} < \text{Energy}$$

Energy informatics is concerned with analyzing, designing, and implementing systems to increase the efficiency of energy demand and supply systems. This requires collection and analysis of energy data sets to support optimization of energy distribution and consumption networks.

Society has an energy consumption problem (Hoffert et al. 2002). We are increasing the CO_2 level in the atmosphere

[3]Although we focus on energy as the main resource to reduce, this framework would equally apply to other increasingly scarce resources, such as water.

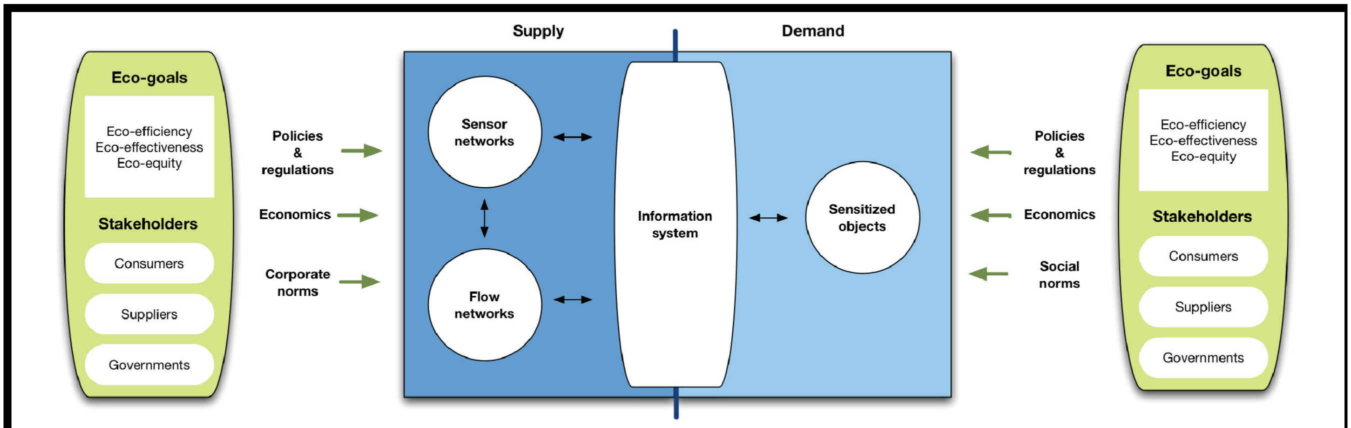

Figure 1. Energy Informatics Framework

because we consume too much energy derived from fossil fuels. We contend that high-level granularity data about the distribution and consumption of energy will enable us to develop information systems for reducing energy consumption. Energy informatics will focus on how information systems can be used to reduce energy consumption, and it will contribute practical solutions to advance environmental sustainability. This requires breaking away from the dominant social sciences paradigm to embrace a solution sciences approach, which incorporates fields such as management science, design science, and policy formation. Energy informatics will apply scientific rigor to pragmatic issues. At its core, the scientific method is a systematic approach to problem solving that can be applied to addressing complex problems as well as testing and developing theories. We need the well-trained minds of IS scholars to deploy research methods aligned with the major research questions that we will later reveal in this article.

The scope of environmental sustainability is far beyond a single organization. An understanding of the ecological problems as systematically interconnected and interdependent is required to develop ecological sustainability (Gladwin et al. 1995). Thus, we present an integrated framework (Figure 1) that incorporates all of the elements of an energy supply and demand system. In line with our perspective, an IS is at the heart of the framework.

The framework arose from reviewing many examples of what organizations are currently doing to solve problems such as traffic congestion, reducing building energy consumption, optimizing delivery truck routes, and cutting component replacement costs. After much reflection and discussion over two years, we began to see the commonality of what underpinned the examples we had studied. We were able to extract the core elements of the framework and visualize their connection. During the development period, we also read the literature in several related areas (e.g., environmental informatics) and did not find anything matching our conceptualization of the relationship between energy and information.

We next describe each of the elements in this framework and how they contribute to the comprehensive understanding that is necessary to produce an integrated solution that considers both the supply and demand side of energy. We start by considering the general features of an energy demand/supply system before moving on to consider the technological infrastructure necessary to improve the efficiency of an energy systems.

Supply and Demand

There are two parties to any energy consumption transaction: a supplier and a consumer. Both sides of this transaction needed to be considered in developing an integrated solution. While the approaches to managing supply and demand are different, they should share a common information system to ensure a cohesive solution. On the supply side, economic and regulatory issues and corporate norms are likely to drive change. Every organization wants to reduce its energy consumption, as this is a cost of business. Less energy contributes to higher profits and lowers carbon emissions. Organizations also need to comply with government regulations (e.g., limits to CO_2 emissions) that likely will be increasingly applied as governments tackle global warming. In addition, corporate opinion leaders (such as the CEOs of Walmart and GE) are pushing a green agenda and setting norms for a positive role by other firms.

There are two types of suppliers: a supplier of energy, such as an electricity utility or natural gas company, and the supplier of a service that consumes energy in delivering the service, such as air conditioning and package delivery. Both forms of supply have a common need for information to manage the flow of the resources they deliver.

In regard to demand, the forces of economic issues play a role, but seem to have less influence on consumers. For instance, the prevalence of SUVs and trucks on U.S. highways is evidence that the cost of energy is not a key determinant in vehicle choice, both when buying and selecting a mode of travel. Humans intertwine rational and social factors when making decisions (Simon 1957), and thus attempts to manage demand need to blend economic forces and behavioral elements, such as social norms. Supplying consumers with information about their energy usage can lead to changes in usage patterns and decreases in overall consumption (McCalley 2006; Wilson and Dowlatabadi 2007). Indeed, we expect that governments will pass regulations requiring the supply of information related to energy consumption.

In some situations, suppliers want the opportunity to manage consumer demand. In the case of the electricity industry, suppliers might want the capacity to turn off some devices (e.g., a refrigerator) during periods of peak demand. Thus, there is a need for a common information system across supply and demand. As to the consumers, they may leverage information about their usage (e.g., postponing doing laundry) if such information were available in real time. Thus, we need information from suppliers on the consumption at the object level (e.g., a TV set) at any time. Concurrently, suppliers want to know what objects are being used so they can turn them off if required or prompt consumers to change their usage patterns. The goal of such an integrated information system is to manage supply and demand to reduce total demand and maintain demand below established thresholds. These joint targets can ultimately be achieved only by a single system.

Now that we have an understanding of the broad features of an integrated demand and supply energy system, we need to identify the major technological components and how they interact.

Energy System Technologies

Three types of technology are present, or should be present, in an intelligent energy system: flow networks, sensor networks, and sensitized objects. An information system, as we shall see, integrates these elements into a single system.

A ***flow network*** is a set of connected transport components that supports the movement of continuous matter (e.g., electricity, oil, air, and water) or discrete objects (e.g., cars, packages, containers, and people).[4] Flow networks are at the heart of many energy distribution and consumption systems. They are in their various forms highly visible in today's society as roads, transmission grids, pipelines, delivery vehicles, and cargo ships. They are also rather invisible in many buildings in the form of heating, venting, and air conditioning (HVAC) ducting that transports air. Because flow networks are so central to economic activity, increasing their efficiency is a necessary step toward creating a sustainable society, especially as CO_2 emissions are an energy consumption problem (Hoffert et al. 2002). While many algorithms exist for optimizing network flows (e.g., the traveling salesman problem), they require detailed information on the flows across nodes and links and the capacity of sources and demand of sinks (Ahuja et al. 2008). Optimizing a network flow is an information intensive problem that might have to be solved on a daily basis or more frequently. To support dynamic optimization, a flow network must incorporate controllers that enable the state of flow to be changed (e.g., change the length of the green signal on a traffic light).

A ***sensor network*** is a set of spatially distributed devices that reports the status of a physical item or environmental condition. It might report, for instance, temperature, air composition (to detect pollution), location and speed of a mobile object, contents of a package in transit, or the traffic on a link. This definition is somewhat broader than that found in the wireless literature (e.g., Haenselmann 2005; Romer and Mattern 2004), because it includes items such as physical packages, which are conveyed by some transport systems. A variety of current technologies can support sensor networks (Akyildiz et al. 2002), such as barcode, RFID, and ZigBee™. A sensor network provides data that can be analyzed to determine the optimum use of a flow network.

A ***sensitized object***, in our terms, is a physical good that a consumer owns or manages and has the capability to sense and report data about its use. For example, some insurance companies have instituted pay-as-you-drive insurance. Vehicles are equipped with a GPS or other distance-tracking devices that record travel information for transmission or uploading to the insurer (Tergesen 2008). Those who drive less pay less insurance. Home appliances can easily be sensitized with smart plugs incorporating a ZigBee transceiver

[4]Flow networks are typically defined, using the nomenclature of graph theory, as a directed graph. We opted for a more general definition to convey the range covered by these networks.

for reporting power consumption (Anonymous 2009). Sensitized objects are essential for managing demand. They provide information about the use of an object so that a consumer is better informed about the impact of the object on their finances and the environment. In addition, there needs to be remote control of the state of some sensitized objects so that suppliers and consumers can manage demand. For example, the electricity supplier might turn off refrigerators for a short period during peak demand in order to prevent adding an inefficient generator to the grid. A commuter might want to get real time traffic reporting on the way to work so that a less congested route can be automatically recomputed for the car's navigation system.

Information System

An information system ties together the various elements to provide a complete solution. It has several important functions.

- Collect data from the sensor network and feed them into flow optimization algorithms
- Transmit data to automated controllers in the flow network to dynamically change a network based on the output of the optimization algorithms
- Supply information to flow network managers so they can manage and monitor their networks
- Supply information to consumers about the consumption of resources within their control
- Manage supply and demand to minimize usage and avoid adding high cost resources to meet peak demand
- Enable consumers to automate or control object usage to reduce energy consumption
- Supply comparative information to suppliers and consumers so they can benchmark their efforts and set new targets for energy reduction
- Supply information to governments on flow network performance

The preceding set of requirements defines an integrated system for an energy system. It recognizes the interdependencies between supply and demand and the major components (flow networks, sensor networks, and sensitized objects). It is the keystone of the energy informatics framework.

The function and purpose of a technological structure, such as the energy system we have described, are typically influenced by external forces. While the overall goal in this case is to increase energy efficiency and reduce CO_2 emissions, the way in which the system will be deployed to achieve these goals will be dependent on a blend of external forces. We first consider the three sets of major stakeholders who will shape how these forces are enacted. Then, we examine the three general eco-goals that are driving much of the thinking and action among those setting the sustainability agenda.

Key Stakeholders

Any major system is buffeted by a variety of stakeholders, those who determine its future (Freeman 1984). We have decided to pay attention to what we judge are the three most critical stakeholders in the typical energy supply/demand system: suppliers, consumers, and governments. There are certainly other stakeholders, and we leave consideration of their particular issues to further research.

Suppliers provide energy (e.g., natural gas) or services that consume energy (e.g., air conditioning). They manage flow networks and in a typical competitive environment suppliers will compete with each other and seek to make their operations more efficient. The energy economy, though, has noncompetitive features. In many states in the United States, there is a government organization, such as the Georgia Public Service Commission, that regulates utilities and protects the interests of consumers. There are also situations where there is a sole supplier (e.g., the HVAC for a building) and open competition (e.g., parcel delivery). Nevertheless, when there is not direct competition, we can still expect suppliers to seek flow network efficiency by their direct actions and also by attempting to change consumer behavior. Thus, we see highway administrators using congestion pricing to reduce road use and speed up traffic flows.

Consumers are important stakeholders because they bear the ultimate cost of all energy consumption. As well as being concerned about energy costs, some consumers, in their other roles as citizens, have become activists for sustainability and have pressured suppliers and governments to reduce carbon emissions.

Suppliers and consumers, frequently driven by self-interest, do not always create outcomes that are in society's long-term interests, and this seems to be particularly the case as we attempt to create a sustainable civilization. Governments need to intervene and enact regulations that change the basis of supplier competition and channel consumer behavior in socially desirable directions. For example, the costs of poor environmental practices are frequently externalized. A company that pollutes a stream with its waste products forces society to deal with the costs of environmental degradation.

When society allows the externalization of such costs, it creates a framework where markets work against sustainability (Grunert and Thøgersen 2005). Without full internalization of environmental costs, those who adopt sound ecological practices can be at a competitive disadvantage if their competitors do not follow the same practices. For example, the coal miner who restores a strip mine will be less profitable than one who does not. If organizations are forced to internalize the full cost of their polluting activities, they have a market incentive to reduce pollution. The economics of sustainability need not be permanently set for organizations. As regulations change (e.g., carbon caps), the economics change and markets can become mechanisms for sustainability. Well-designed and equitable regulations can create economic incentives for improved environmental actions by both suppliers and consumers.

Eco-Goals

The sustainability literature has identified three broad sustainability goals: eco-efficiency, eco-equity, and eco-effectiveness (Dyllick and Hockerts 2002).

Eco-efficiency is "the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's carrying capacity" (DeSimone et al. 1997). Cost reduction motivates suppliers to seek eco-efficient production, and thus eco-efficiency is in line with current corporate goals. It is the foremost goal pursued by organizations, despite growing concerns about global warming. The prevailing philosophy is that markets, augmented by government regulation, will solve the problem. Eco-efficiency is essentially an economic pressure, as organizations will seek this goal in their quest for greater profits. Similarly, consumers will respond to economic pressures to reduce energy consumption (e.g., the success of hybrid cars). Consequently, we see on both the left and right sides of Figure 1 that economics is a key force.

Eco-equity refers to the "equity between peoples and generations and, in particular, the equal rights of all peoples to environmental resources" (Gray and Bebbington 2000). At the heart of nearly all sustainability goals is the belief that there should be a fair distribution of resources both within and across generations (Gladwin et al. 1995). Eco-equity focuses on our social responsibility for the future generations who will bear the consequences of excessive consumption of scarce resources and environmental degradation. This means that we need to develop collectively social and corporate norms that support eco-equity for now and tomorrow. While some might take actions to support eco-equity, it is unlikely that there will be any major realignment of norms unless opinion leaders set new directions (e.g., Walmart's green efforts). We can also expect some actions by governments at all levels to remake social and corporate norms by promoting sustainable energy and lifestyles (e.g., San Francisco's ban of plastic shopping bags). Thus, to address eco-equity, we expect to see increasingly the influence of shifting social norms on consumer behavior and corporate norms on organizational behavior.

The concept of ***eco-effectiveness*** was introduced in 1998 (McDonough and Braungart 1998) without explicit definition, but later explained: "Our concept of eco-effectiveness means working on the right things—on the right products and services and systems—instead of making the wrong things less bad" (McDonough and Braungart 2002). This thinking is very aligned, as the coiners' note, with Drucker's (1954, 2006) life-long concern with educating managers on the difference between efficiency (doing things right) and effectiveness (doing the right things). While eco-efficiency might focus on reducing the energy consumption of artificial lighting, the eco-effective approach would design work places that use natural lighting.

Eco-effectiveness, considered the ultimate solution for ecological problems, requires a shift of mindset and transformation of business models (McDonough and Braungart 2002). Humans need to stop damaging the environment and depleting nonrenewable resources. We need to do more than reducing the tempo of ecological destruction. We need to direct individual and organizational attention to the underlying and fundamental factors of environmental problems and to make possible long-term prosperity and sustainability through a fundamental redesign of the economy. Business needs to adopt goals beyond efficiency, and it needs to also embrace sustainability, restoration, and regeneration as standard organizational aspirations (McDonough and Braungart 2002). The cradle-to-cradle model advocates a transformation from linear thinking to closed loop systems. For example, the carpet manufacturer Interface shifted from selling carpet to leasing it and became responsible for recycling old carpets as a result (Anderson 1998).

We expect that the drive for eco-effectiveness will be reflected in both economic and regulatory forces on suppliers. Some firms will learn that eco-effectiveness is also more profitable. Interface discovered that it could reinvent itself as an eco-effective organization and raise its market value at the same time. Such action generates economic pressure on competitors to mimic the new model. We also expect that when massive industry renewal is necessary, governments will regulate toward a new business model. The shift from the internal combustion engine to an electric motor as a foundation for private transport will likely require significant government intervention to finance and implement. In line with this thinking, the Danish government, a leader in creating an eco-effective society, has put a 180 percent tax on gasoline cars and zero on electric cars as it supports Shai Agassi's creation of an electric car system (Pogue 2009), which is likely to significantly change the decisions of many car buyers.

Seeking sustainability does not mean abandoning economic thinking. After all, economics addresses the problem of allocating scarce resources, and resources such as emission-free energy are a particularly scarce resource. Governments will use regulations to change the economic equation to further promote environmental sustainability. Suppliers and consumers will apply and react to a mixture of economic and social pressures that promote environmental sustainability. In summary, the eco-goals, as we have mentioned in the prior discussion, impact energy suppliers through traditional economic forces, changing corporate norms, and government regulations. They also impact energy consumers via governments' actions, and economic and social norms that influence individual behaviors. This translation of the eco-forces is reflected in Figure 1.

Research Questions

Each stakeholder has a particular set of major issues, and it is these predominant concerns, as they relate to each of the elements of the energy system, that should drive IS research aimed at reducing society's energy consumption. We envision a lattice of interactions between each stakeholder and the system's elements (see Table 1). We examine the research questions by each of the major features of the energy management system.

Sensor Network

A sensor network (Akyildiz et al. 2002) provides information for the optimization and management of flow networks. From the supplier's perspective, the major issue is to design a sensor network that provides sufficient granularity[5] to provide adequate data for an optimal solution. The supplier needs to know where to place sensors, how frequently to poll them, and what data to collect in order to solve the network optimization problems as frequently as required to get high quality solutions. Of course, there will be trade-offs. For example, a denser network will provide better data but the cost might not be recouped by the improved solution.

> *RQ 1: What is the optimum level of information granularity of the sensor network to optimize a given flow network?*

Pollution control and regulation are required to ensure that the current generation does not irreparably damage the environment for future generations or adversely affect the health of current citizens. Regulation is information intensive (Afsah et al. 1996), and is dependent on information that is unique in time and space. Environmental changes are captured in meteorological, biological, physical, chemical, geological, and socio-economic data (Page and Rautenstrauch 2001). Thus, effective pollution reduction requires extensive and complete information, especially on energy consumption because it is a major contributor to pollution. Information gaps (i.e., a lack of information on who is polluting, where they are polluting, and how much they are polluting) severely limit current environmental regulation. However, in an emerging world of massively distributed intelligent remote sensing devices connected to ubiquitous networks, sources of pollution and energy wastage can be identified and their effects measured. We can conceive of tagging and tracking each unit of pollution, just as if it were a pallet with an RFID chip. The information generated by such a vast environmental net will make it possible to assign the external costs borne generally by society (e.g., low quality air and water) to a specific polluter. Society can use this information to internalize these externalities. Such information systems will whittle away the gap by providing better information to target pollution and energy reduction precisely. This ability to remotely sense and measure pollutants will be transformative for the theory and practice of environmental law (Esty and Winston 2006) and will enable governments to formulate energy policies that can be effectively policed.

> *RQ 2: What information granularity enables effective enforcement of energy policy?*

[5]By granularity, we mean the level of detail and frequency of information collection. For example, one of the firms we studied collects several thousand data location points every day for each of its trucks and measures 200 vehicle-related elements every time a truck idles or is started. It uses these data to modify driver behavior and redefine truck routes to minimize energy consumed. It had initially collected vehicle status data more frequently but found that this extra data added little value. Over time, it discovered the right level of detail, or granularity, for its situation.

Table 1. Research Questions Matrix

Stakeholders	Sensor Network	Flow Network	Information System	Sensitized Objects
Suppliers	RQ 1: What is the optimum level of information granularity of the sensor network to optimize a given flow network?	RQ 3: What information, and at what level of granularity, is required to optimize a given type of flow network?	RQ 6: How can an information system integrate supply and demand data to increase energy efficiency?	
Consumers			RQ 7: How can information systems be used to change social norms to increase energy efficiency?	RQ 9: What information do consumers need about the usage of the objects they own or manage to increase their energy efficiency?
Governments	RQ 2: What information granularity enables effective enforcement of energy policy?	RQ 4: What government policies and regulations will impel flow network managers to make them more energy efficient? RQ 5: What government policies and regulations will impel flow network consumers to shift to more energy efficient networks or radically reduce the energy consumption patterns of specific networks?	RQ 8: What data should be reported by an energy information system to inform governments' energy policies?	

Flow Networks

Flow networks are the major suppliers and consumers of energy in an advanced economy. If these networks can be made more efficient by the use of optimization techniques, then CO_2 will be lowered. Such techniques are mathematically challenging and information intensive, particularly for large networks with many nodes. Management scientists have been working on solutions for optimization problems for decades, and the simplex algorithm for the classic linear programming problem was developed in 1947 (Dantzig 1949). Flow networks are often large and highly complex. For example, a parcel delivery company has to jointly solve the problem of how to ship each parcel at lowest cost and how to route each delivery vehicle, and there are various types of vehicles that contain a collection of parcels. IS scholars need to determine the information required, and its level of detail, to optimize the variety of flow networks that occur in society.

> *RQ 3: What information, and at what level of granularity, is required to optimize a given type of flow network?*

Governments manage a variety of flow networks directly (e.g., highways) and regulate the management of others (e.g., transmission grids). As the direct manager, governments have an interest in RQ3. As a regulator, they are dependent on information from network managers to ensure they are operated according to the law and, more importantly given today's challenges, that the network becomes more energy efficient.

> *RQ 4: What government policies and regulations will impel flow network managers to make them more energy efficient?*

More importantly, governments should pursue policies and invoke regulations to shift consumers to lower energy-consuming flow networks (e.g., shifting commuters from private cars to public transit) or to radically reduce the energy consumed by a flow network (e.g., a shift from internal combustion to electric motors for cars using highways). The 2009 U.S. American Recovery and Reinvestment Act,[6] for example, includes tax credits to encourage a shift to solar energy. A number of city governments (e.g., Singapore, London, and Stockholm) have introduced electronic road pricing to reduce congestion by using pricing mechanisms to shift traffic patterns.

> *RQ 5: What government policies and regulations will impel flow network consumers to shift to more energy efficient networks or radically reduce the energy consumption patterns of specific networks?*

Information System

Previously, we identified the key functions that an information system to support an energy system must perform. Implicit in this functional specification are several research questions. First, the overarching criterion is to reduce energy consumption. Thus, IS scholars need to take the broad specification and apply the principles of areas such as design science and management science to develop a deeper understanding of how such a system would work.

> *RQ 6: How can an information system integrate supply and demand data to increase energy efficiency?*

Governments can play a key role in establishing standards, providing economic incentives, and influencing social norms to change citizens' behavior in an environmentally desirable direction. For example, in 2006, the U.S. Federal Government provided tax credits for hybrid cars.[7] Opinion leaders, such as a nation's president or prime minister, can use their position to shift social norms in a direction that enhances environmental goals, especially energy efficiency. Governments already mandate energy standards for new products and the presentation of information about a product's energy consumption (e.g., The Appliance Standards Program of the U.S. Department of Energy and its EnergyGuide label[8]). It is also conceivable that governments direct that energy usage data is broadcast by specified appliances in a standard format using a particular communication technology. The research question is, what information should be broadcast and what are the features of an information system to deliver effectively such information to consumers so that desirable behavior changes are advanced? We anticipate the emergence of smart phone applications that will provide information dynamically to consumers about their energy consumption and this could be influential in changing behavior. Thus, governments are interested in advancing energy efficiency because society needs immediate actions and long-term solutions to global climate change. Thus, the broad question is

> *RQ 7: How can information systems be used to change social norms to increase energy efficiency?*

Finally, governments will need information to understand the impact of network flows on energy consumption so that they can develop energy policies that promote sustainability and reduce emissions. When designing an energy IS, particular attention can be paid to identifying the information that will inform governments. The emissions problem, as we stated earlier, is an energy consumption issue. Consequently, society will need to pay much more attention to managing energy consumption, and may need to adopt approaches similar to the way we manage financial flows. After June 15, 2009, the U.S. Securities Exchange Commission requires that publicly traded companies report their results in XBRL, an XML-based language for financial reporting (McCausland 2000). We would argue that the US Department of Energy should require that all flow networks over a certain size report on some set frequency (e.g., daily) their energy consumption and related data using an XML-based standard. IS scholars could work on developing this language and guiding its implementation.

> *RQ 8: What data should be reported by an energy IS to inform governments' energy policies?*

Sensitized Objects

Many consumers are unaware of the particular steps they can take to reduce their environmental impact. People have different lifestyles and needs, and generic appeals to become green can raise awareness and change social norms, but they often lack individual specificity. Consumers need information, possibly through sensitizing some of the objects they control, on their personal energy-consuming behavior so that they make behavioral changes that have an impact on energy consumption.

---

[6]To review the 2009 U.S. American Recovery and Reinvestment Act, go to http://thomas.loc.gov/cgi-bin/bdquery/z?d111:HR00001:@@@L&summ2=m&.

[7]For information on this incentive program, go to http://www.irs.gov/newsroom/article/0,,id=157632,00.html.

[8]For information on this program, go to http://www.energystar.gov/index.cfm?c=appliances.pr_energy_guide.

RQ 9: What information do consumers need about the usage of the objects they own or manage to increase their energy efficiency?

We have identified nine research questions for IS scholars. Many of these questions jump the boundaries of what is considered typical IS research, but global warming is not a typical problem. It is a species-threatening event that must be addressed with alacrity. Hence, IS academics have to recognize that if they are going to make their contribution (and we strongly believe that IS academics can have a key role), we need to develop the field of energy informatics, address its central IS-related research questions,[9] and embrace the methodologies needed to solve the research problem of our era. At the same time we can incorporate our existing skills in areas such as ubiquitous computing, human–computer interaction, decision support systems, and implementation to design systems that solve these problems.

Green IS in Our Teaching

Already, many higher education institutions have been proactive in creating sustainability institutes (e.g., Arizona State University now has a School of Sustainability and Rochester Institute of Technology formed the Golisano Institute for Sustainability) or in incorporating environmental sustainability into their curricula. Business degrees in sustainability have been created at all levels. For example, at the undergraduate level, Aquinas College and Catawba College both offer a B.S. in Sustainable Business, and the College of Santa Fe has a B.A. in Managing Sustainable Enterprise. At the graduate level, options are more plentiful, with many MBA programs specializing in sustainability (e.g., University of Michigan, University of Maine, Colorado State University, etc.). A list of business related degrees with a focus on sustainability is included in Appendix A.[10]

Likewise, as socially responsible academics, we will need to add Green IS to our curriculum. As a start, we will need to introduce ideas such as green computing into introductory IS classes[11] and advise our students on the personal computing actions they can take to reduce emissions. The traditional systems analysis and design course will need to be augmented to include designing for sustainability as an outcome. For example, in the usual stakeholder analysis, the environment should be included as an entity that will be affected by a new system; it is thus an important stakeholder. Another example is the diagramming of business processes, which could be extended to include data about the waste associated with each process. Because design determines as much as 70 percent of resource usage (Birkeland 2002), it is indeed a critical step in reducing environmental waste. IS designers play a large role in creating the way today's organizations operate, and their task needs to be reframed to include a focus on designing environmentally sustainable organizational practices that monitor, and ideally reduce, the extent of harmful emissions and used resources. A growing trend (and initial step) in the realm of monitoring is the use of life cycle analysis (LCA) to capture the cumulative carbon emissions produced throughout the life of a product (i.e., embodied carbon). Using information resulting from LCA, some pioneers (e.g., Timberland, Tesco, Pepsico, etc.) have taken the lead in publishing carbon usage labels on selected products. Of course, efforts associated with carbon labeling are fraught with complexity and the value of such labels is debatable (Green and Capell 2008). Nevertheless, certifications and regulations are in the works, and many organizations are pressured to provide more information about the making of their products to their customers. These pressures will trickle down to IS, which we surmise will soon be asked to develop systems that incorporate techniques for assessing the energy costs and emissions of an organization's products and services.

On becoming IS professionals, IS students will likely be involved in selecting new technology and software, and thus should learn to be mindful of environmental impacts. They should understand that large data centers can consume as much power as a factory, and computer-related power consumption is about 15 percent of total electricity usage in the United States (Lawton 2007). The five largest search companies, with about 2 million servers, devour 2.4 gigawatts, more energy than the maximum capacity of the Hoover Dam's 2 gigawatts (Lawton 2007). IT investments are growing, and sustainability requires a reduction in computer-related energy consumption. Students should thus be aware of these problems and basic solutions (such as virtualization and thin computing), while being mindful of the truthfulness and real impact of Green IS initiatives on environmental

[9] We contend that these central IS-related research questions are those anchored in the three types of technologies of energy informatics, as presented in Figure 1. Other, potentially more traditional, research questions, also relevant to the energy informatics framework, could be developed around the role and impact of the eco-goals and stakeholders, previously presented.

[10] As this information becomes outdated, the reader may want to visit the Association for Advancement of Sustainability in Higher Education website (www.aashe.org) to get the most data on these degrees.

[11] We wrote a free chapter on Green IS for introductory IS classes, available at http://globaltext.org/books.

sustainability. Greenwashing, which occurs when significantly more resources are channeled into *claims* about being green rather than into actual environmentally sound practices, is also happening in the realm of IS. For example, many technology vendors now offer eco-friendly computers, printers, data centers, and servers; like any other products, such technologies should be evaluated against greenwashing indicators.[12]

To support greater awareness of environmentally sustainable issues in regard to IS, educational materials such as teaching cases and textbook chapters will need to be developed. In addition, academics can help to build practice by writing executive case studies (i.e., the type of cases published in *MISQ Executive*) that illustrate how a company has tackled the challenge of Green IS. Such cases can be particularly influential when used in executive and MBA education. Cases also provide insights that can stimulate research questions.

Green IS and Our Leaders

If our IS leaders, here embodied in our journal editors and association representatives, embrace environmental sustainability, the changes they will put forward will reverberate around the entire IS academic community. We plead for our leaders to not only champion direct changes but also to provide guidance to IS scholars in their quest for environmental sustainability.

Journals and Green IS

Many journals, even after more than a decade of widespread Internet adoption by academics, are still publishing on paper and bound by procedures established decades ago. Clinging to the past is expensive, socially irresponsible, and inhibits scholarship.[13] The future of the journal marketplace has been discussed before, but mainly from an economic perspective (e.g., Weber 2002); the environment, as a key stakeholder, has been ignored. We contend that when many species, including humans, are imperiled by global warming, everyone is responsible for eliminating or reducing activities that are not environmentally sustainable. IS journals do not have a special dispensation. Socially responsible journals will make the move to electronic format, and socially responsible academics will cancel subscriptions to paper journals and make reading articles online their default behavior. Of course, making this transition is fraught with difficulties (as discussed in Saunders (2005) and Gray et al. (2006)), and we do not claim that it would be easy, but it should nevertheless be carefully considered.

Another reason why electronic journals should be considered is that they can potentially advance the field more rapidly. Because paper and postage are expensive, paper-based journals need to restrict their publication pages. They developed a habit of rationing to save paper and postage. This culture of constraint restricts the flow of knowledge and is questionable when the quality of reviewing is so uneven. Societies grow through knowledge sharing, not by knowledge rationing. Moreover, paper-based journals require additional time for their physical production. This incurs unnecessary delays and lessens the value of academic research to practice. Our environment is changing fast and insights delayed by months (sometimes years) are often much less useful than if released as soon as possible. Paper-based journals, given their associated constraints of rationing and dated findings, just don't fit the needs of the information age and the calls for reducing harmful emissions with as much haste as possible.

Journal editors, in our opinion, should make an ongoing commitment to promoting Green IS scholarship and practice. They need to establish sections of their journals dedicated to advances in Green IS and energy informatics. This should be supported by an editorial team that would focus on publishing key ideas and findings rapidly, as time is not on our side. Let us emphasize: we suggest doing more than single special issues on Green IS.[14] Rather, it is a time for ongoing and sustained attention to possibly the most significant issue facing our species. It is time for leading IS journals to guide the field into the green field of energy informatics research and practice.

[12]TerraChoice Environmental Marketing (www.terrachoice.com) publishes a yearly report on greenwashing. It identifies seven indicators (which it calls "sins") that consumers should consider while evaluating products' eco claims.

[13]While we suggest that electronic publishing is beneficial for the environment, we must also acknowledge that life cycle energy analysis with regard to journals' collections depends on the aggregate behavior of individual users, such as our willingness to minimize photocopying and single-sided printing (Gard, and Keoleian 2002).

[14]Such a special issue has been put forward by some journals, such as *Information and Organization, Journal of Systems and Information Technology*, and the *Journal of Strategic Information Systems*.

IS Associations and Green IS

Premier global organizations for academics specializing in Information Systems and Computer Sciences, such as the Association for Information Systems (AIS) and the Association for Computing Machinery (ACM), have not yet shown much interest or concern about the role of IS and IT on environmental sustainability.[15] Given their leadership positions, we claim that they have to tackle this challenge promptly. Smaller organizations, such as the Australian Computer Society (ACS), already promote awareness. ACS has indeed launched a "Policy Statement for Green ICT" that includes suggestions on initiatives that ICT professionals, governments, consumers, and ICT manufacturers can take to help reduce carbon dioxide emissions attributable to the use of ICT equipment. ACS has also sponsored awards at the last three ACIS conferences for best papers on the topic of environmental sustainability in ICT. Such actions could be emulated, and others created, by our leading IS and IT organizations.

IS associations often organize or sponsor conferences hosting over a thousand attendees. Obviously, the ecological footprint left behind by such events is significant. For some conferences, it may be worthwhile to consider electronic alternatives rather than relying exclusively on face-to-face interactions. When physical presence is deemed necessary, let us choose a venue that has, or is working toward getting, USGBC LEED[16] certification. The hotel industry has made great strides in fostering sustainability and has many associations, certifications, and stakeholders supporting its efforts (Fletcher 2006). We should endeavor to steer our business toward ecologically mindful hotels.

Give-away trinkets are also part of a conference make-up, but we dare ask, are they really necessary? How many conference bags has each of us collected over the years, and how many are used for more than a few days? How many of us will wear or use the paraphernalia given away? In truth, most of these items add to already overloaded landfills. Food is another area where our expectations could change; although it is customary to think that a meal must include meat, what if the default were vegetarian? One kilogram of boneless beef necessitates 6.5 kilograms of grain, 36 kilograms of roughage (coarse grains and pasture), and 155 liters of drinking water (Chapagain and Hoekstra 2004). Since grains and roughage also require water (i.e., virtual water), it really takes over 15,000 liters of water to produce a kilogram of beef. Comparatively, a vegetarian diet requires about a 1,000 liters of water per day. Accordingly, one may save more water by not eating a half-kilogram of beef than by not showering for an entire year (Robbins 2001).

The choice of the default can greatly influence outcomes. For instance, when employees are automatically enrolled in a retirement plan, few opt out and participation rates exceed 85 percent, but when they must opt in, participation rates can drop as low as 26 percent (Choi et al. 2005). Making a vegetarian meal as the default might also encourage hotels to think creatively about what they serve, particularly if experience shows that most attendees do not opt-out of the default vegetarian meal. Banishing bottled water, when many bottles are often left half empty anyway, is another concrete action conference organizers could implement. Other advice can be found in a document published by the EPA, entitled "A Guide to Planning and Conducting Environmentally Aware Meetings and Events."[17] Finally, it is left to each of us to adopt eco-friendly behaviors while in our hotel rooms, with towels, sheets, and personal products.

Concluding Thoughts

We all have a responsibility to mitigate global climate change and reduce emissions. Some of us, we believe, have a greater responsibility because of our particular societal roles and expertise. As professors and writers, we can influence many others. We are expected to educate and we should fulfill these expectations by introducing Green IS to future generations as soon as possible. We need to educate students who can apply the principles of energy informatics to optimize flow networks. As researchers, we have learned the scientific method of problem solving. Most of us have followed the field's incentive system and focused on applying the scientific method to theory building. Now, we assert, it is time for some of us to apply these same skills to building the practice of Green IS, and in particular a new subfield of energy informatics. We have an opportunity to demonstrate academic social responsibility and provide IS practitioners with

[15]We acknowledge the presence of Green IT/IS mini-tracks or panels in the most recent editions of AIS's main conferences (AMCIS and ICIS) and affiliated conference (ECIS). However, these tend to be driven by individuals rather than associations such as AIS.

[16]The U.S. Green Building Council (USGBC) is the nation's foremost coalition of leaders from every sector of the building industry working to promote buildings that are environmentally responsible, profitable and healthy places to live and work. The Leadership in Energy and Environmental Design (LEED) certification is a nationally accepted benchmark for the design, construction, and operation of high performance green buildings.

[17]EPA530-K-96-002, September 1996.

leadership in creating energy informatics as a new field. Indeed, if we follow the recommendations of the president of the American Association for the Advancement of Science, we should devote 10 percent of our professional time and effort to contributing to solving global warming (Holdren 2008). What can you do? Here is our recommended starting set of actions.

Research:

- Contribute to the new IS subfield of energy informatics by addressing the nine core questions presented in this article

Teaching:

- Include environmental sustainability as a foundation within all IS-related classes where appropriate
- Produce more educational materials (case studies, etc.) to learn about the impacts and challenges related to Green IS projects
- Introduce energy informatics into the IS major curriculum

Journals:

- Migrate to an electronic format
- Dedicate journal content to Green IS on a continuing basis
- Accelerate the development of energy informatics by developing new procedures for publishing that recognize that normal publication cycles are inappropriate for a problem we must solve soon

IS Associations:

- Acknowledge the environmental challenge and create concrete means to encourage scholarship in the area of Green IS and energy informatics
- Redesign conferences to be environmentally friendly and in lower impact locations
- Create new mechanisms for scholarly interaction that are less resource-intensive than conferences
- Foster conference ecologies where multiple conferences are held at one location (e.g., an extension of the pre-ICIS model) to reduce travel

Some academics contend that corporations should be socially responsible, and we suggest that social responsibility is also an issue for academics. In the area of IS, academic social responsibility means developing a stream of research on how IS can reduce emissions and increase resource usage efficiency, equipping our students (and IS practitioners) with the skills to think Green IS and design green systems, and encouraging our leaders (e.g., usually involved with journals and academic associations) to embrace environmental friendly procedures. It is not a matter of choice, but one of responsibility.

References

Afsah, S., Laplante, B., and Wheeler, D. 1996. "Controlling Industrial Pollution: A New Paradigm," World Bank Research Working Paper 1672.

Ahuja, R. K., Magnanti, T. L., and Orlin, J. B. 2008. *Network Flows: Theory, Algorithms, and Applications*, Upper Saddle River, NJ: Prentice Hall.

Akyildiz, I., Su, W., Sankarasubramaniam, Y., and Cayirci, E. 2002. "A Survey on Sensor Networks," *IEEE Communications Magazine* (40:8), pp. 102-114.

Anderson, R. C. 1998. *Mid-Course Correction: Toward a Sustainable Enterprise: The Interface Model*, Atlanta, GA: Peregrinzilla Press.

Anonymous. 2009. "Socket to Me," *The Economist*, March 6 (http://www.economist.com/science/).

Avital, M., Lyytinen, K., King, J. L., Gordon, M. D., Granger-Happ, E., Mason, R. O., and Watson, R. T. 2007. "Leveraging Information Technology to Support Agents of World Benefit," *Communications of the AIS* (19), pp. 567-588.

Birkeland, J. 2002. *Design for Sustainability: A Sourcebook of Integrated, Eco-Logical Solutions*, London: Earthscan Publications.

Chapagain, A., and Hoekstra, A. 2004. *Water Footprints of Nations*, Delft, The Netherlands: UNESCO-IHE.

Choi, J. J., Laibson, D., Madrian, B. C., and Metrick, A. 2005. "Passive Decisions and Potent Defaults," in *Analyses in the Economics of Aging,* D. A. Wise (ed.), Chicago: University of Chicago Press, pp. 59-78.

Dantzig, G. 1949. "Programming of Interdependent Activities: II Mathematical Model," *Econometrica* (17), pp. 200-211.

DeSimone, L. D., Popoff, F., and World Business Council for Sustainable Development. 1997. *Eco-Efficiency: The Business Link to Sustainable Development*, Cambridge, MA: MIT Press.

Drucker, P. F. 1954. *The Practice of Management*, New York: Harper.

Drucker, P. F. 2006. "What Executives Should Remember," *Harvard Business Review* (84:2), pp. 144-153.

Dyllick, T., and Hockerts, K. 2002. "Beyond the Business Case for Corporate Sustainability," *Business Strategy and the Environment* (11:2), pp. 130-141.

Esty, D., and Winston, A. 2006. *Green to Gold: How Smart Companies Use Environmental Strategy to Innovate, Create Value, and Build Competitive Advantage*, New Haven, CT: Yale University Press.

Fletcher, K. 2006. "Fitting Greening Efforts Into Your Hotel Operation and Marketing Strategies," *HSMAI Marketing Review* (Winter), pp. 69-72.

Freeman, R. E. 1984. *Strategic Management: A Stakeholder Approach*, Boston: Pitman.

Gard, D., and Keoleian, G. 2002. "Digital Versus Print: Energy Performance in the Selection and Use of Scholarly Journals," *Journal of Industrial Ecology* (6:2), pp. 115-132.

Gladwin, T., Kennelly, J., and Krause, T. 1995. "Shifting Paradigms for Sustainable Development: Implications for Management Theory and Research," *Academy of Management Review* (6:2), pp. 874-907.

Glenn, J. C., and Gordon, T. J. 1998. *State of the Future: Issues and Opportunities*, The Millennium Project, American Council for the United Nations University, Washington, DC.

Gray, P., Lyytinen, K. J., Saunders, C. S., Watson, R. T., Willcocks, L. P., and Zwass, V. 2006. "How Shall We Manage Our Journals in the Future? A Discussion of Richard T. Watson's Proposals at ICIS 2004," *Communications of the AIS* (18), pp. 275-295.

Gray, R., and Bebbington, K. 2000. "Environmental Accounting, Managerialism and Sustainability: Is the Planet Safe in the Hands of Business and Accounting?," *Advances in Environmental Accounting and Management* (1:1), pp. 1-44.

Green, H., and Capell, K. 2008. "Carbon Confusion," *Business Week*, March 6, pp. 52-54.

Grunert, K. G., and Thøgersen, J. 2005. *Consumers, Policy and the Environment: A Tribute to Folke Ölander*, New York: Springer.

Haenselmann, T. 2005. *An FDL'ed Textbook on Sensor Networks*, published under GNU Free Documentation License (http://pi4.informatik.uni-mannheim.de/~haensel/sn_book/).

Hoffert, M., Caldeira, K., Benford, G., Criswell, D., Green, C., Herzog, H., Jain, A., Kheshgi, H., Lackner, K., and Lewis, J. 2002. "Advanced Technology Paths to Global Climate Stability: Energy for a Greenhouse Planet," *Science* (298:5595),p p. 981-987.

Holdren, J. 2008. "Presidential Address: Science and Technology for Sustainable Well-Being," *Science* (319:5862), pp. 424-434.

Lawton, G. 2007. "Powering Down the Computing Infrastructure," *Computer* (40:2), pp. 16-19.

McCalley, L. T. 2006. "From Motivation and Cognition Theories to Everyday Applications and Back Again: The Case of Product-Integrated Information and Feedback," *Energy Policy* (34:2), pp. 129-137.

McCausland, R. 2000. "Speaking XBRL: The New Talk of Accounting," *Accounting Technology* (16:5), pp. 52-56.

McDonough, W., and Braungart, M. 1998. "The NEXT Industrial Revolution," *The Atlantic Monthly*, October (http://www.theatlantic.com/doc/199810/environment).

McDonough, W., and Braungart, M. 2002. *Cradle to Cradle: Remaking the Way We Make Things*, New York: North Point Press.

Mines, C. 2008. "The Dawn of Green IT Services: A Market Overview of Sustainability Consulting for IT Organizations," Forrester Research Report, Cambridge, MA.

Pacala, S., and Socolow, R. 2004. "Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies," *Science* (305:5686), pp. 968-972.

Page, B., and Rautenstrauch, C. 2001. "Environmental Informatics: Methods, Tools and Applications in Environmental Information Processing," in *Environmental Information Systems in Industry and Public Administration,* C. Rautenstrauch and S. Patig (eds.), Hershey, PA: Idea Group Publishing, pp. 2-11.

Pogue, D. 2009. "Electric Cars for All! (No, Really This Time)," *New York Times*, March 19.

Robbins, J. 2001. *The Food Revolution: How Your Diet Can Help Save Your Life and Our World*. Newburyport, CT: Conari Press.

Romer, K., and Mattern, F. 2004. "The Design Space of Wireless Sensor Networks," *IEEE Wireless Communications* (11:6), pp. 54-61.

Saunders, C. 2005. " Between a Rock and a Hard Spot," *MIS Quarterly* (29:4), pp. iii-viii.

Simon, H. A. 1957. *Models of Man: Social and Rational*, New York: Wiley.

Tergesen, A. 2008. "Insurance Goes Green," *BusinessWeek*, March 6.

Thibodeau, P. 2007. "Gartner's Top 10 Strategic Technologies for 2008," *Computerworld*, October 9.

Weber, R. 2002. "Some Futures of the Marketplace for Journals," *MIS Quarterly* (26:4), pp. iii-ix.

Wilson, C., and Dowlatabadi, H. 2007. "Models of Decision Making and Residential Energy Use," *Annual Review of Environmental Resources* (32), pp. 169-203.

About the Authors

Richard T. Watson is the J. Rex Fuqua Distinguished Chair for Internet Strategy in the Terry College of Business at the University of Georgia. He has published in leading journals in several fields as well as writing books on data management and electronic commerce. His current research focuses primarily on energy informatics and IS leadership. He has given invited seminars in more than 30 countries for companies and universities. He is a visiting professor at the University of Agder, Norway, a consulting editor to John Wiley & Sons, research director for the Advanced Practices Council of the Society for Information Management, international coordinator for the Addis Ababa University Ph.D. in IS program, and co-leader of the Global Text Project. He has been president of AIS, a co-chair of ICIS, and a senior editor for *MIS Quarterly*.

Marie-Claude Boudreau is an associate professor of MIS in the Terry College of Business at the University of Georgia. Her current research focuses on the role of IS in creating sustainable business practices. Dr. Boudreau has authored articles published in both academic journals (*Information Systems Research, MIS Quarterly, Organization Science*) and practitioner journals (*MISQ Execu-*

tive, The Academy of Management Executive, and *Cutter Benchmark Review*). She taught short courses at l'Université Jean Moulin, in Lyon (France), and at Addis Ababa University (Ethiopia).

Adela J. Chen is a Ph.D. candidate in the Department of Management Information Systems at the Terry College of Business, University of Georgia. Her research interests include the impact of ICT-mediated interruptions on individuals and organizations, interruption management, and the impact of information systems on ecological sustainability. She has published in journals such as *IEEE Transactions on Engineering Management*, *Information & Management*, *Journal of Systems and Information Technology*, and in conference proceedings such as the International Conference on Information Systems.

Appendix A

Business Related Degrees with a Sustainability Focus

Institution	Bachelor's Degree	Master's Degree	Doctoral Degree	Minor	Certificate
Alliant International University		✓			
Antioch University New England		✓			
Aquinas College	✓	✓		✓	
Arizona State University	✓	✓	✓		✓
Bainbridge Graduate Institute		✓			✓
Baldwin Wallace College	✓				
Ball State University				✓	
Benedictine University		✓			
Brandeis University		✓			
California State University, Chico				✓	
California State University, San Bernardino	✓			✓	✓
Catawba College	✓				
City University of Seattle		✓			
College of Santa Fe	✓			✓	
College of the Atlantic	✓				
Colorado State University		✓			
Dartmouth College		✓			
Dominican University of California		✓			✓
Duke University		✓			
Duquesne University		✓			
George Washington University		✓			
Goddard College		✓			✓
Green Mountain College	✓	✓			✓
Handelshøgskolen i Bodø, Bodø Graduate School of Business (Norway)		✓			
Illinois Institute of Technology		✓			✓
Iowa State University		✓	✓	✓	
Maharishi University of Management	✓	✓			
Marlboro College		✓			
Marshall Goldsmith School of Management		✓			
Marylhurst University		✓			

Institution	Bachelor's Degree	Master's Degree	Doctoral Degree	Minor	Certificate
Nottingham University (UK)		✓			
Portland State University				✓	✓
Presidio School of Management		✓			✓
Queen's University (Canada)					✓
Rochester Institute of Technology			✓		
Rochester Institute of Technology		✓			
Royal Holloway, University of London		✓			
San Francisco State University		✓			
St. Petersburg College	✓				
University of Alaska, Fairbanks			✓		
University of British Columbia		✓			
University of California, Berkeley					✓
University of California, San Diego Extension					✓
University of East Anglia (UK)		✓			
University of Maine		✓			
University of Michigan		✓			
University of North Carolina at Chapel Hill		✓		✓	
University of Oregon		✓			✓
University of Pennsylvania		✓			
University of South Florida		✓			
University of South Florida St. Petersburg		✓			
University of Southern Maine	✓			✓	✓
University of Wisconsin	✓				
York University		✓			✓