Green IT: A Matter of Business and Information Systems Engineering?

DOI 10.1007/s12599-011-0165-5

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Published online: 2011-06-18

This article is also available in German in print and via http://www.wirtschaftsinformatik.de: Loos P, Nebel W, Marx Gómez J, Hasan H, Watson RT, vom Brocke J, Seidel S, Recker J (2011) Green IT: Ein Thema für die Wirtschaftsinformatik? WIRTSCHAFTSINFORMATIK. doi: 10.1007/s11576-011-0278-y.

1 Introduction

Recently, Green IT has been discussed with different levels of intensity. Manufacturers, associations, and trade shows are dealing with this subject. Green IT contests are announced and Green IT alliances are formed in addition to Green IT being an objective of public funding programs.

Initially, the discussions focused on energy and resource consumption of information technology. As an example, CO_2 emission (carbon footprint) is used as a parameter to measure if information technology is applied in a sustainable manner. This approach is also referred to as Green-for-IT. However, more and more attention is drawn to the question of how to use information technology to tackle environmental challenges. Hence, the so-called IT-for-Green approach does not consider information technology as a reason for environmental issues anymore but as a potential solution to environmental issues. Putting it differently, the passive role of information technology as a cause of environmental issues is transformed into an active role as a solution to these problems. In terms of the carbon footprint, an example of a new challenge in logistics systems is how information technology can be applied to reduce CO_2 emission.

This panel discusses the impact of Green IT on information systems and how information systems can meet environmental challenges and ensure sustainability. The following questions are addressed by the contributors:

- What is the position of business and information systems engineering (BISE) in the current discussion about environmental challenges and sustainability?
- What position should BISE take in the current discussion about environmental challenges and sustainability?
- What kind of possibilities and impacts can be expected from "green" information systems?
- What are future research areas and fields of action?

The panel consists of the following scholars (in alphabetical order) from the information systems society:

- Prof. Dr. Helen Hasan, University of Wollongong, Australia
- Prof. Dr. Jorge Marx Gómez, Oldenburg University, Germany
- Prof. Dr.-Ing. Wolfgang Nebel, Oldenburg University and OFFIS, together with Marko Hoyer, OFFIS, Daniel Schlitt, OFFIS, Dr. Gunnar Schomaker, OFFIS and Kiril Schröder, Oldenburg University, Germany
- Prof. Dr. Jan Recker
- Dr. Stefan Seidel, University of Liechtenstein, and Dr. Jan Recker, Queensland University of Technology, Australia
- Prof. Dr. Richard T. Watson, University of Georgia, USA and Prof. Dr. Jan vom Brocke, University of Liechtenstein

Nebel et al. point out that there is a strong increase of energy consumption caused by information technologies and that information technologies heavily contribute to the overall energy consumption. Only a small percentage of the energy is transformed into processing power, a significant amount is used for infrastructure tasks, such as cooling and uninterruptible power supply. Since the degree of capacity utilization has only a minor influence on energy consumption of servers, intelligent load management saves energy. The authors refer to a current research project about dynamic load management for alliances of data centers.

Marx Gómez describes environmental management information systems (EMIS) as a type of application system which has been discussed in the BISE literature and applied in business practice for a while. However, current EMIS are mainly applied to ensure compliance with legal regulations and for reporting. He concludes that such systems have to undergo a paradigm shift and integrate sustainability across all corporate areas.

According to Hasan, the Green IT discourse must not only consider tangible things but also activities. Since activities are one of the main objects of research in BISE, this research area should be referred to as Green IS. The author differentiates between a strategy of mitigation and a strategy of adaptation and exemplifies three approaches of Green IS.

Watson and vom Brocke identify energy and information as two basic factors of the development of the civilized world. Therefore, it is only consistent to tackle recent issues of energy consumption with information technology. This approach, which is also referred to as "Energy Informatics", provides an important direction for information systems and will support shaping the scientific profile of this field of research.

Seidel and Recker claim that information technology has to support sustainability of business processes. They discuss an agenda for Green BPM and delineate implications for design, measurement, and implementation of business processes.

Overall the articles reveal that information systems need to participate in the discussion about environmental issues and sustainability and contribute to the solution of current challenges by theoretical and methodological approaches as well as in terms of practical and design methods. As a result, Green IT transforms into Green IS.

If you would like to comment on this topic or another article of the journal Business & Information Systems Engineering (BISE), please send your contribution (max. 2 DIN A4 pages) to the editor-in-chief, Prof. Hans Ulrich Buhl, University of Augsburg, Hans-Ulrich.Buhl@wiwi.uni-augsburg.de.

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2 Green IT: Energy-Efficient and Available Computing Power

No other technology contributes more to conserving scarce resources and protecting our climate than information and communication technologies do. The main goals of green IT are energy and material savings as well as simultaneously increased efficiency. The replacement of physical by virtual products and the related services or the introduction of the smart grid to increase the share of renewable energy can be mentioned as examples here. However, also the awareness is growing that these great achievements come at a price. The energy consumption of ICT itself is – with 17% annually – rising much faster than that of other industries, and the total consumption already reached a significantly high level. CO_2 emissions caused by ICT which, for example, exceed those of air traffic. The energy efficiency of IT is one of the three challenges of the IT industry, a position which was recently confirmed by the German Chancellor at the opening of the CeBIT 2011 in Hannover.

The topic of green IT has been actively discussed in this context for several years in business, politics, science, and media. In the course of the national IT summit, the action plan of Green IT has been developed since 2008. The federal government as well as the economic sector – represented by the Green IT Alliance – and science – represented by the Science Forum Green IT – contributed to this issue. Numerous measures have been adopted, such as a commitment from the federal government to reduce the energy consumption of governmental IT operations of 40% by 2013. In addition, for example, procurement guidelines and labeling requirements have been determined at a European level. There have been educational activities and events as well as publicly funded research projects, such as the funding competition IT2Green[1] carried out by the Federal Government. In short, there is a broad awareness of business, politics, and science for the topic of green IT.

The strong growth in energy consumption of IT is caused by the economically and ecologically desirable steadily increasing IT penetration of products and services within all sectors of the economy, culture, and everyday life. The necessary increase in processing power and communication bandwidth, however, cannot be compensated solely by efficiency gains from new microelectronic technologies. As a result, the energy needs increase in the amount of the already mentioned rate of 17% annually.

Naturally this leads to the question of what further opportunities exist to stop the increase of energy consumption and how energy can be used as efficiently as possible. Here, primarily structural inefficiencies of today's data centers are to be mentioned. Only a minimal percentage of the primary energy is actually used by the servers to provide the required capacity. More than 90% are wasted due to losses in energy transmission, conversion, uninterruptible power supply (UPS), and in the infrastructure as well as due to low server utilization. For instance, the efficiency of the chain from primary energy via the power plant and the pipeline network to the data center is only about 33%. 50% of this remaining energy is often used within the data center for the operation of a UPS and air conditioning.

Only about 30% of the remaining energy is needed by the processor itself, 70% are used for the periphery and the energy management of the servers. In the end, only a small percentage of the energy is actually consumed by servers providing the computing capacity for IT services. Moreover, it is inefficient to use only about 20% of the active servers on average. Their energy consumption is not reduced in proportion to their workload, but unfortunately only marginally. Consolidating and turning off unused servers is the most effective and efficient way to save energy.

It is obvious that this is an important driver for improving IT efficiency. An increase in utilization will hardly increase the energy supplied to the servers. Consequently, the absolute losses in the entire chain from the power plant to the server and in the data center infrastructure will barely increase. Even a tripling of the average utilization of the active servers and the shutdown of the remaining, not required ones could potentially reduce the energy needs of a data center with the same computing power by 66.6%. Of course this would also require to proportionally scale the energy demand for cooling and UPS according to the energy requirements of the hardware, which unfortunately is not the general case today. But again, the industry offers applicable approaches by means of intelligent encapsulation concepts.

But what are the causes of low utilization? Traditionally, the resources installed in a data center are constructed according to the highest expected performance requirements as defined in service level agreements (SLAs). In the worst – no longer standard – case, one server is maintained and kept in operation for each service. The state of the art is to install one or multiple services on virtual machines and then statically assign them to servers. The disadvantage of this static allocation is that the relevant server capacity is planned to cater for the sum of the maximum computing power required by the individual services although these are not likely to be demanded at the same time. Furthermore, usage patterns of the services vary in time and thus result in a fluctuating demand for computing power. Hence, in times of low usage the load on the server decreases again.

On behalf of the Federal Ministry of Economics and Technology, a study was conducted to analyze the potential for increasing energy efficiency of a data center or in a network of data centers through a comprehensive load management (Nebel et al. 2010). In the first stage, such a load management has the objective to

[1] http://www.it2green.de/.

concentrate the active services at a minimum number of servers by means of a load forecast and in accordance with the infrastructure of a data center. This is achieved by dynamic allocation and live migration. The servers not needed are shut down. To ensure the availability of services, the load management always considers the necessary time and resources for restoring a safe assignment. According to our investigations, this dynamic adaptive load management can obtain energy savings of 20% to 40%.

In the second stage, the load management is carried out dynamically within data center networks and across the boundaries of individual data centers. This enables the use of environmental conditions varying from region to region or in time, such as climate or electricity rates, as well as differences in load behavior or infrastructure efficiency. Of course, these concepts take migration costs into account. According to our analyses, the load management across data centers provides additional savings of 5% to 10%. Another benefit of this approach is the ability to shift energy loads in terms of space and to offer a smart grid to compensate for missing capacity.

Currently, the core idea of both stages is being exemplarily tested in real data centers by the AC4DC project funded by the BMWi. The vision is that precisely the computing power that is necessary at a certain point in time is made available securely and with the respective maximum possible energy and resource efficiency. In our view, the approach also contributes to reliable Cloud Computing.

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3 Challenges for the Next Generation EMIS

An Environmental Management Information System (EMIS) is an organizational-technical system for the systematic gathering, processing, and provision of environmental information in a company. Therefore, the application framework of EMIS is basically equivalent to that of business information systems within the business and information systems engineering (BISE) discipline.

Despite the fact that the concept of sustainability found its way into German politics and society already in the beginning of the last decade, the first EMIS, which were developed at the same time, did not receive the desired attention in business practice. From today's perspective, a number of different causes can be identified. A primary cause seems to be that the functionality of those EMIS that have been developed so far was essentially focused on the aim of providing and ensuring compliance with the law and with standards of environmental actions.

Hence, currently used EMIS mainly comply with legal reporting requirements and/or support the use and implementation of standardized environmental management systems (e.g., ISO 14001). In the business sphere, the development and provision of such systems is therefore only assigned to operational management. Traditional definitions mainly support the implementation of operational objectives which also involves pursuing isolated and uncoordinated objectives. Many application systems used in practice demonstrate that such a perspective leads to the realization of isolated solutions. Hence, software systems have been implemented that unconnectedly coexist without any integration effects. In doing so, significant potentials for the prophylactic environmental aspect are not made use of. In sum, these circumstances led to a failure of existing EMIS as regards the acceptance in the enterprise.

Considering the recent research approaches regarding the alignment of EMIS, it becomes evident that research results published under the heading of EMIS often only deal with certain aspects of integrated environmental information systems and do not provide comprehensive business functionality, as provided for example by Enterprise Resource Planning or Business Intelligence systems that are known from BISE. Moreover, it is striking that the information systems outlined in these publications predominantly are of a non-proactive nature. Simplistically (and somewhat polemically), one may state that these information systems are not designed for reducing or even avoiding corporate environmental damage. Instead, these systems are used – such as e.g. almost all waste management systems – to (efficiently) deal with already existing environmental impacts. Third, the question about the successful transfer of research results into business practice, one of great importance for an application-oriented scientific discipline, is rarely raised. Therefore, realignment represents an urgent need!

From the perspective of an application-oriented scientific discipline, this current condition is extremely unsatisfactory, especially since it has been postulated that both the environmental informatics discipline and its artifacts, the EMIS, aim at harmonizing operational economy and ecology. This harmonization must include all aspects of the entire chain – from the input and all transformation processes to the output and, if necessary, reuse or further utilization – in order to provide a holistic orientation in the implementation of next generation EMIS. Future systems must be based on the sustainability discussion and must contribute to the preservation of nature and promotion of economic and social living conditions by means of the initiation of economic, ecological, and social processes.

This raises the claim of aligning environmental information systems with sustainability. Systems that are developed following this postulate must take on a more integrative and strategic orientation regarding their functionality. In this respect, environmental informatics is required to change its starting point to the concept of sustainability. De facto this is a paradigm shift which, among other things, results in the fact that a strategic environmental information management is developed and established which contributes to defining holistic information systems that support the concept of sustainability.

The control efficiency of IT will play a crucial role in sustainable business development. It must be proactive at the beginning of product development, as part of an environmentally integrated production as well as in the strategic decision making, rather than just offering an end-of-pipe solution for passive, subsequent documentation. By using intelligent networked systems and processes, new EMIS will therefore be built on the strategic business level, provide strategically relevant environmental information and decision algorithms, and enable the assessment of sustainable development paths, performance-critical resource prices, and volatile energy markets. This makes it possible to visualize associated risks as well as strategically relevant, system-dynamic cause-effect relationships between economic, environmental, and social indicators.

By providing integrating green web services, the new EMIS will become the connecting link merging the approaches of, for example, Green IS, Green IT, Green business, and Green logistics under the heading of the IT-for-Green view. This guiding principle of the recently launched project IT-for-Green (http://www.it-for-green.eu) also advances the prototype development of such proactive EMIS as part of a highly innovative community of members from academia and industry (http://www.ertemis.eu).

The goal of next generation EMIS must be to deploy a company's entire IT as a resource-directing, integrative nervous system for an intelligent and strategic control, in order to implement an opportunities- and risk-efficient strategic environmental management as well as to enable sustainable shareholder value in this way. Such information systems will gain a more comprehensive operational relevance and thus move back again into the field of strategic company management.

The advance of environmental informatics is realized by its orientation and extension based on the results of the sustainability debate. For companies this will result in automatic, previously unused (because not recognized) options to reduce costs by increasing material and energy efficiency.

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4 Green IS Practice for Mitigation and Adaptation

4.1 Introduction

The Green IT mantra has been around for some time and has mainly focused on reducing the Carbon Footprint of the IT artifact and associated "things". While laudable, this is a perspective that will eventually reach a limit on return for effort. With the more recent attention on Green IS, our attention has turned to a solutions perspective which is more related to "practice". Thus, it may be more sustainable to focus on "activities" rather than "things" and thus deal more holistic with the many wicked problems surrounding climate change. While "things" can be at worst be complicated, many climate change "activities" can be quite complex and will no doubt remain so.

To set the scene, I have always subscribed to the view that it is in our best interest to care for the planet and that each of us should contribute our own particular knowledge and skills to this endeavor. There is a high probability that anthropomorphic climate change will occur and so should be mitigated to protect future generations. However, recent severe weather events here in Australia and elsewhere are reminding us that we may already be seeing the effects of climate change and we urgently need to engage in targeted adaptation programs.

Being conscious of both mitigation and adaption is only one way I take a holistic approach to green matters. Although climate change is the most prominent issue at the moment, it is not the only one. Sustainability needs a holistic approach, and we need to be generally environmentally responsible in terms of population, air, water, soil, forests, species, and oceans. It makes no sense to put all our efforts into stopping global warming but neglect severe degradation of any of the others. Moreover, environmental responsibility should go hand in hand with economic and social responsibility in order to sustain our civilized way of life.

My holistic view of Green IS practice means that in any given situation I see complex interconnected systems of "activities" with specific environmental challenges. The activities approach to Green IS implies re-assessing what we do and the way we do it as well as understanding the mediating role of information systems in enabling these activities to be sustainable. These activities may target mitigation, e.g. initiatives to reduce energy consumption, or adaptation to climate change, e.g. relocating communities in anticipation of rises in sea-level. Green IT, which sees IT as a polluter as well as most of the current Green IS literature address issues of climate change mitigation and these are important. However, I believe that issues of adaptation should also be included under the Green IS banner, not as an admission of failure of mitigation, but as a fact of life.

So what practices can Green IS bring to make a difference to mitigation or adaptation or both? Green IS as a field of study is a subset of the Information Systems (IS) discipline, which naturally concerns the study of "information systems" as IS artifacts. IS artifacts are tools which mediate activities and which evolve to meet the expanding requirements of those activities. As distinct from the IT artifact, which is a relatively simple tool, the IS artifact is a complex socio-technical system defined as an "integrated and cooperating set of people, processes, software, and information technologies to support individual, organizational, or societal goals" (Watson et al. 2010). Information systems can be designed to mediate complex activities in dynamic situations facing uncertain futures. I am inspired by this quote from Dave Gray[2], "when you make the complicated simple, you make it better, but when you make the complex simple, you make it wrong". So if a situation is complex it should remain so and be treated as such.

As an IS professional, I am not overwhelmed by complexity, in fact I revel in it, and believe that IS is in its element when tackling wicked problems. We face a multitude of diverse and complex wicked environmental problems at many levels. Wicked problems can never be completely solved but can be partially resolved using concepts from Complexity Theory, such as emergence, self-direction, social learning, and systems thinking. IS professionals have a wide range of knowledge and skills that suit complexity. They draw on frameworks, methods and techniques from many reference disciplines as appropriate. They also have valuable experience in managing cross-disciplinary projects. They understand the activities of design, development, implementation and maintenance of information systems as well as the business activities which use the system.

Green IS seeks a balance between the negative impact of a system due to its own Carbon Footprint (the Green IT aspect) and the positive effects the system can have in helping to lower the Carbon Footprint of other activities. This is reminiscent of the productivity paradox when many studies showed no correlation between expenditure on IT and productivity. Eventually it was realized that this comparison was too simple for assessing the value of organizational information systems and we have moved on. Getting the balance right for Green IS will probably give us a similar challenge and I will now demonstrate the complexity of this balancing act with some examples.

[2] Founder of Xplane.

4.2 Example 1 – The Activity of Teleworking as a Mitigation Strategy

From the time computer-based networks first appeared and workers could log into organizational systems from home, the advantages of teleworking were proposed. It was thought that such opportunities would be popular with many workers, particularly women and those who had long commutes to work. Many organizations put programs in place but they were not as popular as expected. Question were raised on how well people would work unsupervised and whether workers would miss the social side of work. As typical of a wicked problem, teleworking has quietly become accepted in some circles. Indeed, my own daughter took up the option to work from home two days a week after the birth of each of her children.

More recently attention is back on teleworking as a Green IS issue. Reducing the need to travel to and from work every day may not only lower emissions for the worker involved, but also free up the peak hour commute meaningless emissions from everyone else on the road. However studies say that it is not so simple. The increased energy consumption for the worker at home can be more than the reduction at work. Freeing up traffic can encourage more people to drive and so the emission intensive bottle necks reappear. All sort of activities need to be considered to be sure that telecommuting is really green.

4.3 Example 2 – The Activity "Adaptation to the Impacts of Climate Change: A Chronic Issue"

On the eastern sea-board of Australia where I live State government is planning for consequences of sea level rises. Information systems have been used to model the effect on each local area and all residents have received a map of how properties will be affected by future scenarios. This has all sorts of consequences for managing risk, planning of future infrastructure and services, rezoning of land, property prices, voter backlash, and so on. Can Green IS improve the modeling regime to allow for some of this?

4.4 Example 3 – The activity "Adaptation to the Impacts of Climate Change: An Issue of Crises"

In recent severe weather events much use was made of mobile social technologies to communicate between the relevant authorities and the public. Much of this activity was emergent, bottom up and self directed. During the Brisbane floods the state police acquired 50,000 Facebook friends and 10,000 followers on Twitter. This had obvious advantages with a few reservations about misinformation and inappropriate use. Green IS should surely be interested in this area.

These examples only touch on the complexity of mitigation and adaptation activities. While it is hard to determine what are the best "green" decisions in any particular case, we must act as best we can, monitor what we do, and adjust where needed. This is how it works in complexity.

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5 Energy Informatics: A Critical Imperative for Information Systems

Energy and information are the two critical elements of modern society, a place they have held since the emergence of civilization. Darwin asserted our two most important inventions are fire (a form of energy) and language (a form of information system). The intertwining of energy and information systems is readily apparent over the millennia. A few examples demonstrate this close linkage. Water-powered paper mills in Samarkand in the 8th century mechanized the production of paper, essential for the efficient mass transmission of information and the subsequent rise of literacy. Today's multitude of computer-based information systems can't exist without electricity. The search for oil and natural gas, current major energy sources, is information intensive. Thus, it is surprising that this critical connection has not emerged as a nexus of research until quite recently. We assert that there are two critical imperatives for a major intellectual investment in this nascent discipline by IS scholars.

First, the world faces an ecological crisis in the form of global warming resulting from the release of CO_2 when fossil fuels are burnt. It will take us decades to eliminate CO_2 emissions by capturing and sequestering them or shifting to a range of green energy sources. Meanwhile, we advocate investment in Energy Informatics research, with a particular focus on reducing energy consumption through the development of practical solutions leveraging the transformative power of information systems. Such solutions will be a critical enabler for designing processes with reduced energy consumption and CO_2 emissions. For the past half-century, information systems have been the drivers of productivity gains in advanced economies. We have off-the-shelf technology and well-developed methods for building and deploying information systems as well as for redesigning processes.

It is critical for the world's future that many IS scholars become fully engaged in research, education, and practice that lead to a reduction in CO_2 emissions. Prominent examples in the realm of Energy Informatics are the development and deployment of sensor networks for better managing the demand and supply of energy (Watson et al. 2010) as well as the adoption of IT-enabled sustainable work practices aimed at reducing energy consumption and CO_2 emissions (Seidel et al. 2010).

Second, IS has struggled for decades to create a distinctive academic niche. IS emerged in the U.S. as predominantly a derivative social science, and the journals predominantly publish such research. We classify IS as a derivative field, because nearly all IS research takes one or more social science theories, usually from management, and tests them in an IS context or explains an IS phenomenon in terms of these theories. As a result, much of what we call IS research could just as well be undertaken by academics in the discipline where the theory originated.

In our opinion, IS needs to do two things. It should (a) reorient itself as a solution science and (b) develop a conceptual foundation. We believe that by focusing on Energy Informatics, IS can begin this transformation. IS can make a contribution to solving global climate change, the most critical problem facing the world, by developing solutions. IS as practiced in organizations is a problem solver, and IS research needs to mirror practice and, more importantly, lead practice in solving problems. Such solutions can take the form of software, but also methods and models for the development and deployment of the same (Hevner et al. 2004; March and Smith 1995). The previously mentioned sensor networks are a good example for entire infrastructures that will increasingly become critical in order to manage energy consumption in broader organizational and societal contexts. Focusing on solutions might also help the field to fundamentally think about how it creates value and wealth, which is what today's society rewards, and put us on the path to a conceptual foundation. At the same time, we encourage fellow researchers to develop foundational theory that explains how the transformative power of IS can be leveraged in order to allow for the design of energy efficient processes with reduced CO_2 emissions. Such theory can meaningfully contribute to the conceptual foundation as it informs IS research that focuses on solutions.

The duality of the critical imperative is also captured in the two key questions that we believe Energy Informatics needs to address, namely

- How does society use information to increase energy efficiency?
- How does society reduce the energy required to process information?

The first question gives IS scholars a central societal problem, which must be solved, to address. The second question follows from the first, because as we become more dependent on information to solve the energy efficiency problem, we also have to find better ways to process the additional information or all will be for naught.

IS scholars could elect to send Energy Informatics down the same social science path, but to do so would miss an opportunity to show leadership in both leading in the solution of a critical problem and leading IS in a new direction. We have made a start. Energy Informatics has arisen within the IS field rather than practice, and we need to maintain leadership.

Richard T. Watson
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6 Green Business Process Management

6.1 Introduction

In their paper in the March 2010 issue of MIS Quarterly, Watson et al. (2010) called information systems (IS) researchers to investigate how the transformative power of IS can be leveraged to create an ecologically Green IS sustainable society. In this context has emerged as "the design and implementation of information systems that contribute to sustainable business processes" (Boudreau et al. 2007), based on the argument that the changes enabled through the design of green information systems can go beyond the effects of improved energy efficiency and reduced power consumption that characterize a sustainable information technology (IT) infrastructure (Green IT).

In this commentary, we examine *how* information systems can lead to more sustainable business processes, by discussing the contributions that business process management (BPM) can play in leveraging the transformative power of IS in order to create an environmentally sustainable society (see also Seidel et al. 2011).

The management of business processes, to date, has typically focused on business improvement alongside the dimensions time, cost, quality, or flexibility – the so-called "devil's quadrangle". Contemporary organizations, however, increasingly become aware of the need to create more sustainable, IT-enabled business processes that are successful in terms of their economic but also their ecological and social impact. Exemplary ecological key performance indicators that increasingly find their way into the agenda of managers include carbon emissions, data center energy, or renewable energy consumption (e.g., SAP 2010). The key challenge, therefore, is to extend the devil's quadrangle of business process management to a devil's pentagon, including *sustainability* as an important fifth dimension in process change.

6.2 The Role of Business Process Management in Green Initiatives

In managing business processes to enable business benefits in terms of costs, flexibility, time savings, quality and, indeed, environmental, ecological, or societal sustainability, the use of IT-based systems can be an important enabler, if deployed and appropriated effectively. It is at this intersection of IT-system enablement and process change that we believe the true potential for sustainability transformations lies. Our key premise is that business and IT managers need to engage in a process-focused discussion to enable a common, comprehensive understanding of process, and the process-centered opportunities for making these processes, and ultimately the organization as a process-centric entity, 'green.'

Our reasoning goes as follows: The consideration of only those potentials that come out of Green IT is too limited to facilitate discussions that can help business executives in putting these green IT solutions into business work. A network server platform that is characterized by reduced energy consumption still remains a mere network server platform. If the business processes that run on this platform themselves are not designed to be ecologically sustainable, then the positive effects of an underlying green IT solution will remain minimal if present at all.

At the same time, however, it is impossible to think of undertaking a major sustainability change initiative (involving the redesign of major business processes) without considering what IT can provide to that effect. Still, it is equally impossible to think about any major redesign that does not call for major changes in how employees perform their jobs. Employees and the management of employees are just as important as the underlying IT infrastructure, and the systems that run on this infrastructure, in the transformation to sustainable practices and solutions. Our argument therefore is that BPM provides just the perspective that enables an integrated, holistic approach to the management of sustainability change.

The proposition that we put forward in this statement is that only through the dedicated management of process change, and the application of related techniques, such as process analysis, process performance measurement, and process improvement, the transformative power of IS can be fully leveraged in order to create environmentally sustainable organizations and, in turn, an environmentally sustainable society. Our argument, thus, is that the management techniques associated with BPM will allow us to better understand the transformative power of IS in the context of sustainable development. **Figure 1** encapsulates our view.

Our model suggests that a faithful application of green information technology and green information systems requires a sound understanding of how the technological and system-enabled capabilities facilitate a change in the business processes of an organization. The

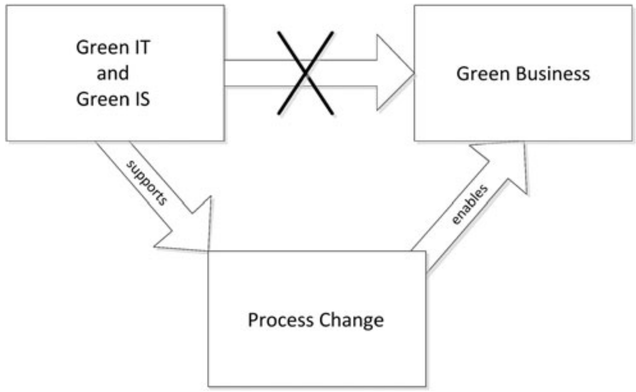

Fig. 1 The role of BPM in IS-enabled sustainability initiatives

promise of business process management is that it enables analysts and managers, but also researchers, to understand these change capabilities, understand the implications of the change, and manage the change itself.

Still, contemporary business process management to date has not explicitly focused on environmental sustainability as a change objective or driver. Thus, we see a need for research in particular to extend our current view of business process management towards the notion of Green BPM that incorporates sustainability as an objective and as a vehicle for managing business process change. We outline important elements in this view in the following.

6.3 A Working Agenda for Green BPM

We identify the following exemplary working areas for research alongside a classical process management lifecycle (Hammer 2010). We do not claim that these issues are exhaustive but rather one appropriate way to conceptualize relevant areas of BPM that may be considered when investigating the role of process management in the context of environmental enterprise sustainability.

(1) *Process design*: It will be necessary to accommodate sustainability-related concepts, such as carbon emissions or energy consumption of business activities in the design of business processes. This, in turn, will allow for analysis and improvement that not only consider economical but also ecological targets. Diagramming business processes with extended process modeling notations, for instance, could be used to document and analyze data about the waste associated with each process.

(2) *Process measurement*: Organizations need to embed sustainability-related targets at all levels of business, starting from the strategy level. Consequently, process measurement needs to accommodate sustainability-related factors such as carbon emissions, energy consumption, and paper consumption. The measurement of these factors not only allows for controlling the accomplishment of sustainability-related targets, but also creates transparency and awareness that is needed in order to reach employees throughout the organization. Consequently, it will be necessary to develop a thorough understanding of the required measurement systems as well as to develop IT systems that collect data and allow for detailed monitoring and analysis of sustainability-related measures.

(3) *Process improvement and process change*: A more detailed understanding is required how the deliberate improvement and redesign of processes can contribute to achieving sustainability targets. While some processes may become more sustainable through rather simple improvements (e.g., eliminate paper production alongside a process), others may require a fundamental redesign (e.g., virtualize a process). Sustainability-aware process improvement methods, in turn, will assist organizations in fully leveraging the transformative power of Green IS.

(4) *Process implementation*: Finally, sustainable processes need to be implemented. In order to do so, organizations are required to allocate sufficient resources, provide eco-aware training to employees, and put into action the previously defined measures. Moreover, dedicated information systems are required to collect data, monitor performance, and create the transparency that is required in order to involve people across the entire organization. Consequently, researchers need to investigate the factors and dynamics that are relevant in the context of implementing sustainable business processes, and which capabilities of information systems assist with this challenge.

6.4 The Way Forward

We suggest at least two main avenues for the way forward. First, IS researchers need to investigate the role of process change in the transformation process towards enterprise sustainability. Such research can employ both qualitative methods for the generation of substantive theory that explains the underlying transformation processes, and quantitative research that aims at developing formal theory. Second, grounded in such theories of change, and drawing on process-related methods and techniques, IS researchers should proceed to more prescriptive, normative, or design-oriented research that delivers well-founded and validated artifacts that can be used to directly impact the implementation of sustainable, IT-enabled business processes (Watson et al. 2010).

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