Green IT and Green IS: Definition of Constructs and Overview of Current Practices

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ABSTRACT

In this paper, the evolution of environmentally sustainable information systems management, addressed through the terms Green IT and Green IS, is analyzed from an IS research perspective. The theoretical foundations of this research area are examined through a literature review and revised in the scope of a content analysis. The characteristics of Green IT and Green IS are contrasted, and impact areas are identified. Based on these findings, the concepts of Green IT and Green IS are thoroughly defined. Next, a wide range of prevalent Green IT practices is assigned to specific value creation processes of IT departments and presented in a catalogue of Green IT measures. Greens IS initiatives, which enable environmentally sustainable business processes and end products, are categorized and consolidated in a comprehensive list of relevant practices. This paper provides an overview of theoretical constructs and practice-oriented implementation measures, thus facilitating insights to both, academics and practitioners.

Keywords

Environmental Sustainability, Green IT, Green IS, Literature Review, Definition, Initiatives, Measures, Practices.

INTRODUCTION

Business firms are increasingly being urged by different stakeholder groups, such as customers, governments and society, to meet their responsibilities concerning corporate sustainability (Molla and Abareshi, 2011). Ninety-five percent of the 250 largest companies worldwide already publish a corporate sustainability report (KPMG, 2011). Sustainable management is understood as a long-term process of simultaneously optimizing economic, environmental and social performance while taking natural resource restrictions into account, thus allowing for enduring business activities without compromising the needs of future generations (Bansal, 2005). To address this multi-faceted challenge, executives rely on the Triple Bottom Line concept (Elkington, 1997) and management tools, such as the Sustainability Balanced Scorecard (Figge, Hahn, Schaltegger and Wagner, 2002). Certainly, corporate sustainability is not restricted to challenges and risks – it comes along with opportunities as well. The sustainability paradigm was identified as the next "business megatrend" (Lubin and Esty, 2010) and is associated with superior efficiency of production processes (Porter and Linde, 1995) and innovations that will change the competitive landscape and create future markets (Nidumolu, Prahalad and Rangaswami, 2009).

Sustainability is a far-reaching concept. Due to the fact that social aspects of sustainability have hardly been addressed by the IS research community, this paper, which reflects the status quo of Green IT/IS research, is focused on environmental sustainability aspects. The concept of environmental sustainability is grounded in management research, in particular in the theory of the Natural Resource-Based View (Hart, 1997). Hart identifies three goals that must be considered by executives to advance the environmental sustainability of business firms: 1) pollution prevention, achieved through minimization of waste and emissions; 2) product stewardship, addressed by consideration of stakeholder demands and optimization of product lifecycles; 3) sustainable development, accomplished through a reduction of the organization's environmental footprint and commitment to a long-term sustainability vision. For the realization of these three goals, information technology (IT) and information systems (IS) are of particular significance (Dedrick, 2010; Watson, Boudreau, Chen and Huber, 2008).

Unfortunately, the lifecycle of IT equipment is associated with several negative environmental impacts (Elliot and Binney, 2008). The manufacturing of IT hardware contributes to the depletion of rare resource. At the end of the product lifecycle, IT hardware is often illegally dumped and then exported to developing countries, where hazardous substances seriously threaten human's health. In the year 2012, 65.1 million tonnes of electrical and electronic equipment were sold in global markets and 45.6 million tonnes of e-waste were generated (StEP, 2012). Furthermore, operating computers, networks, and data centers comes along with vast amounts of electricity consumption. As a result, information and communication technologies are

responsible for two percent of worldwide carbon dioxide emissions (Elliot, 2011). The 33.7 million servers which are currently installed worldwide consumed approximately 235 billion kWh of electrical energy in 2012 – this equals 1.3 percent of the worldwide electricity demand (Koomey, 2011).

At the same time, IS are regarded as crucial enablers for driving the transformation towards a more sustainable economy and society. Academics and practitioners (Krauss, 2010; Melville, 2010; Mingay, 2007; Molla, Cooper and Pittayachawan, 2011; Watson, Boudreau and Chen, 2010) identified a wide range of areas where IT and IS can decrease negative environmental impacts, e.g., through reengineering of business and production processes, building automation, fleet management, or teleconference systems. Beyond enhancing the efficiency of internal processes, IS-based energy monitoring and environmental management systems facilitate transparency and allow measuring the achievement of environmental targets.

These contradictory effects – negative environmental impacts of manufacturing, operations, and disposal of IT, versus positive environmental impacts owing to increased efficiency of internal processes and end user products – are discussed by the IS research community under the headlines of Green IT and Green IS respectively. Despite the discussions on environmental sustainability aspects of IT and IS in research and practice, Green IT and Green IS remain vague concepts (Molla, Cooper and Pittayachawan, 2009). Most researchers differentiate between Green IT, which is usually focused on energy efficiency of IT infrastructure operations and e-waste issues, and Green IS, which refers to information systems that enable sustainable business processes and end products (Vazquez, Rocha, Dominguez, Morales and Ahluwalia, 2011). The variety of understandings and definitions that can be found in IS research reveals the need for an adequate theoretical grounding. For this reason, the first research goal of this paper is to derive unambiguous definitions of Green IT and Green IS from prevalent literature, and to clearly illustrate the differences between these two concepts.

Apart from deriving theoretical constructs that bring clarity to the IS research community, this paper has a strong focus on practical relevance. The insights of this research should be meaningful to both, academics and practitioners (Benbasat and Zmud, 1999). In academic literature and in practitioner reports, a huge variety of Green IT and Green IS measures can be found, but until now, a review and consolidation of these measures is missing. In line with this, the second research goal is to provide an extensive catalogue of Green IT measures which enhance the environmental sustainability of IT organizations, and an encompassing list of Green IS initiatives which enable environmentally-friendly business processes and end products.

ANALYZING THE STATUS QUO OF GREEN IT AND GREEN IS LITERATURE

Research articles referring to Green IT and Green IS

The first step for analyzing the status quo of Green IT and Green IS was to conduct a comprehensive review of the current literature. To do so, papers which included the term "Green IT" or "Green IS" in their title were searched for in the AIS electronic Library (AISeL). The AISeL is the "central repository for research papers and journal articles relevant to the information systems academic community" (http://aisel.aisnet.org/). It contains the proceedings of the most renowned IS conferences as well as some of the top journals of this field. The advanced search function returned 41 documents with the term "Green IT" in the title of the paper plus 21 documents referring to "Green IS". Since this research area is often addressed under the headline of sustainability, the search was extended by the term "sustain*" (the * was used due to similarity of terms, e.g., sustainability, sustainable, sustain etc.). This search delivered 184 results, but not all were directly related to the focus of this paper. To refine the results, the search for documents with the term "sustain*" in the title was combined with the subject terms "Green" (22 results) and "environmental" (16 results). Table 1 presents an advanced analysis of search results.

Year	Green IT	Green IS	Sustain* + Green	Sustain* + Environmental	Total	Source	Green IT	Green IS	Sustain* + Green	Sustain* + Environmental	Total
2008	1	-	2	1	4	AMCIS	13	6	9	2	30
2009	12	2	2	-	16	ICIS	4	6	7	5	22
2010	12	3	6	3	24	PACIS	7	2	2	-	11
2011	11	7	5	7	30	ECIS	5	2	-	-	7
2012	5	9	7	5	26	CAIS	1	1	1	1	4
						MISQ	-	-	1	3	4
Total	41	21	22	16	100	Total	30	17	20	11	78

Table 1: Classification of research results from the AIS eLibrary (AISeL).

The research area of green/environmentally sustainable IT/IS was first discussed in 2008 and had a sharp increase of publications until 2010. From 2010 till 2012, the number of research articles remained relatively stable (see Table 1).

The term "Green IT" is widely used and the quantity of articles referring to this concept had a peak in 2009/2010. However, the predominance of the concept of Green IT is declining due to the fact that the more far-reaching concept of Green IS is increasingly being applied (see Figure 1). Furthermore, it becomes obvious that scholarly journals, such as the MIS Quarterly, mainly address the theoretical concept of environmental sustainability whereas the practice-oriented concepts of Green IT and Green IS can rather be found in conference proceedings. The AMCIS is the conference that provides the largest quantity of publications related to this research area (30 papers), followed by the ICIS (22 papers). The comparison of these two conferences reveals that AMCIS contributions are rather focused on the concept of "green" whereas ICIS articles address "green" and broader environmental sustainability issues equally (see Table 1).
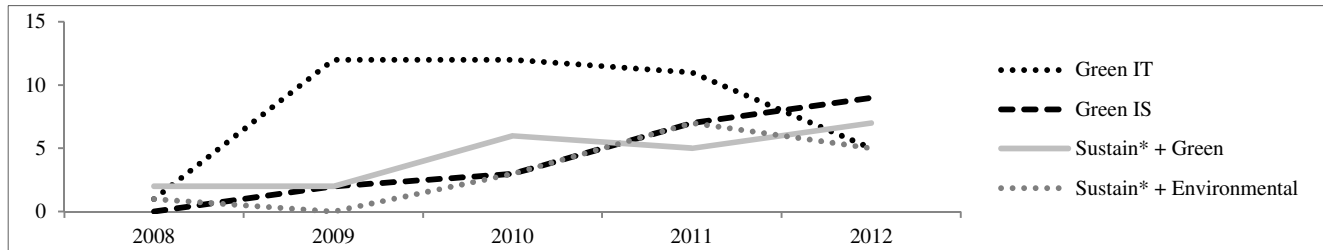

Figure 1: Number of publications in Green/Sustainable IT/IS research from 2008 to 2012.

To ensure scientific rigor, to guarantee recognized quality standards, and to keep the number of articles that had to be reviewed at a manageable level, it was decided to limit the further analysis of the literature from the AISeL to the top IS conferences ICIS, AMCIS, PACIS and ECIS and the journals MIS Quarterly (MISQ) and Communications of the AIS (CAIS). According to this, 78 research results (see Table 1) from the AISeL were analyzed to provide a thorough theoretical foundation for the conceptualization of Green IT and Green IS. In this context, it must be mentioned that the column "total" in Table 1 refers to the number of search results and not to the absolute number of articles. The redundancies in the search that occurred when one article was listed in the results of different search terms (e.g., MISQ published three relevant articles, as discussed below) were eliminated in the subsequent content analysis.

Due to the limited coverage of academic journals, the search for relevant publications in the AISeL was complemented by an examination of the top scholarly journals which are recommended by senior AIS researchers. This "basket of eight" includes the following journals: European Journal of Information Systems, Information Systems Journal, Information Systems Research, Journal of AIS, Journal of Information Technology, Journal of MIS, Journal of Strategic Information Systems, and MIS Quarterly. A search (in all fields) for the terms "Green", "Sustainability" and "Sustainable" was conducted and delivered 3 relevant articles published in the MISQ as well as 9 papers from the Journal of Strategic Information Systems (JSIS). The large quantity of publications in the JSIS originates from a special issue on "The Greening of IT" (Volume 20, Issue 1, 2011). In the end, the search provided 90 search results (78 from AISeL and 12 from the "basket of eight"). The other six top IS journals did not publish any related articles until now. Nonetheless, recent call for papers in the scope of special issues of MISQ, Information Systems Journal (ISJ), Business and Information Systems Engineering (BISE), Australasian Journal of Information Systems (AJIS), and Information Systems Frontiers (ISF) reveal an intense interest for the topic.

Content analysis

The next step was to eliminate redundancies of search results and to explore the scope of the articles. To do so, abstracts were analyzed and the contents of the papers were quickly reviewed to provide a basis for the decision whether the articles were related to Green IT/IS research or not. This process led to the exclusion of several articles and resulted in a final number of 48 articles that were examined in detail (see appendix). The articles of this final selection were classified according to their type of research (theoretical vs. empirical with primary or secondary data, according to Chen and Hirschheim, 2001) and their focus (Green IT or Green IS), as displayed in Table 2. At a first glance, there seem to be quite a lot of empirical studies, but out of these 32 empirical research papers, only 23 actually rely on primary data (10 quantitative studies, 13 qualitative case studies). Further details regarding the research method being applied in each of these papers can be found in the appendix.

Type of research		Green IT	Green IS
Theoretical, non-empirical		10	6
Empirical	Primary data	14	9
	Secondary data	8	1

Table 2: Research methods of the analyzed Green IT and Green IS articles.

Next, the 48 selected articles were scanned for the terms "Green IT" and "Green IS". All the conceptualizations and definitions of Green IT and Green IS were extracted and, depending on the classification of the type of research, included in one of the four tables presented in the appendix of this paper. During the examination of these articles, it became obvious that some authors rely on the definitions proposed by prominent senior researchers in scholarly journals, whereas the majority of authors modified established definitions to fit their specific research purposes. Besides, Green IT was defined in eight cases without any theoretical grounding while seven articles did not even explicitly define their focal research construct at all.

To assure consistency with the status quo of current academic research, and to inhibit that this paper adds another ambiguous definition of Green IT and Green IS to the body of knowledge, the most-cited definitions of Green IT and Green IS were analyzed. The terms "Green IT", "Green IS", "Green information", "sustainable information systems" and "information systems sustainability" were searched for in Google Scholar. By doing so, the scope of the research was extended to any possible academic discipline – according to the fact that Google Scholar is not limited to IS research. To allow for consideration of the most prevalent definitions and to restrict the number of definitions to a manageable quantity, the threshold of articles to be analyzed in detail was set to 50 citations. The results of this interdisciplinary search are displayed in Table 3.

Search term	Reference	Source	Citations	Definitions of Green IT and Green IS
Green IT	Murugesan (2008)	IT Professional	246	**Green IT** refers to environmentally sound IT. It's the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems efficiently and effectively with minimal or no impact on the environment.
	Molla, Cooper, Pittayachawan (2009)	International Conference on Information Systems	58	This paper conceptualizes **Green IT** from the IT infrastructure and capability perspective. This implies that eco-sustainability considerations need to be incorporated within the IT technical and human infrastructure and IT managerial capability dimensions of the IT infrastructure to solve both IT and non-IT (by using IT) related sustainability problems.
Green IS	Watson, Boudreau, Chen, Huber (2008)	Information Systems – A Global Text	71	**Green IT** is mainly focused on energy efficiency and equipment utilization. **Green IS** refers to the design and implementation of information systems that contribute to sustainable business processes.
Green information	Jenkin, Webster, McShane (2011)	Information and Organization	53	'**Green IT**', which addresses energy consumption and waste associated with the use of hardware and software, tends to have a direct and positive impact. '**Green IS**' refers to the development and use of information systems to support or enable environmental sustainability initiatives and, thus, tends to have an indirect and positive impact.
Sustainable information systems	Watson, Boudreau, Chen (2010)	MIS Quarterly	211	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**.
Information systems sustainability	Melville (2010)	MIS Quarterly	186	We define **IS for environmental sustainability** as IS-enabled organizational practices and processes that improve environmental and economic performance.
	Chen, Boudreau, Watson (2008)	Journal of Systems and Information Technology	81	IS can be leveraged to achieve eco-efficiency, eco-equity and eco-effectiveness through automating, informing (up and down) and transforming organizations, respectively.

Table 3: Most-cited Green IT/IS research papers, as retrieved from interdisciplinary Google Scholar (February 15, 2013).

To compare the definitions and to elucidate differences between the constructs Green IT and Green IS, specific impact areas of Green IT and Green IS were identified based on the results that are presented in Table 3 and in the appendix of this paper. Molla et al. (2009) differentiate between three functional areas: sourcing, operations, and disposal of IT infrastructure. Another aspect is IT Governance, which is responsible for aligning IS with corporate strategy. In line with this, environmental targets must be derived from the overarching enterprise sustainability goals. The corresponding Green IS strategy should enhance IS value creation and facilitate environmental sustainability throughout the organization to leverage

firm competitiveness (Loeser et al., 2012). Furthermore, environmental policies, guidelines, and general requirements are defined in the scope of the IT Governance. Apart from these functional areas of the IT value chain in IT organizations or internal IT departments respectively, Green IS can facilitate environmentally sustainable business processes throughout the entire organization (Watson et al., 2008) as well as enabling innovations for environmentally-friendly end products (Buchta, Eul and Schulte-Croonenberg, 2007; Chen et al., 2008).

Referring to this classification scheme, the most-cited definitions of Green IT and Green IS (Table 3) were carefully examined. The detailed explanations, which were retrieved from the texts of the ten selected articles, described the impact areas of Green IT and Green IS. The conceptualizations were thoroughly analyzed and classified. The results of this analysis are contrasted in Table 4. Obviously, the most-cited definitions of Green IT focus on environmental practices that have an impact on sourcing (material requirements), operations (power consumption), and disposal (e-waste) of IT infrastructure. Molla et al. (2009) include aspects of IT Governance in their Green IT concept, whereas the other definitions associate this capability with the concept of Green IS. Furthermore, conceptualizations of Green IS always take the enabler function of IS for environmentally sustainable business and production processes into account, whereas the potential of IS for greening end products and customer services is less considered. Watson et al. (2010) differentiate between Green IT and Green IS, but in line with the predominant conceptualizations of IT and IS, they consider Green IT as part of the broader concept of Green IS.

Reference	Year	Sourcing	Operations	Disposal	IT Governance	Business processes	End products
Green IT							
Murugesan	2008	X	X	X			
Molla, Cooper, Pittayachawan	2009	X	X	X	X		
Watson et al.	2008	X	X				
Jenkin, Webster, McShane	2011		X	X			
Watson, Boudreau, Chen	2010	X	X	X			
Green IS							
Watson et al.	2008				X	X	
Jenkin, Webster, McShane	2011				X	X	
Watson, Boudreau, Chen	2010	(X)	(X)	(X)	X	X	X
Melville	2010				X	X	X
Chen, Boudreau, Watson	2008				X	X	X

Table 4: Functional impact areas of Green IT and Green IS.

Conceptualizing Green IT and Green IS

Molla et al. (2011) argue that clear definitions of central concepts are the first step for well-grounded theory building in new research areas, such as Green IT/IS. The analysis of prevalent literature illustrated that a clear definition and a coherent distinction between the concepts of Green IT and Green IS are required to provide clarity to academics and practitioners. The term *Green* refers to technologies and processes that are environmentally friendly, i.e., which have a lower negative impact on the natural environment than conventional ones. The environmental impact of Green technologies refers to the environmental footprint during their lifecycle (Molla and Abareshi, 2011), while the environmental impact of green processes refers to the reduced need for input resources, decreased pollution, and the reuse of materials (Albino, Balice and Dangelico, 2009). Watson et al. (2008) state that IT and IS are two fundamentally different concepts. In this paper, it is argued that the term *Information Technology (IT)* refers to computer hardware, software, and peripheral equipment (Ijab et al., 2010) whereas *Information Systems (IS)* "is a broad concept that covers the technology components and human activities related to the management and employment process of technology within the organization" (Chen et al., 2010, p. 237). Obviously, the concept of IS covers various aspects: it comprises IT (such as physical servers, office computers and network devices) as well as shared services (such as databases or storage), business applications (such as ERP systems), IT human resources (such as skills and knowledge), and IS-related managerial capabilities for organizational processes and business transformation (Broadbent and Weill, 1997; Ravichandran and Lertwongsatien, 2005).

Based on the comparison and analysis of Green IT and Green IS definitions, this research reveals that *Green IT* practices, on the one hand, are focused on three specific aspects:

1. Consideration of environmental criteria when purchasing IT equipment and services.
2. Energy-efficient IT operations in data centers and in office environments.
3. Environmentally-friendly practices referring to the disposal of IT equipment.

The cross-functional characteristics of *Green IS*, on the other hand, enable:

1. Reengineering of business and production processes.
2. Implementation of IS-based environmental management systems (EMS).
3. Innovations for environmental technologies in end user products and services.
4. Tracking of resource demands and emissions of products and services (lifecycle analyses).

Green IT tackles the decrease of IT-related power consumption that accounts for approximately 2 percent of global greenhouse gas emissions ("IT as a problem") while Green IS allow for innovative solutions that address the remaining 98 percent ("IT as a solution") (Elliot, 2011). In this context, Molla and Abareshi (2011) argue that Green IT refers to the negative first-order environmental impact of information systems (manufacturing, use, and disposal of IT equipment), whereas the concept of Green IS comprises as well the positive second-order impacts (greening of business and production processes) and third-order impacts (reduced resource consumption, waste, and emissions during the lifecycle of end products and services) (Hilty et al., 2006). These theory-based findings are illustrated in Figure 2 and result in the following definitions:

The concept of Green IT refers to measures and initiatives which decrease the negative environmental impact of manufacturing, operations, and disposal of Information Technology (IT) equipment and infrastructure.

The concept of Green IS refers to practices which determine the investment in, deployment, use and management of information systems (IS) in order to minimize the negative environmental impacts of IS, business operations, and IS-enabled products and services.
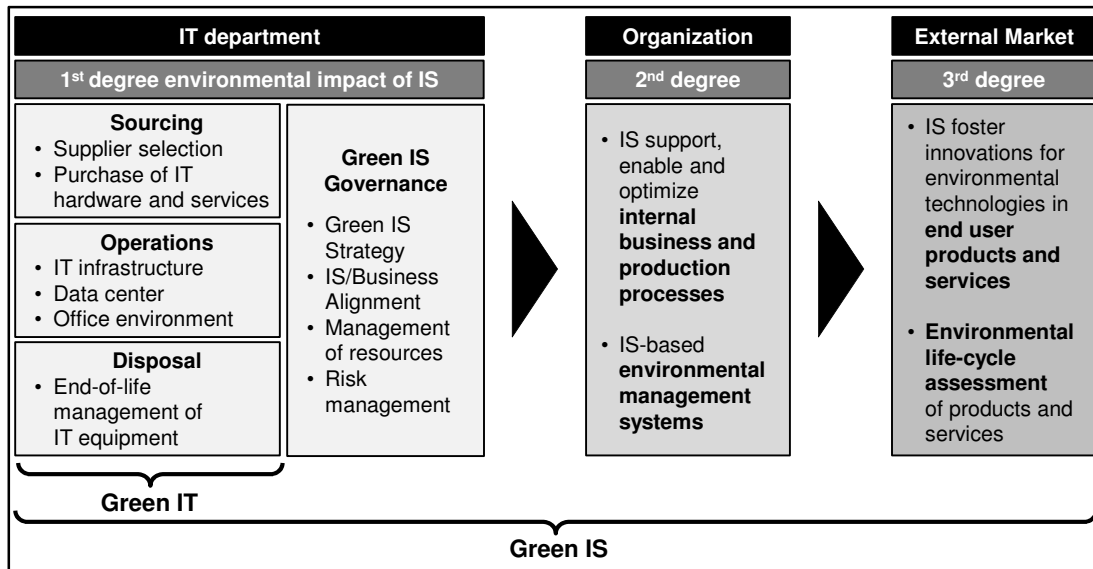

Figure 2: Scope of Green IT and Green IS.

Green IT measures refer to the operational and tactical management of IT departments whereas Green IS practices influence IS strategy alignment and organizational core processes. In line with this, the definition of the concept of Green IS builds on the widely recognized definition of IS strategy by Chen et al. (2010). As elucidated in Figure 2, Green IT is an integral component of the encompassing concept of Green IS.

Measures and initiatives of Green IT and Green IS

To create an exhaustive catalogue of Green IT measures that target the central areas of responsibility of IT departments (see Figure 2), a wide range of literature from academics (e.g., Corbett, 2010; Molla et al., 2011; Sayeed and Gill, 2009; Watson et al., 2008) and practitioners (e.g., Krauss, 2010; Lamb, 2009; Murugesan, 2008; Ruth, 2009; Velte, Velte and Elsenpeter, 2008) was analyzed. The measures and initiatives of the resulting list were assigned to the central processes of IT departments (sourcing, operations, and disposal). Within the sourcing process, two sub-categories were defined: management

of supplier relations, and purchases of IT products (hardware and software) and services (such as external computational and storage capacities, e.g., cloud computing). Due to the variety of possible measures that relate to IT operations, a distinction between operational Green IT management practices, data center measures, and office environment initiatives was made. Moreover, the Green IT data center measures were subdivided into the categories servers and storage, network, cooling, and energy supply. The entire list of Green IT measures is presented in Table 5.

Process	Scope	Focus	Measures and initiatives	
IT Sourcing	Supplier relationships		• Collaborate with suppliers and share knowledge • Define environmental requirements for suppliers	• Encourage suppliers to decrease their footprint • Conduct environmental supplier audits
	Sourcing of IT products and services		• Consider eco-labels when purchasing hardware • Conduct total-cost-of-ownership (TCO) and lifecycle analyses (LCA) • Buy eco-friendly paper and cartridges	• Centralize sourcing of IT equipment • Purchase renewable energy • Purchase energy-efficient cloud services
IT Opera-tions	General IT management		• Develop a Green IT/IS action plan • Develop a Green product and service portfolio • Create an inventory of IT hardware • Consolidate applications • Manage lifecycle of stored data	• Monitor energy consumption • Measure and analyze environmental KPIs • Implement IT performance measurement systems • Detailed energy monitoring of all devices
	Data center	Servers and Storage	• Consolidate servers • Virtualize servers and storage • Deploy blade servers • Deploy energy-efficient processors • Install energy-saving hard disk drives • Install dynamically adjustable fans	• Deploy energy-efficient server power supplies • Right-sizing of server and storage capacities • Activate energy-management functions • Apply scheduling and workload management • Shut down servers dynamically • Monitor energy consumption of servers
		Network	• Install intelligent switches	• Virtualize network
		Cooling	• Install dynamically adjustable cooling systems • Install modern CRAC systems • Install in-row chillers • Utilize liquid refrigerants for server cooling • Deploy free cooling system • Separation of hot and cold aisles • Containment of hot and cold aisles	• Detailed monitoring of air temperatures • Optimize air flows • Eliminate hot spots and air circulation short cuts • Increase data center temperature • Consider energy flows in data center architecture • Reuse data center heat
		Energy Supply	• Optimize energy supply • Install modern and efficient UPS • Increase UPS utilization rates	• Install UPS flywheel instead of batteries • Reduce power conversion steps to decrease power losses
	Office environment		• Use notebooks instead of desktop computers • Utilize energy-efficient desktop PCs • Install thin clients • Deploy LED displays • Activate power management functions of PCs	• Install power management software • Inform and educate end users • Install network multifunction printers • Double sided black & white printing as default
IT Disposal			• Holistic end of IT life management • Reuse computers • Refurbish computers • Extend life of IT equipment • Manage e-waste • Recycle hardware	• Track toxic materials • E-waste policies and rules • Engage in recycling initiatives • Cooperate with suppliers and strive for takeback programs and recycling initiatives

Table 5: Catalogue of Green IT measures.

Next, Green IS initiatives that target the governance aspects of the IT department, the business and production processes of the enterprise, or IS-enabled products and services (see Figure 2) were analyzed in both, academic literature (e.g., Molla et al., 2009; Fradley, Troshani, Rampersad and De Ionno, 2012; Ijab, Molla, Kassahun and Teoh, 2010) and practice-oriented

reports (e.g., Krauss, 2010; Nunn and Bonecutter, 2009; World Economic Forum, 2008). These Green IS initiatives were assigned to three areas: IT department, organization, and external market (see Table 6).

Area	Category	Green IS initiatives	
IT department	IT Governance	• Explicitly formulate a Green IS strategy • Align Green IS with corporate sustainability • Regular meetings between IS and management executives to identify synergies • Organizational integration of Green IS through specific roles and responsibilities • Establish measurable environmental targets • Track IT-related environmental KPIs • Integrate environmental criteria into IT resource management • Internal allocation of IT-related energy costs • Deploy an energy management system • Implement an environmental management system	• Strive for certification of the EMS • Analyze customer demand for green products • Green IT service and product portfolio • Create incentives for employees to go green • In-house and external communication of Green IS initiatives • Establish a dialogue with relevant stakeholders • Issue a public IS sustainability report • Engage in NGOs and industry consortiums • Publish technical papers and best practices • Use Green IS initiatives for marketing • Consider environmental aspects in Make-or-Buy decisions
Organization	Information and transparency	• Track and analyze corporate waste and emissions • Measure resource consumption and report the firm's environmental footprint • Provide aggregated information regarding environmental sustainability aspects to consumers • Implement firm-wide environmental management systems	
	Process optimization	• Smart manufacturing (monitor, manage, and optimize production processes) • Track and optimize resource and material flows • Advanced automation technologies • Use simulations in the product design phase • Dynamic vehicle routing and advanced logistic systems • Supply chain optimization • Virtual meetings and remote working practices (reduce individual travel)	
External market	Innovative end products and infrastructure solutions	• Product lifecycle assessment (tracking of product-related resource demands and emissions) • Building automation (integrated management of light, heating, and cooling systems) • Smart grid technologies (measurement, management, and prediction of electricity demands) • Fuel-saving car technologies (start/stop function, smart engine control units) • Intelligent traffic management systems • Dematerialization initiatives (digital services instead of physical products) • Waste analysis and waste management systems • Environmental innovations through modern technologies • Smart sensors to control and optimize energy flows	

Table 6: List of Green IS initiatives.

Apparently, these Green IS initiatives are less specific than the previously presented Green IT measures. The rather generic nature of Green IS initiatives is a consequence of the conceptual stage of current technologies and management practices: academics and practitioners try to envision IS-enabled processes, products, and services that will shape our future. However, until now, few implementation examples and best practices can be found in this domain.

CONCLUSION

This research reveals that numerous academic papers and practice-oriented reports have been published in the relatively new field of Green IT/IS. Nonetheless, definitions of central concepts remain vague, and a shared understanding of the characteristics and scope of Green IT and Green IS is urgently needed among IS researchers and practitioners. As a consequence, this paper provides 1) clear definitions of these concepts based on the consolidation of current academic literature, and 2) illustrates specific impact areas of Green IT and Green IS. This is an important first step in the theoretization of this new research area and adds to the body of IS knowledge. Most Green IT/IS papers have been published in conference proceedings (especially AMCIS and ICIS) whereas publications in top IS journals are rare. However, forthcoming special issues addressing this important topic clearly indicate an intense interest for this research area.

For practitioners, the most valuable contribution of this research are 1) the catalogue of Green IT measures, subdivided into IT sourcing, IT operations, and disposal of IT equipment, and 2) the list of Green IS initiatives, which are assigned to IT governance, to information and process optimization capabilities that address the entire organization, and to the enabler function of IS for innovative end products and infrastructure solutions. These far-reaching examples of Green IS illustrate the positive impact which information systems can have on environmental sustainability. The encompassing assortment of Green IT/IS practices gives a broad overview to academics and provides useful suggestions for practitioners who strive for implementing Green IT/IS within their organization.

Since empirical evidence is rare in this field, the next step of this research project is a quantitative analysis of the implementation maturity of the presented Green IT and Green IS measures in the scope of a cross-sectional survey.

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APPENDIX

Table A-1: Definitions of Green IT, non-empirical research, AISeL.

Author	Source	Method	Definition Green IT
Brooks, Wang, Sarker	AMCIS 2010	Literature review	We do not define Green IT as purely the hardware component of IT, but as an inclusive concept that goes beyond the working definition provided by Murugesan (2008). We take a sociotechnical view of Green IT (Markus and Robey, 1988). Specifically, we categorize Green IT in two ways: 1) the initiatives that utilize IT infrastructure to change organizational processes and/or practices to improve energy efficiency and reduce the environmental impacts, and 2) environmentally healthier IT products and/or services.
Butler, Daly	ECIS 2008	Theoretical propositions	The IT industry has extended the scope of Green IT to include the manner in which IT is deployed to help reduce GHG emissions, to introduce energy efficiencies, or to reduce energy consumption. Academics such as Boudreau, Watson, and Chen (2008), argue that therefore IT-enabled information systems have a role to play in making business processes environmentally sustainable—they term such information systems Green IS. This study conceptualizes Green IT as including all of the above, in order to avoid the possibility of definitional confusion and to maintain congruency with practitioners' use of the term.
Corbett et al.	AMCIS 2010	Theoretical propositions	Efforts around Green IT have focused primarily on immediate and direct effects, such as power consumption and end-of-life disposal.
Dedrick	AMCIS 2009	Literature Review	n/a
Gadatsch	BISE 2011	Comment	n/a
Loeser et al.	AMCIS 2011	Conceptual strategies	Green IT is the systematic application of practices that enable the minimization of the environmental impact of IT, support the superior goal of corporate sustainability, maximize efficiency and allow for company-wide emission reductions based on technological innovations.
Loos et al.	BISE 2011	Panel discussion	Green-for-IT: energy and resource consumption of information technology. IT-for-Green: how to use information technology to tackle environmental challenges.
Mann, Grant, Mann	AMCIS 2009	Literature review	Green IT can thus be more succinctly defined as the process that focuses on the strategic deployment of operations and information technology to dynamically, sustainably and responsibly align business-oriented goals with green objectives for the entire duration of operations.
Vazquez et al.	AMCIS 2011	Literature review	Green-IT is mainly focused on energy efficiency and equipment utilization and addresses such issues as replacing personal computers with energy efficient thin clients, using renewable energy sources to power data centers and reducing electronic waste from obsolete computing equipment (Watson et al., 2008).
Vykoukal, Wolf, Beck	PACIS 2009	IT from the Resource-based view	Green IT is defined as "the study and practice of designing, manufacturing, using, and disposing of computers, servers, and associated subsystems (monitors, printers, storage devices, etc.) efficiently and effectively with minimal or no impact on the environment" (Murugesan, 2008).

Table A-2: Definitions of Green IT, empirical research based on secondary data, AISeL.

Author	Source	Method	Definition Green IT
Cooper, Molla	AMCIS 2010	Single case study	n/a
Corbett	ICIS 2010	Analysis of CIO articles	Green IT is defined as the collection of information and communications technologies and information systems that are, directly or indirectly, used to reduce the harmful environmental impacts of human activities.
Kim, Ko	AMCIS 2010	Desk research	Green IT practices will have an influence on social, environment, and financial performance either directly or indirectly (Murugesan, 2008; Elliot, 2007).
McLaren, Manatsa, Babin	AMCIS 2010	Multiple-case study, secondary data	"Green IT" can be loosely described as a set of organizational initiatives undertaken to reduce the environmental impact of Information Technology. Green IT involves the study and practice of designing, manufacturing, using, and disposing of information and communication technologies (ICT) in a manner that is resource efficient and has with little or no impact to the environment.
Nanath, Pillai	ICIS 2012	Mini case studies from Computer-world	This study attempts to contribute to this emerging area by providing a holistic view of Green IT implementation in organizations. It builds upon the research agenda proposed by Melville (2010), where three important roles of IS in interaction between organizations and environment have been defined.
Nishant et al.	ICIS 2012	Data from EPA	Green IT is defined as computing technologies that are energy-efficient and have minimal adverse impact on the environment (Boudreau et al., 2008).
Nishant, Teo, Goh	PACIS 2011	Analysis of News reports	Green IT is defined as computing technologies that are energy-efficient and have minimal adverse impact on the environment (Boudreau et al., 2008).
van Osch, Avital	AMCIS 2010	Single case, data from NYT	The research and the business practice in the area of Green IT are primarily reactive and aimed at eliminating waste, increasing efficiency, and lowering energy costs.

Table A-3: Definitions of Green IT, empirical studies based on primary data, AISeL.

Author	Source	Method	Definition Green IT
Cooper, Molla	PACIS 2012	Multiple-case study	Green IT refers to reducing the negative ecological impact of IT (Molla et. al. 2008) and Green IS refers to using IT for solving ecological problems (Chen et. al. 2008).
Kuo	AMCIS 2010	Survey, N=43	As corporate awareness of environmental sustainability has increased within organizational IT departments, there has been an emergence of an area now generally termed 'green IT' where IS and IT are used to improve environmental performance.
Loeser et al.	PACIS 2011	Multiple-case study	Green IT is the systematic application of practices that enable the minimization of the environmental impact of IT, maximize efficiency and allow for company-wide emission reductions based on technology innovations.
Molla	PACIS 2009	Survey, N=109	Green IT is an organization's ability to systematically apply environmental sustainability criteria to the design, production, sourcing, use and disposal of the IT technical infrastructure as well as within the human and managerial components of the IT infrastructure.
Molla, Abarashi	PACIS 2011	Survey, N=176	Both IT hardware manufacturers and firms using IT need to apply principles of environmental sustainability, which include pollution prevention, product stewardship and sustainable development in managing IT. Green IT refers to such practices.
Molla, Cooper, Pittaya-cha-wan	ICIS 2009	Survey, N=146	This paper conceptualizes Green IT from the IT infrastructure and capability perspective. This implies that eco-sustainability considerations need to be incorporated within the IT technical and human infrastructure and IT managerial capability dimensions of the IT infrastructure to solve both IT and non-IT (by using IT) related sustainability problems.
Molla, Cooper, Pittaya-cha-wan	CAIS 2011	Survey, N=146	Green IT is a systematic application of ecological-sustainability criteria (such as pollution prevention, product stewardship, use of clean technologies) to the creation, sourcing, use and disposal of the IT technical infrastructure as well as within the IT human and managerial practices.
Sarkar, Young	PACIS 2009	Semi-structured interviews	Green IT is defined in simple terms as the optimal use of information and communication technology for managing the environmental sustainability of enterprise operations and the supply chain, as well as that of its products, services, and resources, throughout their life cycles (Mingay, 2007).
Sayeed, Gill	AMCIS 2009	Expert interviews	The adoption of Green IT measures reflects a firm's use of its dynamic resources to strategically counter the challenges of a rapidly changing technological and business environment.
Schmidt et al.	AMCIS 2010	Survey, N=116; regression	Green IT comprises the management of all activities and measures of the IT department, which are aimed to reduce the resource consumption by IT, e.g. in terms of energy, material or paper. Furthermore, it includes instruments to control, steer, and communicate the success.
Schmidt et al.	ECIS 2010	Survey, N=500	We refer to Green IT as "the design, production, operation and disposal of ICT and ICT-enabled products and services in a manner that is not harmful and may be positively beneficial to the environment during the course of its whole-of-life" (Elliot and Binney, 2008).
Schmidt, Kolbe	ECIS 2011	Multiple-case study	Green IT is a systematic application of environmental sustainability criteria to the design, production, sourcing, use, and disposal of the IT infrastructure in order to reduce IT, business process, and supply chain related emissions and waste and improve energy efficiency (Molla et al. 2009). Green IT also comprises managerial aspects to control and monitor the effectiveness of implemented measures as well as marketing measures to communicate the success towards important stakeholders.
Tan, Pan, Zuo	ICIS 2011	Single case study	We define green IT as an integrated and cooperating set of people, processes, and computing resources (Watson et al. 2010) that aim at pollution prevention, product stewardship or sustainable development (Chen et al. 2009; Molla et al. 2009a) for the purpose of enhancing environmental and economic performance (Melville 2010).
Vykoukal	ECIS 2010	Survey, N=217, SEM	Although the term "Green IT" is multi-faceted and encompasses the manufacturing and purchasing of energy efficient IT equipment, the efficient operation and utilization of hardware devices, as well as its proper disposal (Murugesan 2008), this article mainly focuses on the minimization of energy consumption of IT equipment as key Green IT objective.

Table A-4: Definitions of Green IS, non-empirical research, AISeL.

Author	Source	Method	Definition Green IS
vom Brocke et al.	BISE 2012	Call for papers	n/a
Dedrick	CAIS 2010	Research agenda	Green IT focuses on improving energy efficiency and equipment utilization through steps such as designing energy efficient chips, virtualization, reducing data center energy consumption, using renewable energy to power data centers, and reducing electronic waste (Watson et al., 2008). A broader scope, defined as Green IS by Watson et al. [2008], includes the use of information systems to enhance sustainability across the economy. This view includes improving efficiency in industries that are major sources of GHG emissions, such as the transportation, manufacturing, and energy sectors.
Hasan	AMCIS 2010	Theoretical discussion	n/a
Ijab at al.	PACIS 2010	Literature Review, conceptual model	Green IS can be defined as the inscription, enactment and/or realization of eco-sustainability values in the spirit, practice and impact of IS. This can be achieved through design and development activities during the pre-use stage of IS and the enactment of Green practices through the acquisition, diffusion and assimilation of IS at the use stage. In addition, the Greenness of IS can be realized as Green impacts during post-use evaluation.
Lei, Ngai	AMCIS 2012	Conceptual model	In this research study, Green IS is defined as the IS or IT used to achieve environmental sustainability (Jenkin, Webster & McShane, 2011).
Vazquez et al.	AMCIS 2011	Literature review	Green-IS refers to the design and implementation of information systems that contribute to sustainable businesses process. Green-IS encompasses the designs and implementation of information systems and ultimately serves as the broader mechanism, or umbrella, in terms of creating sustainability and awareness.

Table A-5: Definitions of Green IS, empirical studies, AISeL.

Author	Source	Method	Definition Green IS
Butler	ECIS 2011	Transcribed conference presentations	This paper conceptualizes a Green IS as constituting particular configurations of people, processes and Green IT.
Chen et al.	ICIS 2009	Survey, N=75, SEM	We differentiate between IS and IT, which contribute to the environmental issues differently. IT contributes to the problem (e.g., e-waste) and IS to the solution (e.g., routing optimization) (Boudreau et al. 2008; Watson et al. 2009). Boudreau and her colleagues argue that IT, which stores, transmits, or processes information, is too narrow a focus and attention should be extended to IS, which is defined as an integrated and cooperating set of people, processes, software, and information technologies to support individual, organizational, or social goals.
Fradley et al.	ICIS 2012	Single case study	In this paper, we conceptualize Green IS as emerging information and communication technology (ICT) innovations. We feel justified in doing so as, consistent with their definition, Green IS constitute novel initiatives that are "explicitly directed at a sustainability goal" (Blowfield and Visser, 2007).
Hedman, Hennings-son, Se-lander	ICIS 2012	Longitudinal single case study	We adopt the term Green IS, as defined by Watson et al. (2010, p. 24): "concerned with analyzing, designing, and implementing systems to increase the efficiency of energy demand and supply systems."
Ijab, Molla, Cooper	AMCIS 2012	Semi-structured interviews	We refer to Green IS as the use of IS and IT for "greening" organizations and for making them more sustainable.
Katchuk, Port	AMCIS 2011	Data center analysis	n/a
Kranz, Picot	ICIS 2012	Survey, N=708	As the term Green-IT typically solely focuses on technologies, scholars prefer the notion of "Green-IS" as used in this article. Researchers argue that beyond technology the term Green-IS also encompasses people, processes, and software (Melville 2010, Watson et al. 2010).
Loeser, Erek, Zarnekow	ICIS 2012	Multiple-case study	Green IS refer to the positive second-order impact (greening of business and production processes) and third-order impact (reduced environmental impact of the end product's lifecycle). Green IS (which includes Green IT) has a wider scope and encompasses all IS-based initiatives, allowing for a reduction of the environmental footprint of the entire organization.
Loock, Staake, Landwehr	ICIS 2011	Field study	The scope of the Green IS movement encompasses improvements in the eco-efficiency of business processes through automation, the development of more sustainable strategies with the help of decision support systems, and an overall improvement of environmental information flows in the organization, among others.
Nishant	PACIS 2012	Desk research	Green IS is conceptualized as comprising different dimensions of sustainability practices that can create competitive advantage for the organization. While green IT directly influences an organization's environmental footprint by reducing energy consumption and better utilization of computing resources, green IS, which is referred to as development of systems to support practices aimed at managing environmental footprint, influences organizations indirectly. We consider these two practices together as both of them are highly interrelated. We use the term "green IT" and green IS" interchangeably.