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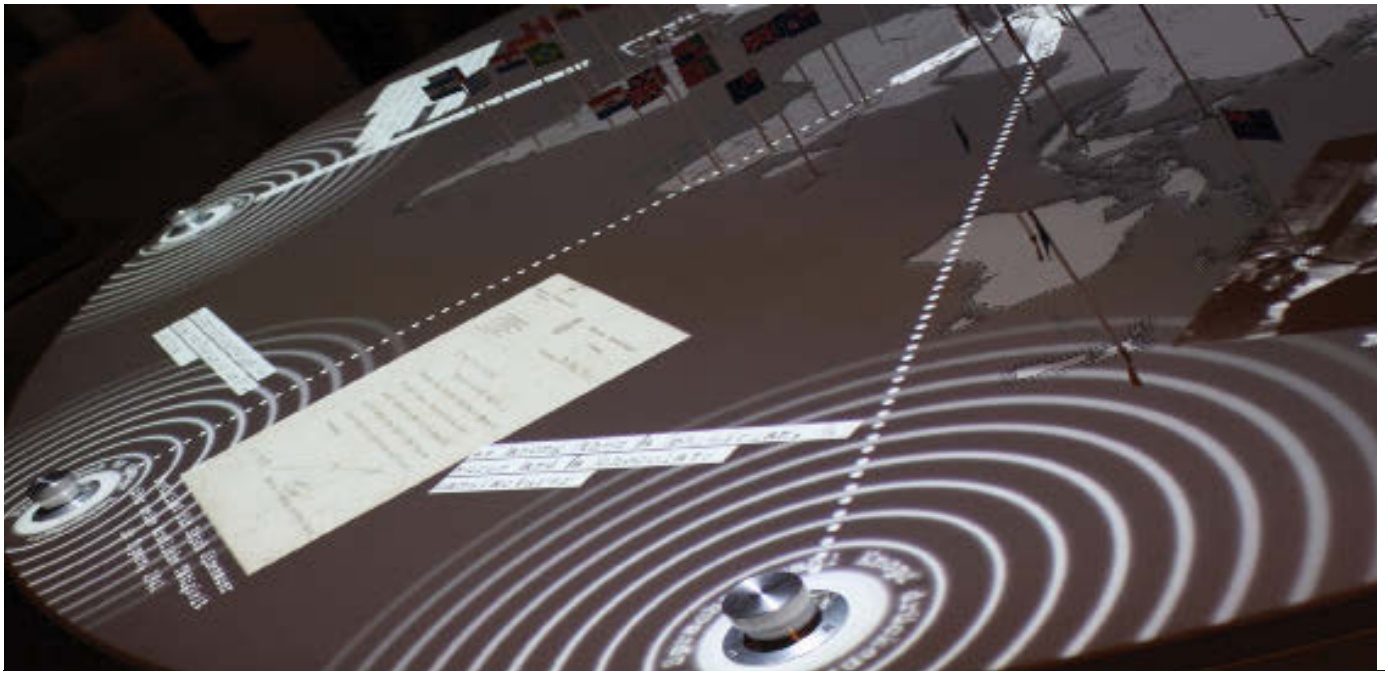
Fabian Löser

Strategic Information Systems Management for Environmental Sustainability

Enhancing Firm Competitiveness with Green IS



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"A new type of thinking is essential
if mankind is to survive
and move to higher levels."

– Albert Einstein (1946, p. 7)

Abstract

During the last three decades, information and communication technologies have fundamentally changed the way we work, live and communicate. The ubiquity of internet services, which become increasingly interactive and complex, together with enhanced connectivity, facilitated by innovative mobile devices, induces an ever-rising demand for computing, storage and data transmission capacities. Today, information systems (IS) constitute the backbone of the globalized economy and are indispensable for modern business and production processes. At the same time, environmental sustainability has evolved as the most pressing societal challenge of the 21st century, in particular due to the looming threats of climate change. By virtue of their global influence and reach, business companies significantly contribute to the creation of environmental problems, but owing to their organizational knowledge, capabilities and resources, they also have the capacity and ability to play a key role in shaping the path towards a more sustainable development. The companies leading the way have noticed that corporate sustainability is not necessarily a burden that negatively impacts their bottom line. If strategically managed, environmental product and process innovations can decrease operational costs, enhance corporate reputation, and differentiate from competitors.

With regard to environmental sustainability, IS play a contradictory role: on the one hand, the manufacturing, operation and disposal of information technology (IT) infrastructure are responsible for serious environmental impacts: from the mining of conflict minerals to carbon dioxide emissions that equal those of the airline industry to enormous amounts of toxic e-waste. On the other hand, IS are perceived as key enablers of a "green" economy: environmental management systems and the reengineering of business processes can substantially reduce the environmental impacts of business organizations, while technological innovations provide opportunities to decrease the ecological footprint of end-user products and services.

Many organizations have started to implement first environmental measures to decrease IT energy consumption and to reduce operational costs, mostly in an unstructured and uncoordinated manner though. Although Green IS practices feature a considerable potential to increase corporate environmentalism while creating promising business opportunities, the adoption of enterprise-wide cross-functional initiatives aimed at implementing Green IS has been rather slow. Economic uncertainties regarding the long-term effects of Green IS adoption and the lack of appropriate management frameworks have been identified as main inhibitors of an encompassing implementation of Green IS initiatives throughout the enterprise.

In this context, this thesis addresses relevant research gaps, contributes to theory development in the evolving Green IS research discipline, develops practice-oriented management frameworks, and emphasizes the importance of following a strategic approach to leverage the competitive potential of Green IS. This cumulative thesis comprises an introduction that includes a literature review and a pre-study, four theory-based conceptual research articles, and two empirical studies, one of them building on qualitative, exploratory case study research whereas the other relies on quantitative data which has been analyzed with structural equation modeling.

This thesis targets four specific research goals to advance theory-building in Green IS research and to promote the adoption of Green IS in practice. First, this thesis clarifies and defines the central terms and key concepts *Green IT*, *Green IS*, *Green IS strategy*, and *Green IS practices* drawing on a transdisciplinary research approach. Second, the most important challenges and inhibitors of Green IS adoption are identified and characterized. In particular, the lack of management frameworks, which encourage a holistic implementation that follows a strategic rationale, the complexity of strategic Green IS alignment, the multi-dimensional performance impacts of cross-functional initiatives and, above all, the uncertainty relating to the business case of Green IS practices, are identified as the most pressing challenges. Third, current actions of business firms to address these challenges are examined. Building on exploratory case study research, distinctive Green IS strategies are identified in managerial practice. Most notably, the empirical insights from quantitative survey research suggest a positive relationship between Green IS adoption and firm competitiveness, thus decreasing the economic uncertainty which inhibits the implementation of far-reaching environmental initiatives. Fourth, practice-oriented management frameworks are developed. The fine-grained Green IS strategy concept advises the formulation of strategies addressing the corporate, competitive, and functional management level. The proposed typology of four Green IS strategies illustrates distinct strategic options, from which executives can choose under consideration of their competitive targets and the firm-specific context. To allow for consistency of Green IS strategies, the presented alignment framework facilitates coherence with economic and environmental corporate goals. Furthermore, the actors, roles and responsibilities relevant to the alignment process are described. In addition, a management framework for the holistic adoption of Green IS, which specifies decisive management areas and distinguishes between three degrees of environmental impacts, is presented along with a comprehensive catalogue of Green IS implementation measures. As a consequence, this research offers both empirical insights and conceptual models to advance the adoption of Green IS initiatives, thus meeting the challenges of climate change and turning corporate sustainability into a business opportunity.

Acknowledgements

Although my personal interest in technological innovations and strategic management, in conjunction with my intuition to preserve this wonderful planet and its nature for future generations, formed a robust intrinsic motivation and made me enjoy exploring this research area during the last four years, the journey into the depth of Green IS research not always resembled a straightforward, paved highway, but sometimes led to winding paths, difficult and steep, which I could not have climbed without the support of my colleagues, family, and friends. First and foremost, I would like to thank my dearly beloved partner An-Sofie, who encouraged me to follow the chosen direction, who stood at my side even in the hardest of times, who shed light on the path, and who gave me the strength to reach the envisioned goal. I would like to thank my family for bringing me up in a way that made me who I am and for their enduring support. I also would like to thank my friends for the controversial discussions as well as their encouragement.

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Thank you all – and may the results of this dissertation be a tribute to your support!

Fabian Löser
Berlin, February 2015

Table of Contents

List of Abbreviations

AISeL	AIS electronic Library
AJIS	Australasian Journal of Information Systems
AMCIS	Americas Conference on Information Systems
AVE	Average Variance Explained
BAO	Belief-Action-Outcome
BISE	Business and Information Systems Engineering
BPM	Business Process Management
BSC	Balanced Scorecard
BVIS	Business Value of Information Systems
CAIS	Communications of the Association for Information Systems
CBS	Comparative Business Scorecard
CEO	Chief Executive Officer
CFA	Confirmatory Factor Analysis
CIO	Chief Information Officer
CMS	Carbon Management Systems
CO_2	Carbon Dioxide
CPMP	Cambridge Performance Measurement Process
CPMS	Consistent Performance Measurement System
CRAC	Computer Room Air Conditioning
CSO	Chief Sustainability Officer
CSR	Corporate Social Responsibility
DPMS	Dynamic Performance Measurement System
ECIS	European Conference of Information Systems
EMS	Environmental Management System

EMIS	Environmental Management Information Systems
EPA	Environmental Protection Agency
EPEAT	Electronic Product Environmental Assessment Tool
ERP	Enterprise Resource Planning
E-waste	Electronic waste
GCSM	Global Conference on Sustainable Manufacturing
GHG	Greenhouse Gas
GoF	Goodness-Of-Fit
HICSS	Hawaii International Conference on Systems Sciences
ICIS	International Conference on Information Systems
ICT	Information and Communication Technologies
IIM	Integrated Information Management
IPMS	Integrated Performance Measurement System
IS	Information Systems
ISF	Information Systems Frontiers
ISJ	Information Systems Journal
ISS	Information Systems Strategy
IT	Information Technology
IT-BSC	Information Technology Balanced Scorecard
KBV	Knowledge-Based View
KPI	Key Performance Indicator
LCA	Lifecycle Analysis
Mgmt.	Management
MIS	Management Information Systems
MISQ	Management Information Systems Quarterly
NRBV	Natural Resource-Based View

PACIS	Pacific Asia Conference on Information Systems
PLS	Partial Least Squares
PMS	Performance Measurement System
R&D	Research and Development
R&DM	Results & Determinants Matrix
RBV	Resource-Based View
RoHS	Restriction of Hazardous Substances
ROI	Return on Investment
RQ	Research Question
SAM	Strategic Alignment Model
SBSC	Sustainability Balanced Scorecard
SEM	Structural Equation Modeling
SGISAF	Strategic Green IS Alignment Framework
SIS	Strategic Information Systems
SISP	Strategic Information Systems Planning
SMART	Strategic Measurement Analysis and Reporting Technique
SSM	Sustainable Strategic Management
SWOT	Strengths, Weaknesses, Opportunities and Threats
Tonne	Also: metric ton; equals 1,000 kilogram
UPS	Uninterruptable Power Supply
VIF	Variance Inflation Factor
VRIN	Valuable, Rare, Imperfectly imitable, Non-substitutable
WEEE	Waste Electrical and Electronic Equipment

A. INTRODUCTION

1. Research Foundations

1.1 Research motivation

Information and Communication Technologies (ICT), such as personal computers, tablets and smartphones, together with the continuously increasing significance of the internet in the last two decades, have fundamentally transformed the way we live, work and communicate (Murugesan & Laplante, 2011). In particular, today's global companies rely on business processes which build on the functionalities of complex enterprise application architectures, operational transaction processing systems and management information systems as well as high-level decision-support systems. ICT enhance the efficiency of the industrial production and the internet gives rise to new business models, both of which contribute significantly to recent economic growth, especially in mature economies (McKinsey, 2011; Laudon & Laudon, 2014). Obviously, ICT have fueled the globalization of business, enabled a new type of digital economy, and led to a modern information and knowledge society.

At the same time, environmental sustainability has entered the political agenda in many countries as an urgent issue, above all because of the looming threats of climate change. Business companies have been identified as major drivers of environmental deterioration, but at the same time, due to their knowledge, resources and capabilities as well as their global influence, they have the leverage to induce fundamental changes for a development towards a more sustainable economy and society (Elliot, 2013). Corporate sustainability can make good business sense due to various organizational motivations to "go green", such as compliance with current and future laws and regulations, increasing pressure and claims from internal and external stakeholders, corporate citizenship and reputation. Apart from external pressures, the new sustainability paradigm also offers attractive business opportunities: the superior efficiency of internal processes can result in operational cost savings, and environmental product innovations can

> *"Business as usual is dead – green growth is the answer to both our climate and economic problems."*
>
> – Anders Fogh Rasmussen, Former Prime Minister of Denmark (in: vom Brocke *et al.*, 2013a, p. 296)

create new markets and enhance revenues (Michaud & Llerena, 2010; Curry & Donnellan, 2012; Corbett, 2013).

Lubin & Esty (2010, p. 45) argue that "sustainability is an emerging business megatrend, like electrification and mass production, that will profoundly affect companies' competitiveness and even their survival." Technology-driven sustainability innovations will fundamentally alter business models and production systems, thus influencing the competitiveness of business firms and rendering corporate sustainability a major strategic issue (Lubin & Esty, 2010; Chen, 2011). A recent Chief Executive Officer (CEO) survey indicates that 70 percent of leading executives perceive environmental sustainability as a significant business issue. In this context, 40 percent of the respondents state that sustainability is even considered as core strategic issue which is permanently placed on the top management agenda (Kiron *et al.*, 2013a). However, most executives are still missing a long-term vision and do not rely on a holistic, technology-enabled sustainability strategy. They rather limit their efforts to implementing unstructured environmental initiatives without following a strategic rationale (Lubin & Esty, 2010). Lacking knowledge of how to appropriately respond to future sustainability challenges as well as prevailing uncertainties with regard to the economic long-term impact of environmental initiatives are seen as inhibitors to substantial actions of business firms (Elliot, 2013).

DeGarmo *et al.* (2011) argue that corporate sustainability is, above all, an information challenge: new environmental performance dimensions must be integrated into measurement systems to facilitate transparency, thus enabling responsible decision-making and accountability towards internal and external stakeholders. Environmental impacts can be tracked with the help of information systems to provide reliable information concerning the environmental footprint of products and services to potential customers, thus enhancing transparency and allowing for premium prices based on superior ecological characteristics.

> *"Technology is accelerating the use of sustainability as a driver of growth, particularly information technology, as it allows greater monitoring, independent verification, transparency, and accuracy of resource usage and its impact."*
>
> – Alan McGill, PwC (in: DeGarmo *et al.*, 2011, p. 14)

According to Shrivastava (1995a, p. 183), "environmental technologies offer a new substantive orientation and a management process for minimizing ecological impacts of economic production while enhancing competitiveness of firms." In line with this, Watson *et al.* (2008) emphasize that information systems (IS) are predestinated to enable the transition towards a more sustainable economy with

resource-efficient business and production processes and innovative environmentally-friendly products.

If corporate sustainability is consistently embedded in organizational processes and properly integrated into management systems with the aid of advanced IS, innovation and economic growth can result. However, to achieve a competitive differentiation, a strategic rationale for investing in IS-enabled environmental initiatives and leveraging their cross-functional potential throughout the entire organization is required. For that reason, this thesis offers research insights and practice-oriented management frameworks to allow for a strategic implementation and holistic adoption of Green IS.

1.2 Fundamental concepts: Green IT and Green IS

To assure a well-grounded understanding of the introductory chapter of this thesis, the most fundamental concepts are briefly described in this section. These concepts build on an extensive review of relevant literature and are being discussed in detail in Part B, Section 6, of this thesis.

First of all, 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.*, 2010b, 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 & Weill, 1997; Ravichandran & Lertwongsatien, 2005).

To facilitate a deeper understanding of the environmental impacts of IS, this thesis builds on a differentiation between three degrees of IS environmental impact (referring to Berkhout & Hertin, 2001; Hilty *et al.*, 2006; Mingay & Di Maio, 2007).

The *first-degree* impact refers to the negative direct environmental effects of information technology (IT), including (Murugesan, 2008):

- the resource requirements of manufacturing IT equipment, such as desktop computers, notebooks, servers, printers or network devices,
- the power consumption to run the IT equipment during the use phase, and
- the electronic waste, which is generated during the disposal of outdated IT equipment.

The *second-degree* environmental impact refers to the potential of IS to decrease energy and resource consumption as well as the reduction of waste with regard to internal processes of the enterprise, with the aid of (El-Gayar & Fritz, 2006; vom Brocke & Rosemann, 2010):

- reengineering of business and production processes resulting in superior resource efficiency,
- IS-based environmental management information systems (EMIS), which allow to track, analyze and optimize firm-wide resource flows, and
- environmental management systems (EMS), which monitor corporate waste and emissions, thus assuring regulatory compliance and facilitating transparency concerning the environmental footprint towards external stakeholders.

The *third-degree* environmental impact refers to the potential of IS to decrease the ecological footprint of end-products and services, for example through (GeSI, 2008):

- IS-enabled building automation, which allows for an integrated management of light, heating and cooling systems,
- smart grid technologies, which facilitate the dynamic management and balancing of a varying electricity demand and supply of regenerative energy,
- fuel-saving car technologies, which rely on intelligent engine control units, or
- dematerialization initiatives, which allow for a substitution of physical products through digital services, such as music-streams or e-books.

These three IS environmental impacts differ from industry to industry, as displayed in Figure 1.

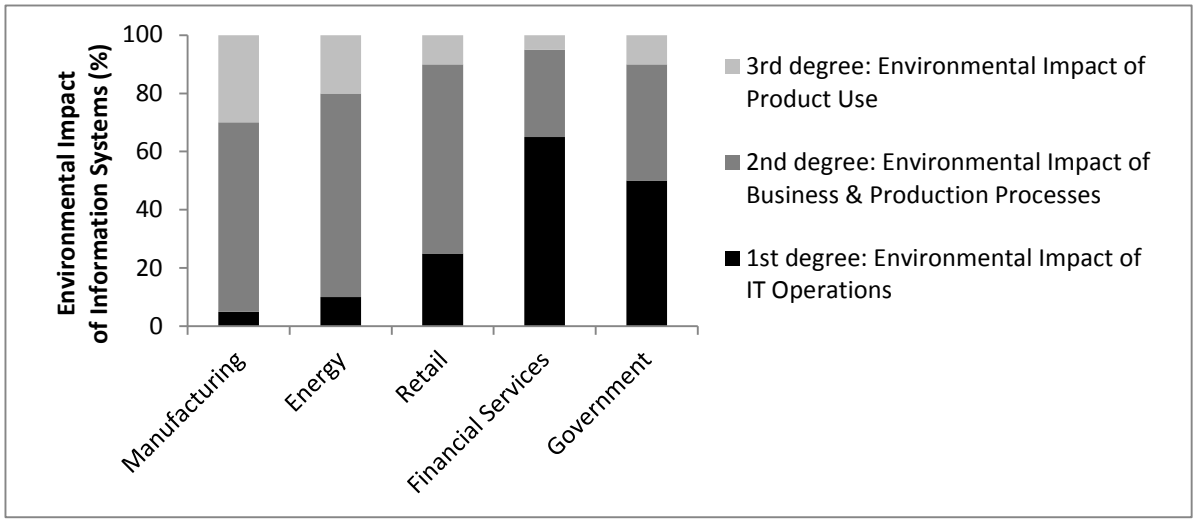

Figure 1: Three degrees of IS environmental impact by industry sector (Source: Mingay & Di Maio, 2007, p. 3).

In manufacturing industries, for example, the environmental impact of a company's IT infrastructure is comparatively low due to the resource-intense production processes, which lead to a large environmental footprint. The negative environmental impacts which relate to the use phase of end-user products are also high. Accordingly, IS are predestined to reduce the footprint of such companies through the reengineering of internal processes and to drive product innovations that decrease the environmental impact throughout the entire product lifecycle.

For a company from the financial services industry (e.g., a bank) the situation differs significantly. Here, the direct IT environmental impact represents a large share of the organizational footprint due to the fact that most of its business processes rely on IS. The second-degree impact, by contrast, is comparatively low because a bank does not manufacture any physical goods and thus does not consume large amounts of energy and raw materials. Similarly, end-user services, such as money transfers, do not have significant environmental impacts. As a consequence, a financial services company has a substantial interest to execute its business processes on a highly resource efficient IT infrastructure to reduce its organizational footprint (Mingay & Di Maio, 2007).

These two examples elucidate that the strategic management of IS for environmental sustainability necessitates adequate solutions which may differ considerably from firm to firm and from industry to industry. For this reason, the differentiation between three degrees of IS environmental impact is central to this thesis for deriving detailed, practice-relevant research findings.

The first-degree environmental impact, which is described in detail in section 2.1, is usually addressed through the concept of *Green IT* (Dedrick, 2010), which is, in the scope of this thesis, defined as follows:

> *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 more far-reaching concept of *Green IS*, which also comprises the positive second- and third-degree IS environmental impacts (Watson *et al.*, 2010), as described in section 2.2, is defined as follows:

> *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.*

1.3 Research goals

Although the potential of Green IS for making business operations more sustainable is promising, only few academic studies build on empirical data because this research area is still in its infancy (Melville, 2010; Jain *et al.*, 2011). Accordingly, until now, conceptual models and theoretical discussions are prevailing while empirical evidence is rare. In addition, practice-oriented management frameworks that guide the planning and implementation processes of Green IS are missing (Molla *et al.*, 2011; Mohan *et al.*, 2012). As a consequence, IS executives are hesitant in their responses to the challenges of environmental sustainability. They face considerable uncertainties with regard to the profitability of sustainability investments and how IS can be managed strategically to leverage their potential in enabling product and process innovations (Corbett, 2013; Elliot, 2013).

In this context, Dedrick (2010) emphasizes the significance of the evolving Green IS research stream. This field addresses a new managerial key issue of IS executives, who are requested to reduce the environmental impacts of the IT infrastructure and to provide IS-enabled solutions that decrease the environmental footprint of the organization while delivering economic business value (Chen *et al.*, 2008; Elliot & Binney, 2008; Murugesan, 2008; Watson *et al.*, 2008; Corbett, 2010).

Apart from improving environmental sustainability, realizing the potential of IS to enhance firm competitiveness remains a major challenge for both business executives and academics (Melville *et al.*, 2004; Schryen, 2013). While IT infrastructure resources exhibit the characteristics of a commodity and do not enhance competitiveness per se (Carr, 2003), IS management capabilities, which are associated with strategic alignment and support of core business processes, are unique and have the potential to create competitive advantages (Rivard *et al.*, 2006). In this context, the formulation of appropriate IS strategies and the strategic alignment of those strategies with the business have been the dominant concern of IS executives for more than a decade (Luftman & Derksen, 2012). Corporate sustainability now adds a third dimension to the strategic IS/business alignment process, thus further increasing its complexity. Obviously, this induces a necessity to investigate the strategic potential of Green IS, making it a relevant question in IS research with a substantial significance for management practice.

In the scope of this thesis, practice-oriented research, which both conceptually and empirically assesses the environmental and competitive potential of Green IS and related management capabilities, addresses this topic. The objective of this research is to add to the theoretical body of knowledge, to provide empirical insights being relevant to both scholars and practitioners, and to develop management frameworks that advance the environmental sustainability of organizations. Drawing on a

classification scheme of Elliot (2011, p. 229) for Green IS research which is meaningful to business executives, four specific research goals are defined for this thesis:

Research Goal 1: ***Terminology***. *Clarify and define central terms and key concepts to add to the theoretical body of knowledge and to advance the Green IS research discipline.*

Research Goal 2: ***Challenges arising***. *Locate economic uncertainties and holistically analyze the impacts of Green IS on the environment. Investigate possible application areas of Green IS and assess related business opportunities.*

Research Goal 3: ***Current responses***. *Understand cause-and-effect relationships between stakeholders, companies, executives, and environmental actions to determine the role of Green IS in this context. Evaluate the business impacts of Green IS adoption to decrease economic uncertainties which inhibit the transformation towards a more sustainable economy.*

Research Goal 4: ***Future actions***. *Give guidance for the development of critical resources and capabilities to appropriately address challenges of environmental sustainability, turning them into opportunities that enhance ecological and economic value creation. Develop managerial frameworks for strategy formulation and identify possible Green IS measures and initiatives for their implementation.*

1.4 Research process and structure of the thesis

This thesis follows the structured research process of Österle *et al.* (1992), which consist of eight specific steps, as displayed in Figure 2.

Step 1: The research is motivated by the existence of a problem or new challenge in management practice. As described in Section 1.1, the shift towards a new type of corporate management, which integrates aspects of environmental sustainability, results in both challenges and opportunities while confronting executives with high levels of uncertainty. Section 2 explains in detail why IS are perceived as enablers of a sustainable economy while also exhibiting serious environmental impacts. Reducing these impacts while leveraging IS for enabling a sustainability-oriented transformation of organizations is delineated as a new challenge and leadership

opportunity for CIOs. Section 3 presents the results of a pre-study, which illustrates the current status quo of Green IT and Green IS in German companies. These empirical insights provide a basis for the following research by illustrating what has been done already by organizations to go green while identifying issues which inhibit a holistic implementation of Green IS to enhance resource efficiency throughout the entire company.

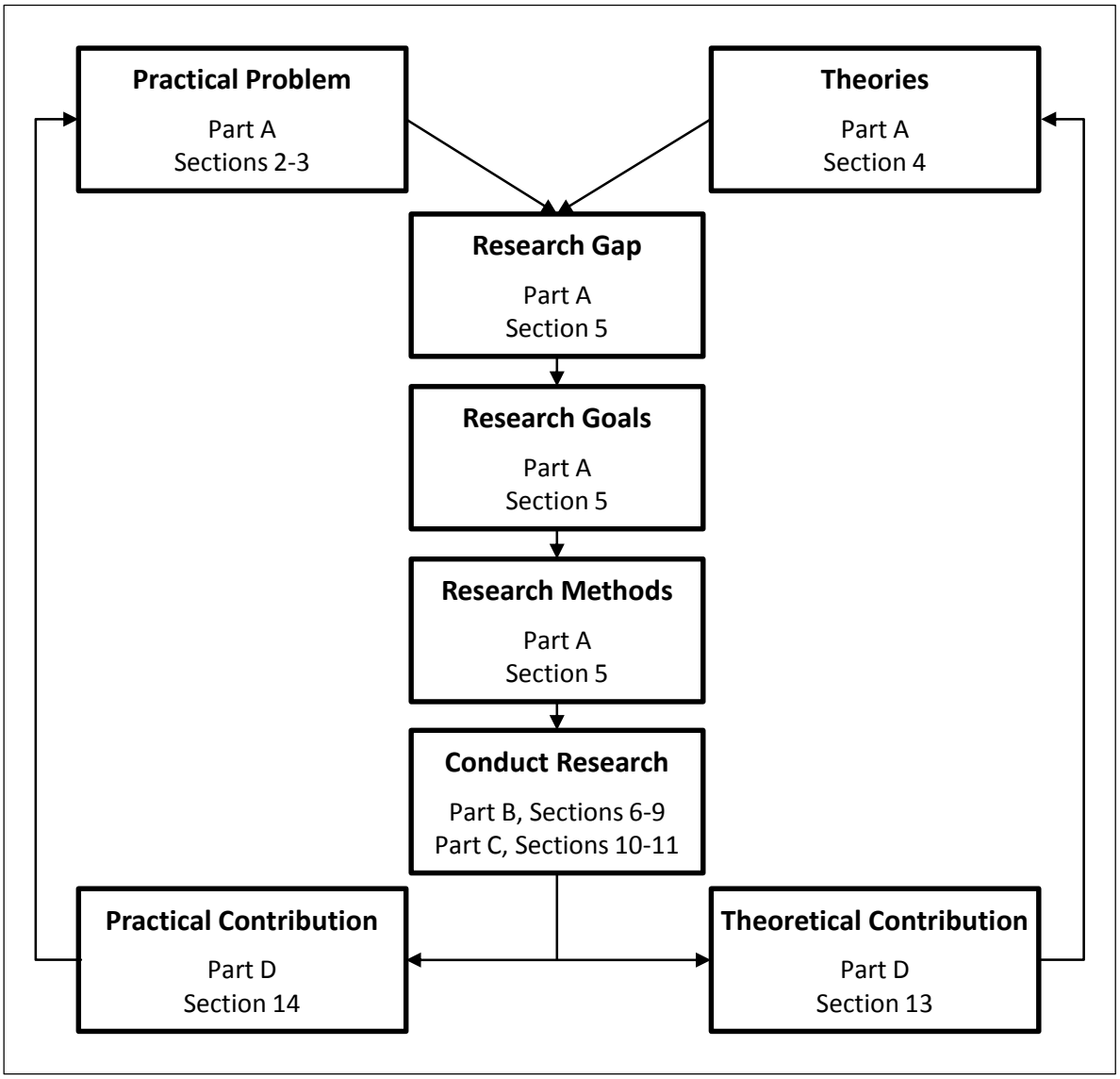

Figure 2: Research Process of this thesis (adopted from Österle et al., 1992).

Step 2: Next, related research in relevant areas has to be evaluated and the prevalent theories and concepts, which can be used to study the subject area, have to be identified. This is done in Section 4, where fundamental theories are introduced, followed by reviewing the current state of Strategic Information Systems Research, Corporate Sustainability in Management Research, and Environmental Sustainability in IS Research.

Step 3: Based on the research requirements referring to the identified practical problem and in conjunction with the current state of management and IS research, specific research gaps are identified and mapped to the four research goals in Section 5.1.

Step 4: The identified research gaps are matched with the four research goals of this thesis in Section 5.1. Furthermore, details concerning how specific research questions are addressed in the scope of six international conference and journal publications, which are at the heart of this thesis, are provided.

Step 5: To address the relevant research gaps, appropriate research methods have to be selected. The characteristics of this research are described in Section 5.2 and the established methods, which were applied to achieve the envisioned research goals, are presented in Section 5.3.

The first five steps of the research process constitute Part A of this thesis, as illustrated in Figure 3.

Step 6: Next, the actual research has to be conducted to address the research gaps and to achieve the research goals. Section 5.4 provides an overview of the six research articles constituting the main body of this thesis. In particular, the conducted research is classified according to two fundamentally different research principles. As illustrated in Figure 3, four articles are classified as theory-based conceptual research and are presented in Part B of this thesis. These articles are complemented by two empirical studies that can be found in Part C. One of these articles draws on design-oriented exploratory case study research whereas the other builds on quantitative data being analyzed with structural equation modeling.

Step 7: The academic research findings that have been derived from this conceptual and empirical research are consolidated in Section12, thus closing the research gaps which were identified in Part A. In addition, Section 13 highlights the theoretical contributions and points out how this research adds to the body of knowledge of the evolving Green IS research discipline.

Step 8: Based on the research findings, management implications are derived in Section 1. In particular, this section illustrates how the empirical insights shed light on the practical problem, which was delineated in part A of this work, and how current and future challenges can be addressed with the management-oriented frameworks that were developed in this thesis. The limitations of this thesis and areas of further research are described in Section 1. Finally, Section 1 ends this thesis with concluding statements that reveal how the four high-level research goals were achieved in the scope of this thesis.

The last two steps, in conjunction with the limitations of this research and the identification of future research areas, constitute Part D of this thesis, as illustrated in Figure 3.

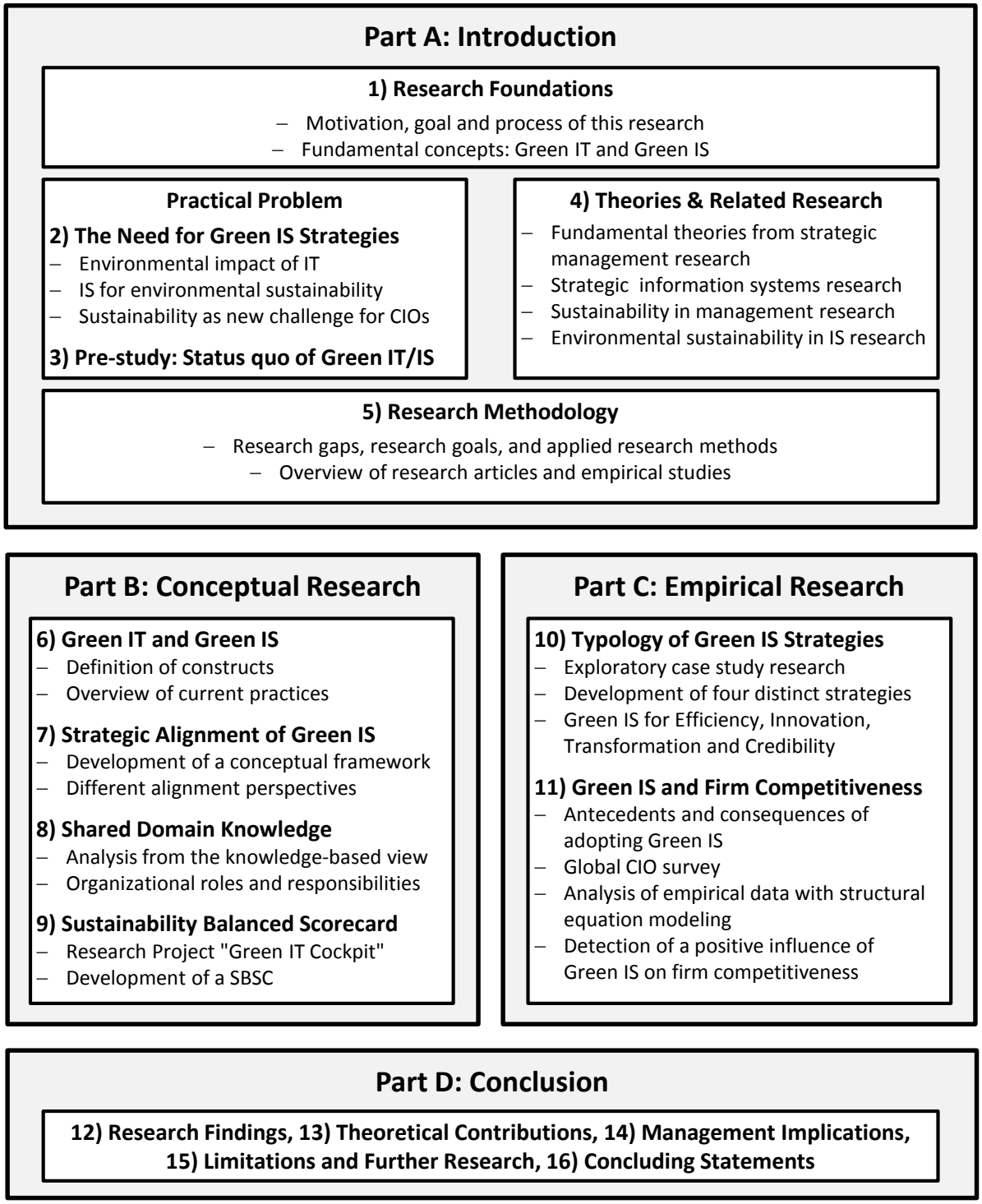

Figure 3: Structure of this thesis.

2. The Need for Green IS Strategies

2.1 The environmental impact of information technology

The first wave of IT-related environmental measures focused on enhancing the efficiency of IT infrastructures, in particular in data centers, due to rapidly rising energy costs and related carbon dioxide emissions (Harmon & Demirkan, 2011). Academic research, public institutions as well as private business organizations started to address the environmental impact of IT under the headline of Green IT in 2008 (Loos *et al.*, 2011). An often-cited study of Gartner had revealed that IT, due to the consumption of electrical energy during its operations, is responsible for approximately 2 percent of worldwide carbon dioxide (CO2) emissions, an amount comparable to that of the airline industry (Mingay, 2007). CO2 is one of the greenhouse gases (GHG) which are driving one of the most pressing sustainability threats: global climate change. IT, which was previously perceived as a clean technology, suddenly lost its ecological innocence (Murugesan, 2008). The fact that the individual and organizational IT penetration was quickly gaining momentum due to intensifying use of the internet and social media, resulting in continuously increasing demands for computational power, data storage and transfer capacities, called for quick responses from the IT industry (Harmon & Auseklis, 2009). Academics from IS research started to analyze the environmental impacts of IT, differentiating between manufacturing, operations and disposal of IT infrastructure (Murugesan, 2008; Molla *et al.*, 2009b).

The production of IT hardware, such as displays, desktop computers, servers, hard drives, network devices, and smartphones, requires large amounts of raw materials, many of which are toxic or scarce natural resources. Interestingly, in the 1980s, a microprocessor was produced with 12 chemical elements whereas today's modern processors require around 60 elements – more than half of all existing elements on earth. Examples are antimony and niobium (used for micro capacitors), palladium (relays), indium (LC displays), gallium (LED displays), neodymium and tantal (mobile phones) (Schatten, 2011). Due to the frequent replacement of modern IT equipment, the worldwide market is huge: in 2013, spending on IT devices reached 669 billion USD while 140 billion USD were invested in data center systems (Gartner, 2014). With regard to IT spending per employee, insurance companies exhibit the highest IT spending levels, followed by banks, the media and entertainment industry, utilities, public institutions, software and internet

The ever-increasing utilization of web applications, mobile devices and cloud services results in a continuously growing demand for computing and storage capacities.

companies, telecommunications and energy (Gartner, 2011). In total, an estimated 65.1 million tonnes of electrical and electronic equipment were sold worldwide in 2012, implying an enormous consumption of raw materials (StEP, 2012).

At first glance, the daily use of IT seems to have no environmental impacts since these devices do not directly produce harmful emissions. However, the electrical energy which is necessary to power these systems entails substantial CO2 impacts (Murugesan, 2008). With around one quarter, the biggest share of total CO2 emissions caused by human activities stems from the power sector (GeSI, 2008).

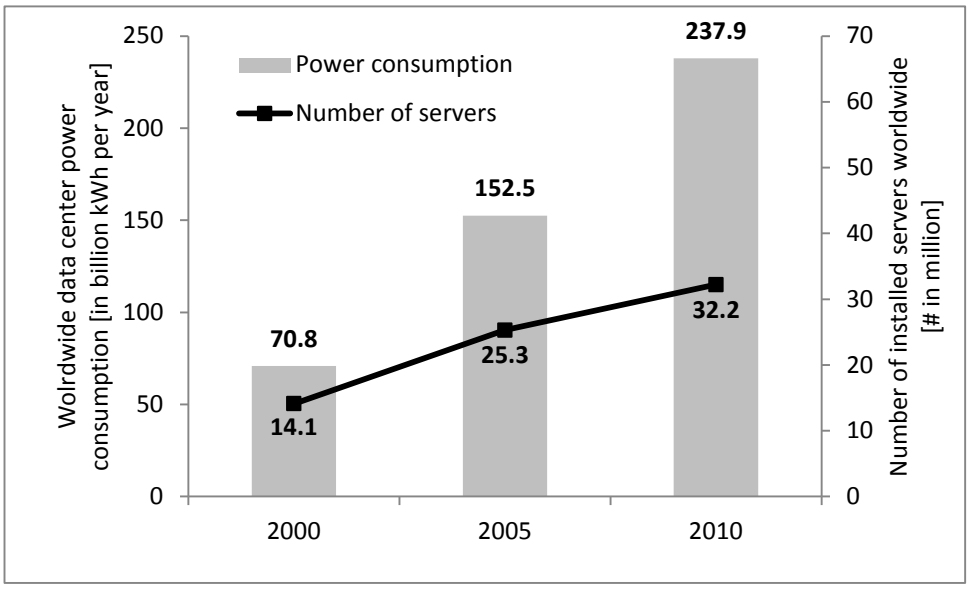

Figure 4: Data center electricity use and number of servers worldwide (Source: Koomey, 2011).

Between the years 2000 to 2005, the energy consumption of data centers worldwide increased by 115 percent (see Figure 4). The staggering growth of data center capacity demands, coming along with increasing levels of energy consumption, resulted in various Green IT initiatives, which aim at increasing data center energy efficiency and decreasing operational costs. These initiatives were rapidly adopted in the last years and slowed down the quick growth of data center power consumption. Although recent internet streaming and cloud services as well as social media platforms demand for continuously increasing data center capacities, the number of servers has only risen by 27 percent from 2005 to 2010 whereas the computational power and storage capacities increased significantly (Dedrick, 2010). This was possible due to Green IT measures which gave rise to improved server utilization rates, innovative cooling techniques and a new generation of microprocessors (Murugesan, 2008). As a result, a moderate 56 percent growth of data center power consumption could be observed from 2005 to 2010 (Koomey, 2011). Today, data centers are accountable for approximately 1.3 percent of global electricity consumption – which corresponds to 271 billion kWh annually. According to the

Environmental Protection Agency (EPA), data centers in the US are responsible for an energy bill of more than 50 billion USD annually – which makes the implementation of energy efficiency initiatives financially attractive (Karanasios, 2010).

As previously mentioned, IT devices contain a wide range of chemical elements, many of which are toxic if they are not properly treated when the equipment is recycled or disposed (Ruth, 2009). In particular, the heavy metals lead, mercury, arsenic, chromium, cadmium as well as contaminants such as beryllium or brominated flame retardants can seriously threaten the physical health of human beings. In developed countries, various conventions and laws regulate the correct treatment of electronic waste (e-waste). Examples are the Restriction of Hazardous Substances (RoHS) Directive, which sets strict specifications for the utilized raw materials in the process of manufacturing IT equipment, and the Waste Electrical and Electronic Equipment (WEEE) Directive, which regulates the collection and recycling of IT hardware as well as e-waste taking back obligations for IT manufacturers. Both directives became law in the European Union in 2003 and similar regulations have been adopted in the US, Japan, Korea, Australia and Canada recently (Butler & Daly, 2009; Lee & Kim, 2011). However, to circumvent these cost-intensive treatments, substantial amounts of e-waste are illegally shipped to under-regulated developing countries, for example to China, India, Pakistan or Nigeria (Sthiannopkao & Wong, 2013). In 2012, 46 million tonnes of e-waste were generated worldwide – and this volume is supposed to increase by approximately 10 percent per year (StEP, 2012; Lei & Ngai, 2013).

2 % of worldwide CO2 emissions, 32 million servers, consuming 237 billion kWh per year and 46 million tonnes of e-waste indicate that ICT have a substantial environmental impact.

To show their commitment towards environmental sustainability and to differentiate their products from those of competitors, IT manufacturers have started to adhere to voluntary normative standards, thus demonstrating the energy efficiency of their newest products. The most prevalent label in this context is the Energy Star, introduced by the EPA in 1992 (Ruth, 2009). In its current version 5.0, the Energy Star label evaluates the power consumption of IT hardware and has induced a reduction of more than 40 million tonnes of CO2 emissions (Butler & Daly, 2009). Another widespread label is TCO, which is more far-reaching than Energy Star and assesses the entire lifecycle of IT equipment. The Electronic Product Environmental Assessment Tool (EPEAT) assists organizations in comparing the environmental characteristics of IT hardware. The tool also supports

a selection process for purchasing environmentally-friendly equipment (Murugesan, 2008).

Analyzing these IT-related environmental first-degree impacts from an organizational perspective, the management of IT in an environmentally favorable manner requires a holistic approach along the lifecycle of IT, including the sourcing of IT infrastructure, which should have been manufactured with a minimum of (toxic) raw materials, operating the organization-wide IT infrastructure (in data centers and the office environment) in an energy-efficient way, and responsibly managing the end of the lifecycle of outdated IT equipment. These issues are addressed by the management concept of Green IT. With regard to the design of IT hardware, a strong focus on energy efficiency could recently be observed: multicore processors, advanced integration of further functionalities on one chip, solid state disks and highly efficient power supplies have significantly reduced the energy consumption of desktop and server computers. Concerning IT operations in organizations, most Green IT measures focus on making data centers more energy efficient. Green IT initiatives, such as server consolidation and virtualization, intelligent power management functions, dynamically adjustable cooling, separation of hot and cold air flows, and optimized uninterruptable power supplies (USPs), can significantly decrease data center power consumption. In office environments, thin clients, mobile instead of desktop computers, power management software, LED displays and multifunction printers are common measures. The end-of-IT-life can be managed by refurbishing, reusing and recycling outdated hardware (Murugesan, 2008). An extensive list of Green IT initiatives can be found in Appendix C, Table 44.

> *"IT now has a new role to play – helping create a greener, more sustainable environment while offering economic benefits."*
>
> – Murugesan & Laplante, 2011, p. 17

Because most of these Green IT initiatives reduce the energy consumption of IT operations, they are also financially rewarding, especially in times of continuously rising energy prices (Murugesan *et al.*, 2013). The *first wave* of Green IT thus describes the implementation of numerous efficiency-focused, mostly profitable measures by a wide range of companies (Harmon & Demirkan, 2011).

2.2 Information systems for environmental sustainability

Whereas the *first wave* of Green IT aims at a reduction of IT-related negative environmental impacts, thus addressing the 2 percent of IT-induced worldwide CO_2 emissions, the *second wave* of Green IS is focused on IS-enabled product and process innovations and solutions (Elliot, 2011; Harmon & Demirkan, 2011). These environmental initiatives, also called environmentally sustainable ICT, Greening by

IT, IT-for-Green, or Green-through-IT (Loos *et al.*, 2011; Nedbal *et al.*, 2011) address the remaining 98 percent of CO2 emissions as well as other corporate waste and emissions (Curry & Donnellan, 2012). Although IT-related emissions will most probably rise due to the increasing ICT penetration in modern societies (Dedrick, 2010), Green IS will provide important solutions to tackle climate change and future sustainability challenges by transforming infrastructure technologies and entire industry sectors such as transport, manufacturing, or energy (GeSI, 2008).

Green IS initiatives can drive environmental sustainability and economic growth since they assist organizations in maturing: from sustainability as an obligation to regulatory compliance to resource efficiency to market leadership (DeGarmo *et al.*, 2011). Information systems provide the necessary information and tools to embed environmental sustainability into operations and decision-making processes throughout companies and entire supply chains. By making impacts measurable and visible, transparency towards customers and stakeholders creates value for the organization, e.g., through price premiums or intangible assets such as corporate reputation (Harmon & Auseklis, 2009; Watson *et al.*, 2010).

> *"The second wave will encompass the adoption of ecological strategies that will redefine markets, spur technological innovation, and lead to shifts in process, behavior and organizational culture that will integrate business models with environmental responsibility."*
>
> – Harmon & Auseklis, 2009, p. 1707

To understand how Green IS can enhance environmental sustainability throughout organizations, the concept of *environmental technologies*, stemming from Strategic Management Research, is of great value for theoretically grounding this thesis (Shrivastava, 1995a, p. 185):

> "*Environmental technologies* are defined as production equipment, methods and procedures, product designs, and product delivery mechanisms that conserve energy and natural resources [...] and protect the natural environment. Environmental technologies are evolving both as a set of *techniques* (technologies, equipment, operating procedures) and as a *management orientation,* [such as] environmentally responsible approaches towards product design, manufacturing, environmental management, technology choice, and design of industrial systems."

Referring to this definition, the importance of information systems for enabling corporate environmental sustainability becomes clear: innovative IS-enabled technologies can enhance the resource efficiency of operating procedures, production equipment and end-user products. Furthermore, IS provide the

necessary tools for strategic management to translate sustainability-oriented management goals into corresponding actions by integrating environmental aspects into decision-making processes and business operations (Butler, 2011).

> *"We are using software to create transparency; we set targets for sustainability goals and make the progress visible to encourage awareness and personal accountability."*
>
> – Peter Graf, CSO, SAP (in: DeGarmo *et al.*, 2011, p. 8)

In this context the differentiation between specific environmental impacts, as described in Section 1.2, is helpful to systematically categorize potential Green IS initiatives. With regard to enterprise-wide waste and emissions, the second-degree environmental impacts of Green IS facilitate firm-wide emission reductions by tracking resource flows and providing environmental information that is essential for the optimization of internal processes.

Practical examples in the domain of IS-enabled environmental measurement and accounting are (Moeller & Schaltegger, 2005; GeSI 2008; Nunn & Bonecutter, 2009; Melville, 2010; Murugesan, 2010; Loos *et al.*, 2011):

- firm-wide environmental management systems (e.g., ISO 14001),
- energy management systems (e.g., ISO 50001),
- carbon management systems (CMS),
- integrated environmental management information systems (EMIS),
- accounting of environmental impacts to ensure compliance with laws and regulations,
- tracking of environmental data throughout the supply chain,
- waste management systems which also control the use of toxic and hazardous materials,
- evaluation and simulation of environmental risks and opportunities with executive decision-support systems,
- provision of platforms for emission trading systems,
- benchmarking of process-related resource intensity within and across industries,
- assessment and reporting of environmental data towards internal and external stakeholders.

Information systems are the main driver of organizational change since they are the backbone of today's business processes (Ramirez *et al.*, 2010; vom Brocke *et al.*, 2013a). Accordingly, the second opportunity of Green IS to decrease organization-wide environmental impacts is the optimization or reengineering of internal business and production processes (Nunn & Bonecutter, 2009; Ruth, 2009; Dedrick, 2010; Melville, 2010; Loos *et al.*, 2011; vom Brocke *et al.*, 2012):

- Green business process management (BPM) provides a holistic perspective for modeling, analyzing and improving internal processes to leverage the transformative power of IS for environmental sustainability,
- reduction of the energy and resource use in the manufacturing sector with intelligent, IS-enabled production systems,
- optimization of processes throughout the supply chain,
- digitization of organizational workflows (e-billing, e-commerce etc.),
- improvement of transportation systems and company logistics,
- development of new e-business models,
- reduction of individual travel through virtual meetings,
- telework and remote working practices.

Business process reengineering is expected to further gain in importance due to the new sustainability challenges. These involve complex relationships, in particular between environmental, social and economic dimensions, and require closed-loop systems, which address the entire lifecycle of products and services. Hence, central IS-based data repositories, collaboration with suppliers and innovative processes offer the opportunity to implement a holistic approach which involves the entire supply chain (DeGarmo *et al.*, 2011; Lee & Kim, 2011).

Whereas the second-degree impact is mainly leveraged through process innovations, the third-degree environmental impact of Green IS is based on the potential of driving infrastructure and product innovations which decrease resource consumption, emissions and waste during the entire lifecycle (Lee & Kim, 2011). Examples are (GeSI, 2008; World Economic Forum, 2008; Dedrick, 2010):

- energy-efficient building design and automation through intelligent monitoring and control systems for a dynamic management of lighting, heating and cooling systems,
- smart electrical grids, which dynamically adjust electricity demand and supply of regenerative energies through various sources, such as wind turbines, photovoltaic panels and pumped-storage hydroelectricity,
- fuel-saving car technologies with start/stop functions and optimized engine control units,
- intelligent traffic management systems,
- dematerialization initiatives, substituting physical products through digital services (e-books, mp3 & music streams, online banking etc.),
- software for performing lifecycle analyses (LCA) of products and services.

As a consequence of these multifaceted opportunities to decrease the environmental footprint of organizational processes as well as reducing the negative impact during the lifecycle of end-user products and services, the Green IS research discipline has evolved from an IT-centric perspective to a holistic approach comprising business enterprises and products (Harmon & Demirkan, 2011). If the potential of Green IS

to enhance environmental sustainability in all these areas is leveraged, Green IS will become a key enabler of corporate sustainability. Due to the fact that sustainability has been identified as the next business megatrend (Lubin & Esty, 2010), Green IS will have a substantial impact on firm competitiveness in the future. Nonetheless, economic uncertainties, strategic complexities and risks restrain business executives from rapidly transforming their enterprises with the help of Green IS (Elliot, 2013).

2.3 Corporate sustainability as a new challenge for CIOs

The term Chief Information Officer (CIO) is defined by Grover *et al.* (1993, pp. 108–109) as "the highest-ranking IS executive who typically exhibits managerial roles requiring effective communication with top management, a broad corporate perspective in managing information resources, influence on organizational strategy, and responsibility for the planning of IT to cope with a firm's competitive environment."

The role of the CIO has evolved over the last three decades. In the 1980s, the role of IS directors was mostly technically oriented, with a typical task being the set-up of the technical infrastructure for a rather unimportant service function. Only a few innovative companies integrated CIOs into the top management team. During the 1990s, leading IS executives were assigned new responsibilities for the strategic planning and control of the technological IT infrastructure, which supported modern business processes, thus gaining in importance for organizations. Towards the end of the 1990s, with the increasing penetration of IS within organizations and the evolving opportunities of e-commerce, CIOs became responsible for driving business growth and began to influence business strategies. In the 2000s, after enormous investments in modern IS, CIOs were challenged to prove the real business value of their systems. At the same time, IS became the key driver of organizational change while CIOs were expected to have a thorough understanding and a vision of future technologies that could have a strategic influence on the long-term development of the business (Chun & Mooney, 2006). Today, IT infrastructure and IS capabilities are fundamental for business operations while the strategic technological foresight has made CIOs important members of the top management team with a substantial influence on business strategy (Lubin & Esty, 2010; Banker *et al.*, 2011).

The most important challenges of CIOs are the reengineering of business processes, the strategic planning of IT strategic, the enhancement of operational productivity, and the generation of technological innovations that create additional revenues. First and foremost, the alignment of the IS function with the business strategy has been the top CIO concern during the last ten years (Luftman & Derksen, 2012). With

the increasing significance of corporate sustainability, CIOs might now seize a new challenge.

In 2013, 93 percent of the 250 largest companies worldwide issued a corporate social responsibility (CSR) report and 51 percent of the reporting companies even included CSR information in their annual reports to stockholders (KPMG, 2013). In a global CEO survey, 70 percent of leading business executives rated environmental sustainability issues as significant or highly significant for their business (Kiron *et al.*, 2013a), 61 percent stated that sustainability is on the top management agenda, and 62 percent considered pursuing a sustainability-oriented strategy as necessity to be competitive (Kiron *et al.*, 2013b). However, only around a quarter of a wide range of companies have embedded sustainability in their business practices with a formal and structured program (McKinsey, 2011). One reason for this gap between perceived importance and actions taken is a lack of C-level leadership (Krauss, 2010) – many companies have a CSR function without strategic significance or assign the responsibility for environmental sustainability to low-level functional managers (McKinsey, 2010). At the same time, the siloed thinking in organizational departments and the missing involvement of CIOs in firm-wide sustainability initiatives are major inhibitors of the implementation of cross-functional Green IS initiatives that are not restricted to the IS department: operations and logistics departments strive for optimizing production and supply chain processes, product development managers try to decrease the environmental footprint of products, human resources departments think about telework, CSR groups advocate for sustainability, but often without direct influence on current business practices, and the IT department focuses on Green IT instead of leveraging synergies and initiating firm-wide sustainability initiatives which address the entire organization (Dedrick, 2010).

> *"The CIO has the responsibility to create an integrated viewpoint from a business angle, which will help position the organization competitively from a standpoint of energy, resource, and emission management."*
>
> – Pat House, C3 (in: DeGarmo *et al.*, 2011, p. 64)

Obviously, strategic sustainability initiatives require C-level commitment and leadership with the corresponding responsibilities and competencies (Lubin & Esty, 2010). The alignment of sustainability initiatives with the business strategy, the definition of goals, the tracking and accounting of environmental impacts to facilitate transparency and raise awareness are, in their core, information challenges. Due to this situation, and owing to the fact that CIOs and their IT departments possess the necessary experience from IT/business alignment, change initiatives and process transformations, CIOs are predestined to play a decisive role in corporate sustainability initiatives (DeGarmo *et al.*, 2011). In 88 percent of the

responding companies from a global study conducted by Forrester Research, IT organizations were involved in planning and executing corporate sustainability strategies while they even took a central part in 38 percent of the participating organizations (Krauss, 2010).

According to Nunn & Bonecutter (2009), CIOs are well-positioned to advocate the use of information systems for implementing corporate sustainability programs and to drive product and process innovations. Due to the cross-functional characteristics of the IS function, CIOs can rely on their experience to embed sustainability into business practices across the enterprise and even throughout the entire supply chain. CIOs are also familiar with the challenge of assessing the business value of IS – a challenge which is similar to demonstrating the contribution of sustainability initiatives to the long-term success of a company (DeGarmo *et al.*, 2011).

David Kepler, who is both the CIO and CSO of The Dow Chemical Company, underlines this reasoning based on his personal experience. He explains: "the skill sets I've built during my experience as CIO have helped in the CSO role, because both require an understanding of the strategy and making sure that resources and priorities get linked to that strategy. Effective execution depends on how you link multiple businesses to some common themes in the company and then drive a change of behavior. The enterprise-wide, cross-business-unit coordinating experience as CIO has been very useful in making the case for sustainability" (in: DeGarmo *et al.*, 2011, p. 22).

To support CIOs in appropriately addressing this new challenge, this thesis offers practice-relevant empirical insights and develops management frameworks for a holistic implementation of Green IS initiatives that follows a clear competitive logic. Hence, this research categorizes specific impact areas of Green IT and Green IS, conceptualizes an alignment framework for harmonizing the IS and sustainability function with the business, illustrates four distinct types of Green IS strategies, lists a wide range of measures to translate these strategies into actions, and empirically verifies the positive contribution of Green IS to short- and long-term competitiveness.

3. Pre-Study: Status Quo of Green IT and Green IS

For a deeper understanding of the practical problem (referring to the previously introduced research process, as displayed in Figure 2), a pre-study was conducted. Tan *et al.* (2011) argue that the relatively new research area of Information Systems for Environmental Sustainability lacks empirical evidence, especially with regard to empirical studies that investigate the implementation of Green IT/IS practices. Accordingly, the pre-study was aimed at answering two basic research questions:

- What drives the adoption of Green IT/IS?
- What is the current implementation maturity of Green IT/IS in German companies?

To address this research gap and to facilitate a starting point for the following conceptual and empirical research, this section provides preliminary insights from descriptive survey research. The empirical findings of this quantitative study add to the body of Green IT/IS knowledge, where conceptual models, theoretically derived propositions and anecdotal examples are still prevailing (Jenkin *et al.*, 2011).

3.1 Research method

To analyze the status quo of Green IT and Green IS in organizations, descriptive survey research was identified as appropriate method. Survey research is the most widely used method in IS research (Chen & Hirschheim, 2004). The goal of this empirical study was to illustrate the current implementation maturity of Green IT and Green IS practices in German organizations and to evaluate the significance of different motivational factors that led to the adoption of these practices. Following the recommendations of Pinsonneault & Kraemer (1993), this descriptive research built on a cross-sectional survey with business organizations as subject and included antecedent variables (drivers of Green IT/IS adoption). For the implementation of the survey, Dillmann's (2007) Tailored Design Method for mail and internet surveys was applied.

The structure of the survey was based on Zarnekow *et al.*'s (2005) model of Integrated Information Management (IIM), which differentiates between three core processes in the value chain of IT organizations: source, make and deliver of IT services. Furthermore, IT governance plays a vital role for the alignment of the IT organization with the business. Accordingly, the questionnaire consisted of four specific parts: IT governance, IT sourcing, IT operations, and IT service delivery.

To evaluate the implementation maturity (Park *et al.*, 2012) of Green IT measures and Green IS initiatives, the following amounts of structured, pre-defined, closed questions (Brace, 2004) were specified for the questionnaire:

- 12 questions that refer to general company characteristics and to properties of the IT department/organization in particular;
- 21 survey items that refer to five categories of Green IT/IS implementation drivers (environmental, compliance, ethics, financial, and competitiveness);
- 17 survey items that evaluate Green IS Governance initiatives;
- 61 survey items that refer to the implementation maturity of a wide range of Green IT measures (IT sourcing: 12 items; IT operations: 49 items; IT service delivery: 13 items).

The questions were developed based on a review of current Green IT and Green IS literature (Murugesan, 2008; Molla *et al.*, 2009; Sayeed *et al.*, 2009; Butler, 2010; Iacobelli *et al.*, 2010), taking into consideration the motivational factors driving the implementation of Green IT/IS (Dedrick, 2010; Kuo, 2010; Molla & Abareshi, 2011). The survey items were measured with a 5-point Likert scale (Brace, 2004) and were validated in a pre-test, which was conducted with seven IS researchers and five practitioners. Because of the flexibility, the ease of use for participants, the low costs and the advantages referring to data analysis techniques, a web-based survey was implemented with the widely used freeware tool Lime Survey (http://www.limesurvey.org).

The survey was aimed at executives of German IT organizations as well as IT directors of internal IT departments of German enterprises. The contacts were retrieved from the Hoppenstedt database (http://www.hoppenstedt-firmendatenbank.de) where leading IT executives from IT organizations were selected. Furthermore, directors of IT departments of large German enterprises were also invited whereas medium-sized and small companies were disregarded because of their insufficiently large data centers. Invitations were sent via email and the response rate was improved through three rounds of survey reminders. In total, managers from 79 companies participated in the survey, thus giving a broad overview of the current Green IT and Green IS implementation maturity in German companies. The characteristics of the participating companies (industry, number of employees, annual sales volume) are displayed in Appendix A. Due to the length of the complete survey (101 questions), the respondents could opt for a specific area that corresponds to their personal expertise (IT governance, IT sourcing, IT operations, or IT service delivery). As a consequence, the number of answers varies depending on the specific functional area. However, the questions concerning the motivations for implementing Green IT and Green IS and the general characteristics of the IT organization and its business and environmental impacts were answered by all participants (n=79, unless stated otherwise).

3.2 Empirical results

The empirical data were collected from April 2012 to January 2013. In total, 79 companies from 17 industries participated in the survey. 20 of those are active in IT-specific industry branches, such as IT solutions, hardware, software, or internet services. The company sizes of the firms represented in the survey ranged from small IT service providers to internationally leading DAX companies (see Appendix A, company characteristics). The annual IT budgets ranged from less than 1 million Euros up to more than 500 million Euros per year. For this type of preliminary, exploratory research the analysis of data relies on basic descriptive statistics (Pinsonneault & Kraemer, 1993).

Table 1: Drivers and goals of Green IT/IS adoption.

Driver	Goal	Median	Mean	Standard deviation
Environmental (mean = 3.57)	Decrease resource consumption.	4	3.98	1.2
	Increase awareness of users for IT-related environmental issues.	3	3.80	1.00
	Decrease environmental impacts.	3	3.63	1.12
	Measure and monitor environmental impacts.	3	3.25	1.05
	Avoid e-waste.	3	3.19	1.04
Compliance (mean = 3.40)	Comply with environmental laws and regulations.	3	3.64	1.26
	Facilitate transparency through quantification of environmental impacts.	3	3.39	0.68
	Comply with highest reporting standards.	2	3.17	1.21
Ethics (mean = 3.38)	Contribute to the achievement of firm-wide environmental targets.	3	3.66	1.21
	Enhance firm reputation.	3	3.51	1.13
	Take stakeholder claims into account.	3	3.19	1.00
	Promote collaboration of business units to enhance corporate sustainability.	3	3.15	1.15
Financial (mean = 3.25)	Decrease costs of IT operations.	4	3.91	1.08
	Increase efficiency of business processes.	3	3.17	1.13
	Achieve cost leadership position within specific industry.	2	3.00	0.71
	Increase efficiency of production processes.	2	2.93	1.13
Competitiveness (mean = 3.09)	Acquire expert knowledge regarding environmental technologies.	3	3.33	1.20
	Consider technical restrictions.	3	3.30	1.24
	Decrease dependence on limited natural resources.	3	3.13	1.02
	Support business units with innovative environmental technologies.	2	2.90	1.13
	Differentiate from competitors.	2	2.83	1.22

At first, the organizational drivers for adopting Green IT and Green IS were analyzed. With regard to the motivational factors driving the implementation of Green IT and Green IS, the empirical results show that reducing the resource consumption of the IT infrastructure is the most important reason, followed by the goal of decreasing the costs of IT operations. In total, the survey participants assessed the importance of 21 factors which could play a role for the implementation of Green IT and Green IS measures and initiatives (see Appendix A).

For a detailed evaluation of the survey results, the goals of Green IT and Green IS were then classified into five categories: environmental, compliance, ethics, financial, and competitiveness. This classification scheme is based on a range of studies which have investigated the adoption of Green IT and Green IS (Chen *et al.*, 2009; Molla, 2009a; Kuo, 2010; Molla & Abareshi, 2012). As displayed in Table 1, environmental motivations appear to have the highest mean value (mean = 3.57). Compliance-oriented motives are placed second (mean = 3.40), with ethical motives featuring only a slightly lower mean value (mean = 3.38). The mean value of the importance of financial reasons is only placed fourth (mean = 3.25). However, the goal to decrease the costs of IT operations was rated as the second most important single driver for the implementation of Green IT and Green IS. Enhancing firm competitiveness with a focus on long-term business success is currently the least important of the five drivers (mean = 3.09). These results suggest that at this moment only a few companies are able to leverage the potential of Green IS to differentiate their product and service offerings from those of their competitors.

In a second step, the specific characteristics of the IT governance and the strategic significance of an environmentally responsible information systems management were analyzed. As illustrated in Figure 5, nearly half of the responding companies manage their IT department as a service center. About a third still relies on managing the IT function as a cost center whereas only 13 percent apply the modern profit center approach (Ragu-Nathan *et al.*, 2001; Kaplan, 2006).

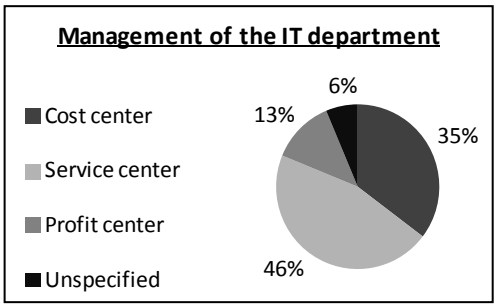

Figure 5: Management approach for running the IT department.

More than half of the companies that participated in the survey state that the IS function is very important for their business and critical for the long-term corporate

success. 30 percent say that the IS function influences their business strategy while 15 percent argue that IS only play a supportive role with regard to their core business (Figure 6).

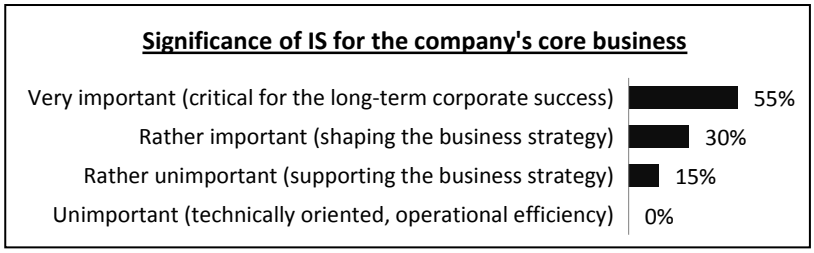

Figure 6: Significance of information systems for the company.

Another indicator for the importance of IS throughout the enterprise is the budget of the IT department in relation to the annual sales volume of the company. Usually, a significant difference can be observed for companies from different industries (Gartner, 2011). In this survey sample, as displayed in Figure 7, nearly half of the companies spent less than two percent of their annual sales volume for IT. About a third of the participating organizations had an IT budget with a volume between two and five percent of the sales volume. 15 percent spent a considerable share, between five and ten percent, of their annual turnover for IT, and three percent even spent more than ten percent of their sales volume for IT.

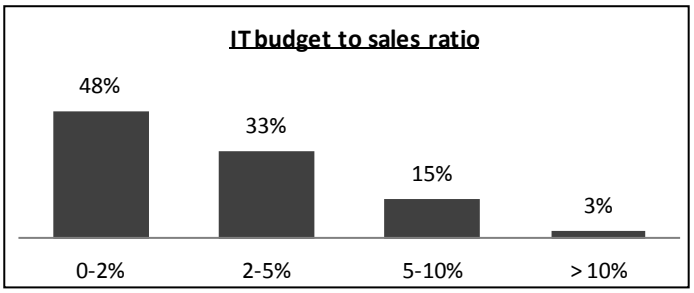

Figure 7: IT budgets in relation to the annual sales volume.

Concerning the strategic orientation of Green IT/IS initiatives, half of the respondents stated that Green IT/IS strategies primarily support the corporate sustainability strategy (Figure 8). For nearly 40 percent of the companies, Green IT/IS strategies support the business strategy, which underlines their intention to not only improve environmental characteristics but also to benefit from economic opportunities being associated with measures that enhance resource efficiency. However, in only 9 percent of the companies the corporate strategy is actually shaped by Green IS-enabled product innovations which are supposed to have the potential to increase firm competitiveness. Finally, none of the participating companies was following a transformational approach to fundamentally change core business processes with the aid of Green IT/IS.

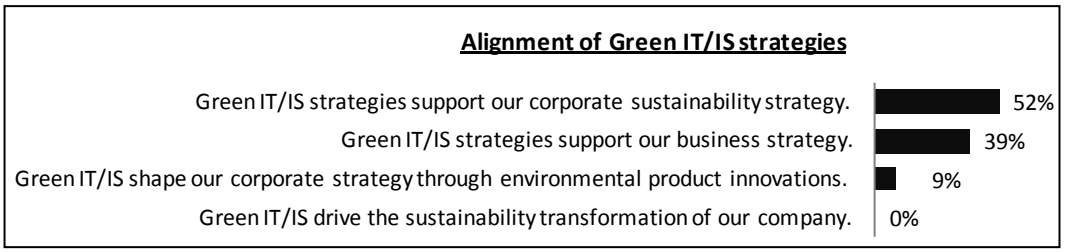

Figure 8: Strategic alignment of Green IT/IS initiatives.

For a further assessment of the necessity to generate financial benefits apart from environmental ones, the profitability requirements for the implementation of Green IT/IS measures were analyzed (Figure 9). Roughly a fifth of the companies implements only those Green IT/IS measures that feature a payback period of less than one year. Nearly half of the respondents are willing to invest in Green IT/IS initiatives that are profitable within three years while another fifth states that they also invest in measures which require a longer time span to pay off. About ten percent even implement initiatives which are not profitable. For these organizations, the environmental benefits suffice for justifying the investments in Green IT/IS.

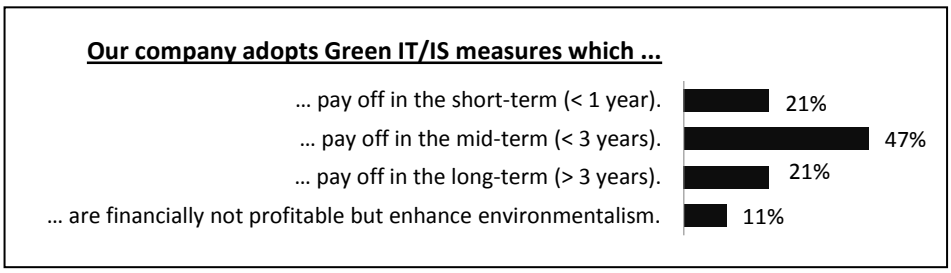

Figure 9: Profitability requirements for adopting Green IT/IS measures.

To gain a deeper understanding of the focus of environmental initiatives which are being considered by the organizations it was evaluated which of the three degrees of environmental IS impacts (as introduced in Section 1.2) are being analyzed by IT organizations in practice today. 58 percent assess first-degree impacts and almost just as many estimate the organization-wide second-degree impacts. As displayed in Figure 10, a third of the companies even consider the product-related third-degree impacts.

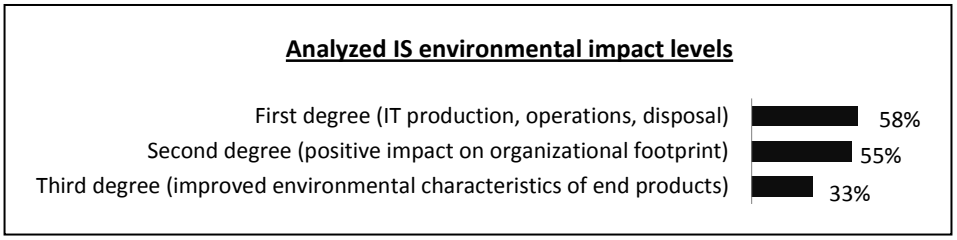

Figure 10: Evaluation of the analyzed environmental impacts.

For the accounting of IT-related first-degree impacts, it is important to differentiate between different types of impacts. As illustrated in Figure 11, nearly all IT organizations track the CO2 emissions related to the energy consumption of IT operations. About half of the survey participants stated that they also take the environmental consequences of disposing IT hardware into account. Approximately forty percent analyze environmental characteristics when purchasing IT equipment while only fifteen percent rely on holistic lifecycle analyses to minimize the overall environmental footprint of their IT infrastructure.

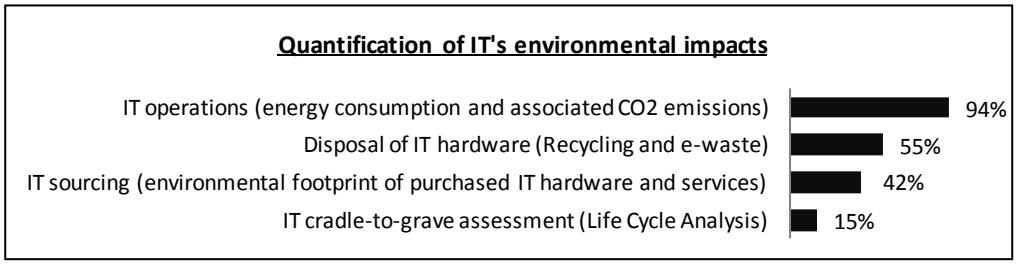

Figure 11: Evaluation of the analyzed first-degree IT environmental impacts.

Finally, the proportion of IT-related CO2 emissions in comparison to the companies' overall emissions was assessed. For nearly two thirds of the companies, the emissions that were caused by IT infrastructure operations accounted for less than two percent of the enterprise-wide emissions. Only for IT-intensive companies without production facilities and low overall emissions, such as banks, government institutions or the IT service industry, the proportion of IT-related CO2 emissions rises significantly above ten percent (Mingay & Di Maio, 2007). This underlines the importance to make use of the potential of Green IS to reduce firm-wide CO2 emissions through product and process innovations, as explained in Section 2.2.

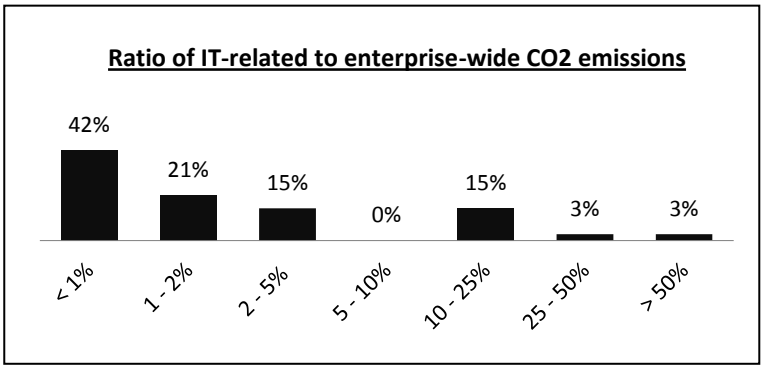

Figure 12: Share of IT-related CO2 emissions.

Apart from these general management aspects concerning the IT organization, the implementation maturity of 91 Green IT/IS measures was assessed on a 5-point Likert scale (completely implemented, mostly implemented, partly implemented, implementation planned, not implemented) concerning the following areas:

- IT governance: 17 measures
- IT sourcing: 12 items
- IT operations management: 7 items
- data center operations: 32 items
- IT in the office environment: 10 items

IT governance

As displayed in Figure 13, around 20 percent of the companies have implemented an energy management system and an environmental management system while an additional 60 percent have either started the implementation process for such a system or are planning to do so. The consideration of environmental aspects in IT investment decisions has been put into effect by 10 percent of the companies while another 50 percent are currently integrating these aspects into their IT sourcing processes. The internal communication of Green IT/IS initiatives to promote the engagement of the IT department also appears to be a popular measure. The internal allocation of IT-related energy costs has been accomplished by less than 10 percent of the participating organizations. However, the majority of the firms conceive the importance of creating financial incentives for an energy-efficient IT infrastructure by assigning the energy costs of IT operations to the IT department. Around 15 percent of the companies align their Green IT/IS initiatives with the corporate environmental goals whereas a third of the firms do not even consider a harmonization to be necessary, or they are lacking firm-wide sustainability goals.

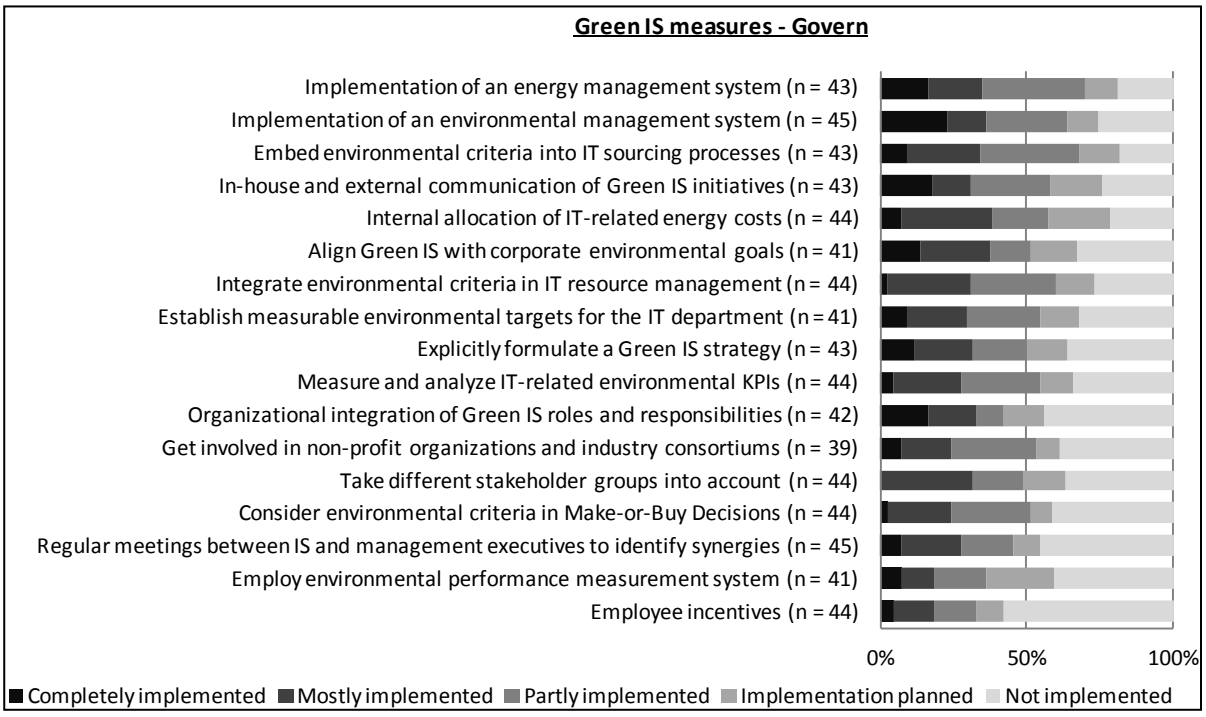

Figure 13: Implementation maturity of Green IS initiatives in the area of IT Governance.

As the results show, environmental aspects have only been successfully integrated in the IT resource management so far, but more than half of the companies have at least started the implementation. About a third of the companies have defined first environmental targets and mostly finished to establish a concrete measurement of environmental performance indicators. About half of the companies still lack a Green IT/IS strategy, and a large share of them has not even thought about how to define organizational roles and assign responsibilities for an environmentally sustainable management of IS.

The implementation maturity of the following measures is less pronounced in practice today: a) engaging in industry associations, such as the Green Grid; b) the consideration of different stakeholder groups; c) the appreciation of environmental aspects in Make-or-Buy decisions; d) regular meetings between IS and management executives to advance environmental initiatives throughout the enterprise; e) the use of sophisticated environmental performance measurement systems; f) the creation of concrete employee incentives to promote an environmentally responsible behavior.

IT sourcing

With regard to the sourcing of environmentally sustainable IT equipment and services, one can differentiate between two aspects: the sustainability-oriented management of the supplier relationships and the selection and purchasing of concrete IT products (hardware and software) and services. The empirical data (see detailed survey results in Appendix A) show that most IT departments rely on a centralized sourcing process, which is beneficial for the consistent integration of environmental criteria. Most companies have started to take readily available information, such as eco-labels, into consideration whereas carrying out more complex lifecycle assessments or situation-specific analyses is rather an exception. A close cooperation with suppliers to improve environmental characteristics of IT products is also not common among the survey participants.

IT operations: data center

Concerning the management of IT operations, enhancing the energy efficiency of IT equipment is at the heart of prevalent Green IT measures. The highest maturity of Green IT implementation can be observed in the data center, in particular with regard to server and storage systems (see Appendix A). Frequently implemented measures are the consolidation and virtualization of servers and storage, right sizing of IT equipment, and the use of blade servers and energy-efficient processors. While energy-efficient hardware is already deployed by many IT organizations, the active use of energy management functions, workload management, or the dynamic shut down of servers are still uncommon.

The power supply is also frequently targeted by Green IT initiatives: increasing the utilization rates and using energy efficient uninterruptable power supplies (UPS) as well as the monitoring of energy consumption demonstrate a relatively high maturity with measures having been implemented by a third of the participating organizations.

In the area of data center cooling, various measures have been implemented so far: the optimization of air flows within data centers, the separation or containment of hot and cold aisles, and the dynamic control of cooling systems have been mostly implemented by more than half of the organizations. The deployment of modern computer room air conditioning (CRAC) systems and free cooling systems, which require far-reaching changes of the data center infrastructure, have been mostly implemented by a quarter of the companies. Reusing data center heat, installing in-row chillers or the utilization of liquid refrigerants are less common in German data centers.

IT operations: office environment

In today's office environments, network multifunction printers have been implemented by roughly two thirds of the organizations. Further resources are saved by setting black & white double sided printing as default (see detailed survey results in Appendix A). About half of the organizations make use of teleconference systems to reduce individual travel of employees, thus decreasing CO2 emissions. Energy-saving LED displays are also frequently used, and notebooks start to substitute desktop computers which require more electrical energy. However, the use of energy-efficient desktop PCs or the activation of energy management functions are not very common yet. Furthermore, only 3 percent of the respondents state that they completely migrated their systems to thin clients. Although these systems feature superior power efficiency, the migration comes along with a number of drawbacks and the implementation requires complex software and hardware changes.

3.3 Discussion of preliminary empirical insights

The analysis of a wide range of motivational factors for the implementation of Green IT/IS initiatives shows that various underlying dimensions influence the perception of executives. Hence, this thesis is aimed at a more profound evaluation of the competitive potential of Green IT/IS. The empirical results underline the strategic importance of the IS function for today's organizations and emphasize the significance of innovative technologies for corporate long-term success. For that reason, the participants were finally asked to determine their primary strategic purpose when adopting Green IT/IS initiatives. As illustrated in Figure 14, 49 percent stated that they primarily aim at enhancing resource efficiency and

decreasing costs of IT operations. Obviously, half of the participating IT executives have an internally-oriented view and mainly perceive Green IT/IS as an opportunity for cost reductions while achieving environmental benefits without particular efforts. This is also in line with the empirical results, which show that the implementation maturity of Green IT/IS measures is still low for the majority of companies. 32 percent of the respondents go a step further and take an externally-oriented point of view, stating that they primarily aim at improving the corporate image by considering the claims of different stakeholder groups. However, it remains to be seen whether the chosen initiatives fundamentally decrease environmental impacts or if there is more green marketing than real actions.

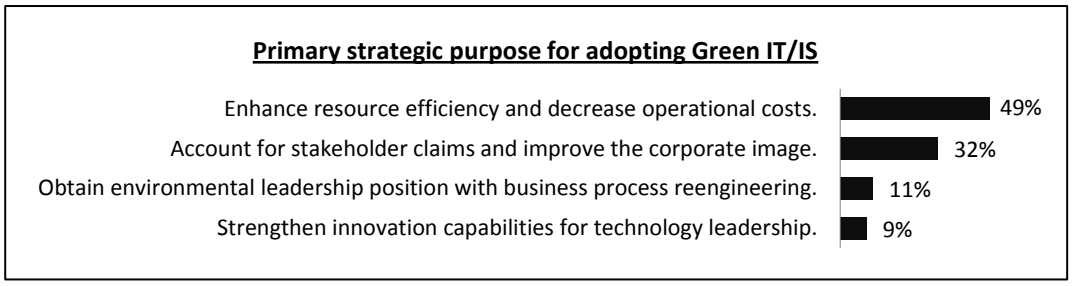

Figure 14: Evaluation of the main strategic purpose of Green IT/IS initiatives.

11 percent of the respondents target an environmental leadership position, which can be achieved with resource efficient internal business and production processes. Such an approach requires a fundamental transformation of internal structures and work routines, making use of the potential of Green IS throughout the entire enterprise. Finally, 9 percent of the executives strive for an environmental technology leadership position, which can be attained with IS-enabled product innovations. This approach focuses on end-user markets and is associated with an externally-oriented competitiveness perspective.

The preliminary insights of this pre-study reveal that the implementation of Green IT and Green IS has been started, but there is still ample room for improvement. Although a wide range of possible measures exists, only a few have reached a considerable level of maturity in the majority of organizations. Most implemented measures target the energy efficiency in data centers. In office environments, only less complex initiatives have been realized. Regarding IT governance, it becomes obvious that structured planning, steering, management and control processes are still missing in roughly two thirds of participating organizations.

These results are similar to another study of Green IT maturity conducted by Park *et al.* (2012). In that study, the authors underline that an integrative monitoring and measurement approach as well as a more sophisticated capacity management is required to dynamically manage unused server resources in data centers.

Furthermore, the considerable energy-saving potential of thin clients and cloud computing is not being realized in office environments. With regard to IT sourcing, a better integration of sustainability criteria is required and the deployment of existent IT equipment should be optimized throughout the organization. Equally to the insights of the presented pre-study, Park *et al.* (2012) promote the consideration of environmental sustainability aspects during supplier selection processes and observe a low maturity of cooperating with key suppliers in this context. In addition, they argue that e-waste is not adequately treated and that firm-wide environmental performance management systems should facilitate a holistic lifecycle management perspective. Finally, they underline the importance of the formulation and implementation of specific strategies that leverage the potential of Green IT and Green IS (Park *et al.*, 2012).

Lubin & Esty (2010, p. 44) make comparable observations and state that "most executives know that sustainability will profoundly affect the competitiveness of their organizations. Yet most are flailing around, launching a hodgepodge of initiatives without any overarching vision or plan." These empirical insights from management practice delineate the practical problem and elucidate the need for a strategic approach in managing the implementation of Green IT/IS initiatives.

In the next section of this thesis, current academic research is analyzed before specific research goals are derived from the practical problem and the theoretical research gap in current literature.

4. Theoretical Background and Related Research

4.1 Fundamental theories from Strategic Management Research

Due to the fact that this thesis addresses strategic aspects of environmental sustainability in information systems management, the research builds on fundamental concepts and theories from strategic management research. In the leading IS academic journal, MIS Quarterly, Drnevich & Croson (2013, p. 485) define strategy as "a set of management decisions regarding how — through choice of industry, firm configuration, resource investments, pricing tactics, and scope decisions — to balance the firm's tradeoffs between being efficient (reducing cost) and being effective (creating and capturing value) to achieve its objectives." The main goal of strategic management research is to understand the sources and mechanisms that result in a sustained competitive advantage for a business firm. Factors such as the strategic positioning of the firm in the market as well as internal resources and capabilities play a fundamental role in this research area (Mata *et al.*, 1995). The field has largely been influenced by Andrew's (1971) *Concept of Corporate Strategy*, in the scope of which he presents a framework to assist managers in matching the strengths and weaknesses of a company with the opportunities and threats of its external environment (SWOT analysis) (Barney, 1991). Accordingly, strategic management specifies the general orientation of a business firm with the goal of creating long-term competitive advantages, determining an attractive market position while considering company-specific resources and capabilities (Chan & Huff, 1992).

4.1.1 Porter's Strategic Positioning Approach

With regard to the strategic positioning of a firm, Porter's (1980) seminal piece *Competitive Strategy: Techniques for Analyzing Industries and Competitors* has profoundly advanced the field. Porter builds on the structure-conduct-performance paradigm, which states that the attractiveness of a specific market position depends on the competitive intensity that can be analyzed through specific structural factors (five forces analysis). Porter recommends occupying the most attractive market position while defending that position against competitors. Porter (1996, p. 62) explains that "a company can outperform rivals only if it can establish a difference that it can preserve. It must deliver greater value to customers or create comparable value at a lower cost, or do both." Most importantly, he argues that the definition of a strategy always involves trade-off decisions: "Strategy is making trade-offs in competing. The essence of strategy is choosing what not to do. Without trade-offs, there would be no need for choice and thus no need for strategy" (Porter, 1996, p.

70). According to Porter, firms can choose between two fundamentally different strategies: *cost leadership* and *differentiation*. These two generic strategies aim at industry-wide market leadership. The third possible option is to implement a *focus* strategy, either following a cost leadership or differentiation approach while focusing on a very restricted market segment (Porter, 1980).

The cost leadership strategy is based on the achievement of economies of scale and operational excellence with regard to internal processes. Strict cost control and minimization result in the lowest costs per product unit throughout the industry, giving the firm the possibility to sell the products for the lowest price in the market, allowing for high sales volumes while maintaining acceptable profit margins (Porter, 1980). The role of IS to enable such a strategy is to facilitate tools for cost monitoring and lean operations, the automation of processes, the efficient management of resources, the provision of inter-organizational IS to enhance efficiency throughout the supply chain, or the allocation of real-time data to reduce stock capacities in warehouses. Interestingly, a cost leadership strategy does not imply low IS investments – superior production sites and state-of-the-art business processes frequently rely on a top-notch IT infrastructure (Banker *et al.*, 2011).

The differentiation strategy is oriented towards premium products and services which offer particular features, such as exceptional design, technological innovations, superior quality, or even intangible aspects such as brand image. The products create a unique value for customers, thus allowing for the realization of high-end product prices (Porter, 1980). IS can be a vital enabler of top-class research & development as well as superior customer services, which are being required for the realization of differentiation strategies (Banker *et al.*, 2011).

4.1.2 The Resource-Based View

The second major perspective that evolved during the 1990s in strategic management research is the Resource-Based View (RBV). The RBV is focused on firm-specific assets that had largely been ignored by Porter's externally-oriented strategy approach. Whereas Porter argues that competitive advantage is based on industry structure, the RBV argues that the creation of competitive advantages is rooted in firm-specific resources and capabilities, which should be the fundament for strategy formulation (Spanos & Lioukas, 2001). Resources can be tangible, such as physical assets, infrastructure or financial capital; intangible, as for example brand image or reputation; or they can be personnel-based, encompassing knowledge, technical know-how and organizational culture (Grant, 1991). Capabilities are organizational competencies, such as processes and business routines, and describe the firm’s ability to assemble, integrate, deploy and combine resources. In this context, "a firm is said to have a sustained competitive advantage

when it is implementing a value-creating strategy not simultaneously being implemented by any current or potential competitors and when these other firms are unable to duplicate the benefits of this strategy" (Barney, 1991, p. 102). The RBV assumes resource heterogeneity among business firms and posits that in order to create and sustain a competitive advantage, the resources must fulfill the so-called VRIN criteria, i.e., they must be valuable, rare, imperfectly imitable and non-substitutable (Barney, 1991).

Although the RBV emphasizes the significance of internal resources and capabilities, it acknowledges the importance of the external environment (Collis & Montgomery, 2008). The basis for strategy-formulation should be the identification of rent-generating resources and capabilities which are unique and best exploit the opportunities of the external market environment (Grant, 1991). Due to its applicability and the possibility to analyze the sources of competitive advantage in detail, the RBV has become the dominant paradigm in strategic management and IS research (Drnevich & Croson, 2013).

Wade & Hulland (2004, p. 109) explain that the RBV "provides a valuable way for IS researchers to think about how IS relate to firm strategy and performance. The theory provides a cogent framework to evaluate the strategic value of IS resources. It also provides guidance on how to differentiate among various types of IS — including the important distinction between IT and IS — and how to study their separate influences on performance."

Drnevich & Croson (2013, p. 485) define *IS resources* as

> (1) the tangible resources that make up the physical IT infrastructure components, (2) the human IS resources that represent the technical and managerial skills, and (3) the intangible IS-enabled resources such as knowledge assets

while *IS capabilities* are described as

> (1) the firm's ability to mobilize and deploy its IS-based resources, creating value in combination with other resources and capabilities, and (2) the firm-specific IS-enabled knowledge and routines that improve the value of non-IS resources.

Physical assets, such as IT infrastructure devices, do not fulfill the abovementioned VRIN criteria because they are equally available to competitors. IT infrastructure resources feature the characteristics of a commodity (Carr, 2003) and cannot be the sources of sustained competitive advantages (Wade & Hulland, 2004). IS capabilities, on the other hand, are critical to firm performance because they lead to a superior, and, above all, unique deployment of a firm's IT resource base (Wade & Hulland, 2004). The sophisticated combination of hardware and software resources

can result in a firm-specific IT infrastructure which enhances the efficiency of internal organizational processes in an inimitable way, thus creating long-term competitive advantages. Furthermore, IS capabilities contribute to product and process innovations and can enhance a company's core competencies (Ravichandran & Lertwongsatien, 2005; Benitez-Amado *et al.*, 2010). In this context, Grant (1991, p. 119) argues: "while resources are the source of a firm's capabilities, capabilities are the main source of its competitive advantage."

Referring to Wade & Hulland's (2004) typology of IS resources and capabilities, consisting of outside-in (external relationship management, market responsiveness), inside-out (IT infrastructure, IS technical skills, cost efficient IS operations), and spanning capabilities (IS-business partnerships, IS management and planning), this thesis mainly focuses on IS spanning capabilities. These capabilities are important for the strategic management of the IS function and the alignment with the business. They have a large potential for the creation of value while being unique and difficult to imitate. As Sharma & Vredenburg (1998, p. 735) explain, such capabilities "are the coordinating mechanisms that enable the most efficient and competitive use of the firm's assets. The competitive advantage of these capabilities stems from their elusive nature based on social complexity and embeddedness in organizations."

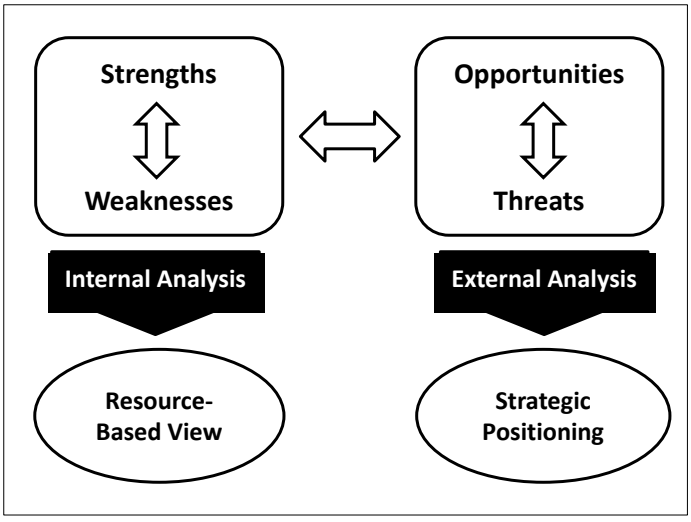

Figure 15: The relationship between SWOT analysis, RBV and Strategic Positioning (Source: Barney, 1991, p. 100).

Porter's industry analysis and strategic positioning approach, which is based on the premise that strategy and firm performance depend on the industry structure, and the RBV, which posits that the firm's unique resources and capabilities are the essence of competitive advantage and should guide strategy formulation, are seen as complementary in both strategic management and IS research (Spanos & Lioukas, 2001; Melville *et al.*, 2004; Rivard *et al.*, 2006). The fact that the two approaches

focus on different dimensions makes their concerted application particularly useful to cover both internal firm characteristics and external market aspects, thus covering all aspects of the SWOT strategy framework, as illustrated in Figure 15. In particular for strategic IS/business alignment, the concurrent consideration of internal resources and capabilities as well as external market characteristics is of great importance (Henderson & Venkatraman, 1993).

4.1.3 Dynamic Capabilities

To understand the mechanisms underlying the creation of competitive advantage in modern high-tech industries, such as information and communication technologies, semiconductors or information services, an extension of the RBV was needed to explain flexible market responsiveness, rapid product innovation and the dynamic reconfiguration of resources and capabilities to match the requirements of the external environment (Teece *et al.*, 1997; Leidner *et al.*, 2011). Dynamic capabilities are defined as "the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments. They reflect an organization's ability to achieve new and innovative forms of competitive advantage" (Teece *et al.*, 1997, p. 516). Eisenhardt & Martin (2000, p. 1107) clarify that "dynamic capabilities are the antecedent organizational and strategic routines by which managers alter their resource base to generate new value-creating strategies." Accordingly, dynamic capabilities refer to a process-oriented approach which explains how a company's key resources adapt to changing business environments. Since a wide range of IS capabilities features the attributes of dynamic capabilities, the significance of IS for the creation of competitive advantage was fundamentally strengthened by this new theory (Wade & Hulland, 2004).

Strategic IS alignment can be interpreted as dynamic capability due to its importance for adapting to rapidly changing environments (Lo & Leidner, 2012). Green IT/IS represent a disruptive technological change (Sayeed & Gill, 2011) and in this context, a dynamic form of strategic IS/business alignment can result in competitive advantages (Tallon & Kraemer, 1998; Wilden *et al.*, 2013).

4.1.4 Knowledge-Based View, Natural RBV, and Stakeholder Theory

Since IS research focuses on generation, processing and evaluation of information, the knowledge-based view (KBV), which is a recent extension of the RBV, is a useful theoretical lens. In today's business environment, knowledge is perceived as the most important strategic resource since it is unique and can neither be replicated nor imitated (Osterloh & Frey, 2000; Drnevich & Croson, 2013). As a consequence, knowledge generation, integration as well as inter- and intra-organizational knowledge transfer are regarded as sources of competitive advantage (Tsai, 2001;

Kearns & Sabherwal, 2007a). In Section 8 of this thesis, the social context of knowledge sharing among organizational units is analyzed. The inter-departmental cooperation between IS, business and sustainability domains is considered as being key to the strategic alignment of Green IS.

Another extension of the RBV is the natural resource-based view (NRBV), which provides an appropriate theoretical background for analyzing the consequences of Green IS adoption (Corbett, 2010; Molla *et al.*, 2011). The NRBV takes the natural environment, which has been largely ignored by management theory, into account and connects the availability of natural resources with specific management capabilities which can ultimately result in sustained competitive advantages (Hart, 1995; Banerjee, 2002). Shrivastava (1995a, p. 189) emphasizes that "environmental technologies seek alignment of corporate technologies and businesses with the natural environment." In this context, Hart (1997) proposes four stages from pollution prevention to product stewardship to clean technology to sustainability vision. These environmental strategies have fundamentally shaped sustainability thinking in management research and are thus part of the theoretical foundation underlying this thesis.

Finally, Stakeholder Theory plays a vital role in the context of corporate sustainability management because strategies have to take those groups, which have an essential influence on the achievement of the corporate objectives, into account. Stakeholders are "any identifiable group on which the organization is dependent for its continued survival; such as employees, customers, suppliers, government agencies, shareowners, financial institutions etc." (Freeman & Reed, 1983, p. 91). Banerjee (2002, p. 179) illustrates the usefulness of Stakeholder Theory for this thesis: "The stakeholder perspective of corporate environmentalism involves a recognition of stakeholders' environmental concerns, which are translated into strategic actions designed to improve a firm's environmental performance, as well as its relations with key external stakeholders."

4.2 Strategic Information Systems Research

This thesis fundamentally builds on the notion of strategic information systems (SIS), which can be described as "information systems used to support or shape an organization's competitive strategy, its plan for gaining and maintaining competitive advantage. They can significantly change business performance, contribute to attaining a strategic goal, and fundamentally change the way the company does business or the way it competes in its industry" (Chan & Huff, 1992, pp. 191–192). The discipline of SIS research has been dominated by the question of how SIS can support and advance business strategies to contribute to the achievement of corporate goals (Ravichandran & Lertwongsatien, 2005).

An overarching research theme in this context is strategic information systems planning (SISP), whose focus has evolved from the design of specific applications for strategic purposes, such as management information systems (MIS), to the development of SIS for the creation of competitive advantage. In this context, SISP plays a proactive role in shaping innovate business strategies and influences the design of organizational processes and IT governance mechanisms (Amrollahi *et al.*, 2013; Teubner, 2013). The practical significance as well as the evolution of this research stream, which is the central discipline this thesis can be assigned to, is presented in Section 4.2.1.

A sub-stream of this research area is Business Value of IS (BVIS) research, which deals with the question of how IS contribute to firm performance and to the creation of competitive advantage (Lo & Leidner, 2012) (Section 4.2.2). Furthermore, the formulation, content and implementation of information systems strategies (ISS) has been of great interest to the IS community (Ward, 2012) and can be seen as the sub-research area this thesis mainly contributes to (Section 4.2.3). IT Governance comprises the development of structures and processes to manage and control the IS function and is closely related to the central research topics of this thesis (Section 4.2.4). In particular the process of strategic alignment, which is both a core process of IT governance as well as a key research topic of the SIS research stream (Ragu-Nathan *et al.*, 2001), is of great importance for this thesis (Section 4.2.5). Finally, the concept of the balanced scorecard is briefly introduced as a tool for performance measurement and the implementation of information systems strategies for environmental sustainability (Section 4.2.6).

4.2.1 The evolution of SISP research

The SISP research stream evolved during the 1980s and the topic has been one of the top concerns of IS executives ever since (Luftman & Derksen, 2012). This is not surprising when taking the significance of this topic into account: worldwide IS spending has reached an annual level of 2.1 trillion USD in 2014 (Gartner, 2014) while the delivery of real business value and the contribution of IS investments to competitive advantages are not always clear (Ravichandran & Lertwongsatien, 2005). In the past, heavy investments in IS had not delivered the envisioned results. This challenge was called the productivity paradox and was the main reason for intensified research in the area of SISP, focusing on the alignment of IS and business in particular. Due to the importance of this research topic and its dominance in IS research, the "Strategic Information Systems Era" dawned at the end of the last century (Amrollahi *et al.*, 2013). Today, SIS foster firm-wide innovation, shape business models and strategies, contribute to the creation of competitive advantage and are acknowledged as strategically valuable assets. This progress was significantly influenced by SISP research and the development of sophisticated IS

strategies (Ragu-Nathan *et al.*, 2001). To delineate how the SISP research stream evolved in the course of time, the relevant decades are now being briefly described.

During the 1960s, the so-called data processing era, IS planning did not have a strategic dimension and was focused on the automation of data processing without being linked to business strategy (Teubner, 2013). The 1970s can be labeled as the Management Information Systems (MIS) era because functional managers started to make use of IS that could provide management-relevant information for planning and controlling tasks in an organizational context. However, IS were seen as functional tools and not as something that could impact the domain of strategic management (Ward, 2012). In the 1980s, the competitive dimension of IS was recognized and the era of Strategic Information Systems (Planning) began. New technological solutions were perceived as sources of competitive advantage due to their potential to advance value chain integration and to support competitive positioning through technological innovations. When SIS started to enter the top management agendas, the formulation of IS strategies and the alignment of these with the business strategy became a mandatory part of SISP (Merali *et al.*, 2012).

Table 2: Evolution of the SISP research stream (adopted from: Merali *et al.*, 2012; Teubner, 2013).

	1980s	1990s	2000s	2010+
SISP Focus	Technical planning	Demand-oriented planning	Competitive planning	Integrated IS/business planning
Goal	Technically reliable and usable applications	Effective and efficient solutions for business	Competitive advantage	IS-based business solutions and innovation
Dominant Alignment Challenge	Aligning SIS with business strategy	Integration of SIS with business	SIS for networks and resource-based competition	SIS for complex, dynamic, distributed contexts
Integration Focus	Systems	Processes	Resources	Global socio-economic systems
Business Model Innovations	Value chain	Extended enterprise	Value webs, global reach	Distributed, socially relevant

During the 1990s, strategic IS/business alignment was still the prevalent issue of IS management since the enormous investments that had been made to create IS-based competitive advantages did now show the expected results. At the same time, the rising significance of internet applications and the fact that IS became ever more integral to business underlined the significance of IS for strategic management. Accordingly, SISP research analyzed organizational, social and relational aspects

between IS and business with the aid of the knowledge-based view while the scope of alignment was extended to intra- and inter-organizational perspectives due to intensifying cost pressures which led to a rising significance of outsourcing and offshoring practices. Another important aspect of this decade was the revolutionary Business Process Reengineering (BPR) discipline, which aimed at enhancing the efficiency of internal and inter-organizational processes, thus reducing costs and enabling entirely new business models based on IS innovations (Merali *et al.*, 2012; Ward, 2012).

During the era of webs and networks in the 2000s, the role of information and knowledge for the creation of competitive advantages in a global, network-oriented context was the guiding principle of SISP research. Inter-organizational business processes and the sharing and transfer of knowledge became increasingly important while the RBV was the dominant research paradigm, with an increasing focus on the extensions of the knowledge-based view and IS-enabled dynamic capabilities. In particular, it was acknowledged that IT itself cannot be a source of sustained competitive advantages. Its potential is rather rooted in the synergistic relationship between IS capabilities and organizational resources (Merali *et al.*, 2012; Ward, 2012).

Today, IS are a vital part of business processes and business models, thus requiring a dynamic form of alignment since strategic planning processes have become fundamentally integrated. Especially the new e-enabled business models and the enhanced customer experience, which can be obtained with IS-based services, have gained in importance. Furthermore, SIS are perceived as dynamic capabilities which can assist firms to flexibly adapt to uncertain competitive contexts and rapidly changing external business environments. Global socio-economic contexts have become contingencies which shape SIS planning processes while IS-based process and product innovations are still growing in importance for the creation of competitive advantages (Merali *et al.*, 2012). In this context, this research advances the academic progress in the SISP discipline by providing practice-oriented recommendations and frameworks for integrating new aspects of environmental sustainability into strategic alignment and IS strategies.

4.2.2 Business value of IS

It was argued above that IT infrastructure components are equally available to most firms and thus cannot be the basis of sustained competitive advantage whereas the sophisticated configuration and management of these IT resources can be the source of such an advantage (Wade & Hulland, 2004). Apart from the strategic significance of IS, the operational relevance based on the creation of business value for the firm by either reducing the costs of internal processes or by enhancing the value of

products and services is at the heart of IS research (Mata *et al.*, 1995) because IT organizations have to give evidence for bottom line savings or top line revenues that result from IS projects and services (Harmon *et al.*, 2010). Accordingly, "the business value of investments in IS has been, and is predicted to remain, one of the major research topics for IS researchers" (Schryen, 2013, p. 2).

The business value of IS can be defined as "the impact of investments in particular IS assets on the multidimensional performance and capabilities of economic entities at various levels, complemented by the ultimate meaning of performance in the economic environment" (Schryen, 2013, p. 5). However, the relationship between IS and firm performance is complex and difficult to understand (Wade & Hulland, 2004). The RBV has become the dominant theory in this research stream because "it illuminates a clear path between strategic IS-related resources and measurable organizational outcomes" (Nevo & Wade, 2011, p. 403). IS research has only recently come to the conclusion that IS do not directly generate competitive advantages but generate business value through complementary organizational assets and capabilities, e.g., organizational transformation, efficient business processes, innovativeness, customer services, value chain integration, knowledge management or firm agility (Benitez-Amado *et al.*, 2010; Besson & Rowe, 2013). The external environment also has an influence on the generation of business value through IS. The central message of this research stream is that "if the right IS are applied within the right business process, improved processes and organizational performance result" (Melville *et al.*, 2004, p. 292).

Buchta *et al.* (2007) argue that companies move through four stages of IS value creation. In the first stage, the IS function is viewed primarily as a cost driver and thus executives focus on decreasing IS-related costs. In the second stage, the potential of IS to optimize business processes is recognized and IS indirectly support business strategy. The next stage is to increase sales with IS through innovation and enhanced customer services whereas the fourth stage describes companies which understand how to develop innovative business models and address new markets with the aid of IS.

Since this thesis focuses on aspects of value generation through environmental sustainability, specific facets of IS business value creation are of particular importance (Corbett, 2010). Most obvious, Green IS can enhance resource efficiency of internal business and production processes which generate business value through operational cost reductions (Ambec & Lanoie, 2008). Furthermore, the IS-enabled capability of innovativeness, which describes "the firm's ability to encourage creativity and the development of new products or business processes" (Benitez-Amado *et al.*, 2010, p. 88), is a key organizational capability for corporate sustainability. Another example is the IS-enabled Green Business Process

Management (BPM) capability, which concerns "the understanding, documenting, modeling, analyzing, simulating, executing, and continuously changing of business processes with dedicated consideration paid to the environmental consequences of these business processes" (vom Brocke *et al.*, 2012, p. 7). Prior research has shown the value-creating potential of IS in the scope of organizational transformations (Gregor *et al.*, 2006; Elliot, 2011), which are of particular importance for a sustainable development and which can be fostered by Green IS due to "the disruptive nature of IS innovations, the deep digitization of business and their cross-organization and systemic effects" (Besse & Rowe, 2012, p. 103).

In this thesis, the RBV has been useful for analyzing how Green IS resources and capabilities can generate business value and enhance firm competitiveness through IS-enabled organizational capabilities.

4.2.3 Information Systems Strategy

Owing to the digitization of products and services in conjunction with the rise of the internet, the potential to enable innovative business models, and the significance of IS for technological and organizational transformations, IS strategy has become an important subject on top management agendas during the last two decades (Teubner, 2013). In a recent study of the Wall Street Journal, 87 percent of executives stated that they perceive IS as being key to the strategic success of their business (Chen *et al.*, 2010b). As a consequence, IS strategy has become one of the major IS research streams (Chen *et al.*, 2010b). The dominant themes of this area, such as the strategic use of IS, the efficient management of IT infrastructures, the role of the IT department and its impact on organizational infrastructure and processes as well as the exploitation of innovative technologies for competitive differentiation (Croteau & Bergeron, 2001) are fundamental topics being addressed in this thesis. While the positive impact of IS strategies on firm performance has been revealed by prior studies (e.g., Leidner *et al.*, 2011), this research investigates the relationship between Green IS strategies and firm competitiveness.

As previously argued, the standardization and commodification of IT infrastructure resources have shifted the focus of IS-related competitive advantages to the configuration and management of such systems with the aid of sophisticated IS strategies, which leverage the strategic potential of IS (Henderson & Venkatraman, 1993; Leidner *et al.,* 2011). Most importantly, IS strategies "provide a focused strategic direction for the department [...] in order to make the right decisions in support of the company's desired strategic directions" (Lo & Leidner, 2012, p. 2).

The Strategic Grid, developed by McFarlan (1984), was the first conceptual model to assess the strategic role of IT within the organization. In this typology, four specific modes of IT management, depending on the specific needs of the organization, were

described: strategic, turnaround, factory, and support. Recent research differentiates between ideal profiles of the IS function, such as partner, systems provider, architecture builder, technological leader, or project coordinator (Guillemette & Paré, 2012).

In IS research, a large variety of strategies has been discussed (Teubner, 2013). Earl (1989) proposed to differentiate between information systems strategy (the interface to the business and its processes), information technology strategy (implementation- and technology-focused), and information management strategy (formalization of practices, processes and procedures). The IS strategy, which is focused on the alignment of IS with business goals, is of particular interest for this thesis.

According to Mintzberg's (1987) well-known strategy concept, a strategy can have different characteristics (strategy as a plan/ploy/pattern/position/perspective) while these different types of strategies can be seen as complementary. In their seminal and much-cited work on IS strategy, Chen *et al.* (2010b) draw on Mintzberg's Five Ps to conceptualize three different types of IS strategies, which have evolved in the scope of an extensive review of current IS literature (Table 3).

Table 3: Three Conceptions of IS Strategy Identified from IS Literature (Source: Chen *et al.*, 2010b, p. 239).

Conception: IS strategy as...	... the **use of IS** to support business strategy.	... the **master plan** of the IS function.	... the **shared view of the IS role** within the organization.
Definition of IS strategy	Position: For a chosen business strategy, how can IS be used to support business strategy/gain and sustain the targeted competitive advantage?	Plan: What IS assets (IS staff, IS process, infrastructure, applications, IS budget) are required and how to allocate the existing ones efficiently?	Perspective: What is our view towards IS within the organization?
Standpoint	Business-centric	IS-centric	Organization-centric
IS and business strategy relationship	IS strategy is developed as an inherent part of the business strategy.	IS strategy is viewed as functional level strategy.	IS strategy is an organizational level strategy.
Desired impact of IS strategy	Ensure business strategy is implemented and the desired strategic position of a business is achieved.	Identify IS assets requirements; ensure required assets are retrieved and effectively allocated.	Provide a shared understanding across the organization to guide subsequent IT investment and deployment decisions.
IS/business alignment	Intrinsic a priori alignment	Ex post alignment	Dynamic alignment

This thesis builds on Chen *et al.*'s (2010b) IS strategy conceptualization and argues that a holistic IS strategy should be formulated and implemented at the three

common management levels: *IS strategy as the master plan of the IS function* at the functional management level, *IS strategy as the use of IS to support business strategy* at the competitive level, and *IS strategy as the shared view of the IS role within the organization* at corporate level.

4.2.4 IT Governance

Due to the fact that strategic IS/business alignment and the delivery of IS business value are fundamental tasks of IT Governance, the concept of IT Governance is briefly introduced in this section although not all facets of IT Governance are covered in this thesis. According to the IT Governance Institute (2005, p. 10), "IT governance is the responsibility of the board of directors and executive management. It is an integral part of enterprise governance and consists of the leadership and organizational structures and processes that ensure that the organization's IT sustains and extends the organization's strategies and objectives." Jewer & McKay (2012) explain that IT Governance is important on account of the pervasiveness of IT in today's organizations and because of its significance for managing internal processes and the external business environment. Business and IS executives have the responsibility to assure that an appropriate IT Governance is in place. Central tasks of the IT Governance are (IT Governance Institute, 2005):

a) Strategic IS/business alignment
b) Delivery of IS business value
c) IT-specific risk management
d) IT resource management
e) IT performance measurement

Obviously, the new aspects of environmental sustainability will also have to be integrated into IT governance policies, procedures, structures and accountability systems (Webb *et al.*, 2006). Extended IT Governance will be important to leverage the potential of Green IS for environmental and competitive benefits (Wati & Koo, 2011). In particular, appropriate organizational roles and responsibilities have to be defined in executive steering groups (IS policies and priorities), IS/business strategy groups (identification of business needs and coordination of IS activities), and IT strategy groups (Ward & Peppard, 2002).

4.2.5 Strategic Alignment

For the creation of IS business value, as discussed previously, a sophisticated IS strategy is needed. However, to assure effectiveness ("doing the right things") and efficiency ("doing things right") of the IS function (Luftman, 2000, p. 6), IS strategies have to be aligned with the goals and strategies of the business (Henderson & Venkatraman, 1993). Strategic alignment aims at optimizing the

return on IS investments and leveraging the core resources and processes of the firm with IS to create competitive advantage. In addition, alignment is important to provide both a consistent strategic orientation and flexibility to the IS function to take advantage of technology-related business opportunities (Avison *et al.*, 2004).

Strategic alignment research draws on contingency theory and builds on the premise that the IS function will only be effective in generating business value if it is well-aligned with the business strategy (Kearns & Lederer, 2000). Owing to this IS/business alignment is central to IS strategy research. The concept of strategic alignment has been defined as "the degree to which the priorities, goals, and objectives of the IS strategy are aligned with the priorities, goals, and objectives of the firm's business strategy" (Oh & Pinsonneault, 2007, p. 244). While previous research viewed alignment as an outcome, recent literature considers alignment as a dynamic and continuous process (Avison *et al.*, 2004). The potential of IS investments can only unfold if IS are applied in a strategic context and if they consistently support the central business objectives and goals (Luftman, 2000; Hu & Huang, 2005). However, Oh & Pinsonneault (2007, p. 241) explain that "the relationship between IS, business strategy, and firm performance appears to be complex and findings have often been inconclusive." The consideration of environmental sustainability aspects in strategic alignment makes this already complex process even more challenging.

The practical importance of strategic alignment has been recognized since the 1970s. During the last two decades, it has even become the most important challenge for CIOs (Luftman & Derksen, 2012) and its relevance is continuously growing due to the rising pervasiveness of ICT (Hu & Huang, 2005), the rapid technological changes which can recently be observed (Leidner *et al.*, 2011) as well as the increasingly dynamic nature of market environments (McLaren *et al.*, 2011). Different modes of deploying IS throughout the enterprise can be distinguished while their suitability depends on the specific characteristics of the core business and its specific strategic targets (Croteau & Bergeron, 2001). Accordingly, a detailed understanding of a dynamic form of alignment between competitive strategies and IS capabilities is urgently required (McLaren *et al.*, 2011). Although being a critical success factor for leveraging the potential of IS to support or even shape business strategies (Croteau & Bergeron, 2001; Ragu-Nathan *et al.*, 2001), strategic alignment continues to be a major concern of IS executives while IS research offers only limited recommendations and solutions (Avison *et al.*, 2004).

Regarding strategic alignment in IS research, two specific research streams can be identified. The first research stream investigates the alignment of IS and business strategies, planning mechanisms, and organizational infrastructure and processes. As Henderson & Venkatraman (1993, p. 473) explain, "strategic alignment is not an

event but a process of continuous adaptation and change." In this context, the RBV and the theory of dynamic capabilities are appropriate theoretical lenses. According to these theories, a superior strategic alignment process can constitute a dynamic capability which is firm-specific and unique, thus leveraging core organizational resources and capabilities to create a sustainable competitive advantage (Kearns & Lederer, 2003).

The second strategic alignment research stream focuses on the social dimension of alignment, involving the actors and the mutual understanding between them, inter- and intra-organizational communication structures as well as knowledge exchange processes (Reich & Benbasat, 2000; Preston & Karahanna, 2009). This research stream focuses on social enablers and inhibitors of strategic alignment, e.g., top management support, good working relationships, or concerted strategic planning processes. The knowledge-based view is a suitable theoretical lens to study top managers' perception of technological possibilities and IS executives' awareness of business opportunities. The internal transfer and sharing of knowledge results in shared domain knowledge, which is an enabler of strategic alignment (Kearns & Sabherwal, 2007a).

This thesis adds to the body of knowledge in both research streams by analyzing each of the two perspectives in a distinct research article. The first article (Section 7) focuses on the integration of environmental aspects into the strategic alignment process, offering guidance to IS executives by proposing four specific modes of Green IS alignment. This work builds on the Strategic Alignment Model by Henderson & Venkatraman (1993), which is the most widely applied alignment framework in IS research and practice (Avison *et al.*, 2004). The second article (Section 8) investigates enablers and inhibitors that refer to the social dimension of strategic Green IS alignment, drawing on Reich & Benbasat's (2000) much-cited social dimension model (Hu & Huang, 2005).

4.2.6 Performance Measurement

To translate aligned Green IS strategies into corporate actions and to evaluate the achieved results, performance measurement systems (PMS), defined as "set of metrics used to quantify both the efficiency and effectiveness of actions" (Neely *et al.*, 2005, p. 1229), are useful due to two reasons (Simmons, 2000, p. 16):

- First, performance measurement systems provide the analytic discipline and communication channels to formalize business strategy and ensure that strategic goals are communicated through the business.
- Second, performance measurement systems are the primary vehicle to monitor the implementation of these strategies.

In the context of selecting and adopting IS-enabled environmental initiatives, measuring their effectiveness and efficiency is of particular importance. Only if current PMS are extended in such a way that IS and business executives consider both environmental and financial performance dimensions in their decision-making, the implementation of Green IS strategies will be successful (Perego & Hartmann, 2009). As pointed out by Epstein (1996, pp. 75–76), "the success of an environmental strategy implementation depends on accumulating, aggregating, measuring, and reporting information related to corporate environmental impacts to various managers within the corporation." Moreover, holistic PMS allow for transparency and communication of environmental performance outcomes towards external stakeholders (Perego & Hartmann, 2009).

The Balanced Scorecard (BSC), developed by Kaplan & Norton (1992), has become the most widely applied modern PMS. The BSC does not only rely on financial indicators but builds on different performance dimensions, which can be customized according to the firm's strategic requirements (Kaplan & Norton, 1996). As Figge *et al.* (2002, p. 269) explain, the BSC links "operational and non-financial activities with causal chains to the firm's long-term strategy, thus supporting the alignment and management of all corporate activities according to their strategic relevance." The traditional BSC builds on the four perspectives *innovation and learning*, *internal processes*, *customers*, and *financial*. The BSC can be understood as a future-oriented tool which assist in defining quantifiable targets from different performance perspectives and which is suitable for deriving adequate measures to implement a specific strategy.

Its multidimensionality and the possibility to customize the BSC has resulted in a wide range of modified BSCs (Petrini & Pozzebon, 2009). The BSC approach is particularly useful to integrate aspects of environmental sustainability into a single strategic management tool and it can provide a distinct IS-oriented perspective. Several research articles have discussed how a BSC can be adapted for IT management (IT-BSC) (e.g., van Grembergen, 2004) or for corporate sustainability management (SBSC) (e.g., Figge *et al.*, 2002). The research article presented in Section 9 is focused on this topic and illustrates how a Green-IT-BSC can be developed. This research emphasizes that the BSC is highly appropriate to hierarchically link goals, indicators and measures from different performance dimensions towards environmental and financial outcomes. The clearness of the presentation of cause-and-effect relationships and the linkages to high-level strategic objectives also facilitate a better communication of strategies and environmental goals throughout the enterprise and thus promote the implementation of such strategies.

4.3 Corporate Sustainability in Management Research

In 1987, the World Commission on Environment and Development discussed the social and environmental consequences of human activities and highlighted that the earth's ecosystem and, consequently, the future of mankind are endangered due to an unsustainable behavior (Ambec & Lanoie, 2008). In this context, sustainable development was defined as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Subsequent United Nations Conferences on Environment and Development brought the topic of sustainability to the political agenda and initiated a societal debate about resource depletion, industrial pollution, habitat destruction, population growth, and, in particular, the looming threats of climate change (Banerjee, 2002). The latest of these conferences, "Rio + 20", held in 2012, highlighted that the progress towards a sustainable society is far too slow. Hence, research and practice are needed to provide solutions that reduce social disparity and the over-exploitation of natural resources.

In the last decade, corporate sustainability has emerged as a new business "megatrend" (Lubin & Esty, 2010) and the topic increasingly influences corporate strategies (Petrini & Pozzebon, 2009). As a recent study (Kiron *et al.,* 2013b) with 2,600 executives from commercial enterprises shows, the topic of sustainability has found its way to the top management agendas. 20 percent of the respondents stated that sustainability is temporarily on the agenda, 39 percent said that sustainability is permanently on the agenda but not a core issue, and 26 percent answered that sustainability is already a permanent fixture on the top management agenda and a core strategic consideration. Another study, conducted by KPMG (2013), highlights that 93 percent of the 250 largest companies worldwide and 71 percent of the 100 largest companies from 41 nations (N100, 4,100 companies in total) report on their corporate sustainability activities.

> *"Sustainability is making every decision with the future in mind."*
>
> – Andrew N. Liveris, CEO, The Dow Chemical Company (in: DeGarmo *et al.*, 2011, p. 24)

Business firms are of critical importance because they are seen as key actors in the context of sustainable development due to their involvement, influence and global reach (Stern, 2006; Shrivastava *et al.*, 2013). Although companies are responsible for severe environmental impacts worldwide, they also have the ability to contribute to a sustainable future through corporate sustainability (Hart, 1995; Melville, 2010; Elliot, 2013). Corporate sustainability management "covers all systematic activities to measure, analyze and improve economic, social and environmental aspects of a company to (a) achieve a sustainable development of the organization and (b) enable the organization to create a relevant contribution to a sustainable development of

the economy and society, now and for the future" (Schaltegger *et al.*, 2013, p. 219). This definition reflects the triple bottom line approach, which takes the economic, environmental, and social performance of companies into account (Elkington, 1997).

Corporate social responsibility (CSR) is often used synonymously to corporate sustainability. CSR has been defined as "a comprehensive set of policies, practices and programs that are integrated into business operations, supply chains, and decision-making processes throughout a company, with the aim of incalculating responsibility for current and past actions as well as future impacts" (Petrini & Pozzebon, 2009, p. 179). CSR is similar to the corporate sustainability concept due to its consideration of external stakeholder interests, its long-term focus and its consideration of the triple bottom line (Petrini & Pozzebon, 2009). According to Carrol (1991), CSR concentrates on economic, legal, ethical and philanthropic responsibilities of the enterprise. McWilliam & Siegel (2006, p. 117) underline that CSR refers to "actions that appear to further some social good, beyond the interests of the firm and that which is required by law." As a consequence, being a good corporate citizen, demonstrating ethical behavior by protecting the environment and advocating for human rights are at the heart of CSR policies while competitiveness aspects are usually excluded.

Historically, government regulations and stakeholder pressures were the major drivers of corporate sustainability management (Porter & van der Linde, 1995). This is changing, however, with management perception shifting from regulation- and stakeholder-induced pollution prevention as a necessary evil to market-driven product innovations and technology changes that offer not only environmental and social benefits, but also economic opportunities, such as resource efficiency, cost reduction, new customer value and business models as well as long-term profitability (Banerjee, 2001; Orsato, 2006; Ambec & Lanoie, 2008; Albino *et al.*, 2009). Against this background, this thesis focuses on environmental sustainability aspects, and investigates the specific role of information systems in enabling corporate environmentalism, which has been defined as "the organization-wide recognition of the legitimacy and importance of the biophysical environment in the formulation of organization strategy" (Banerjee, 2002, p. 181).

With its increasing significance for the competitiveness of business firms, corporate environmentalism has evolved from being a complementary management task into an integral part of strategic management activities (Porter & Kramer, 2006; Schaltegger *et al.*, 2013). The role of environmental sustainability with its potential to create competitive advantages has become subject of intensified discussion among strategic management scholars (Hart, 1997; Sharma & Vredenburg, 1998; Christmann, 2000; Banerjee, 2001; Dyllick & Hockerts, 2002; Nidumolu & Prahalad, 2009). Several benefits can arise from environmental management

(Sharma & Vredenburg, 1998; Ambec & Lanoie, 2008; Hagström *et al.*, 2011; Kiron *et al.*, 2013b):

- Cost savings through enhanced resource efficiency of internal processes
- Higher profitability as a consequence of environmental product innovations that differentiate from competition
- Increased revenues because of access to new markets
- Increased market share due to improved corporate reputation
- Enhanced customer loyalty due to intensified stakeholder relationships
- Improved ability to attract and retain highly skilled employees
- Lower capital costs as a consequence of reduced environmental risks

To realize the potential of these competitive benefits, corporate sustainability strategies play an important role (Shrivastava, 1995b). Fundamentally, two distinct types of environmental strategies can be distinguished. On the one hand, companies can follow a process-oriented approach to decrease the environmental impacts of their internal operations. This strategy results in a reduction of operational costs through enhanced resource efficiency of business and production processes and thus allows for the realization of competitive cost leadership strategies (Chang, 2011). On the other hand, companies can pursue a market-oriented approach and optimize the environmental performance of their products and services during their entire lifecycle (Albino *et al.*, 2009). Based on the superior environmental characteristics, competitive differentiation strategies can be implemented (Stead & Stead, 2008). Importantly, both strategies, which build on the premises of Porter's generic competitive strategies (Section 4.1.1), have the potential to lead to the creation of competitive advantages through environmental process and product innovations (Christmann, 2000; Dangelico & Pujari, 2010).

The NRBV provides an appropriate theoretical perspective to analyze competitive effects of environmental management practices and strategies (Hart, 1995; Chang, 2011). Sharma & Vredenburg (1998, p. 730) explain that "innovative environmental strategies can lead to the development of firm-specific capabilities which can be sources of competitive advantage." As a consequence, environmental sustainability is increasingly being integrated into strategic decision making (Shrivastava *et al.*, 2013).

Certainly, the creation of competitive advantages is highly context-dependent and uncoordinated environmental sustainability initiatives without strategic coherence are ineffective (Banerjee, 2002). It is a complex challenge to leverage the competitive potential of sustainable business practices while decreasing negative environmental impacts. Environmental sustainability needs to be addressed with a holistic approach (Chen, 2011; Paulraj, 2011), involving the entire organization and

being part of corporate, competitive, and functional level strategies (Banerjee, 2001; Stead *et al.*, 2004; Chen *et al.*, 2010b). However, there is a high level of uncertainty with regard to the development of future technologies and the transformation of business activities towards markets that have yet to emerge (Elliot, 2011).

Based on the delineated sustainability challenges and opportunities, this thesis aims at exploring the role of IS to leverage the competitive potential of environmental sustainability. In particular, this research develops a typology of Green IS strategies (Section 10) and empirically assesses the impact of Green IS strategies and practices on firm competitiveness (Section 11).

4.4 Environmental Sustainability in IS Research

Corbett (2013, p. 341) describes the evolving Green IS research stream as follows:

> "Just as the importance of addressing environmental concerns has risen in the management literature, so too has environmental sustainability emerged as a key topic in the IS literature. Beyond initial analyses regarding the negative ecological impacts of information technologies, there is growing recognition that IS represents a potentially powerful positive force for dealing with climate change because IS has the ability to shape beliefs about the natural environment, is deeply embedded in organizations, and can transform business practices at all levels and across all functions. Green IS brings together work from a range of different IS sub-fields and unites them through the common interest in protecting the planet for future generations."

As outlined in Section 2.1, IT, on the one hand, is part of the environmental problem. The manufacturing of IT hardware requires rare and toxic resources, and it raises environmental and ethical issues because of the inhuman work conditions in the mining and assembly industry. The worldwide use of IT consumes vast amounts of electricity that induce significant carbon dioxide emissions, while the disposal of e-waste threatens the ecosystem (Elliot & Binney, 2008; Corbett, 2010). Since 2008, the negative environmental impacts associated with IT are addressed under the heading *Green IT* (Jenkin *et al.*, 2011; Harmon & Demirkan, 2011; Molla *et al.*, 2009), as defined in Section 1.2.

On the other hand, academics and practitioners acknowledge that IS are part of the solution and argue that *Green IS* are crucial enablers for corporate sustainability (see Section 1.2) (Watson *et al.*, 2008; Chen *et al.*, 2008; Dedrick, 2010; Melville, 2010; Thambusamy & Salam, 2010). Green IS support cross-functional capabilities and decrease the environmental footprint of the entire organization – through

environmental management systems, supply chain innovations, and the reengineering of business and production processes. Moreover, Green IS are not restricted to the boundaries of the organization, thus allowing for innovative, market-oriented products and services with reduced ecological footprints regarding their lifecycle (Watson *et al.*, 2010; Harmon & Demirkan, 2011). These products and services allow for competitive differentiation if the superior environmental characteristics are perceived and valued by customers (Albino *et al.*, 2009; Dangelico & Pujari, 2010; Mohrenfels & Klapper, 2012). However, the transformation of organizations and their business models with the help of Green IS will require a far-reaching long-term strategy (Dao *et al.*, 2011; Harmon & Demirkan, 2011; Molla *et al.*, 2011).

Unfortunately, executives are confronted with high levels of uncertainty when it comes to future challenges of environmental sustainability and how these should be addressed with IS-enabled solutions (Elliot, 2013). This uncertainty, in particular with reference to the economic long-term benefits of Green IS initiatives, inhibits the holistic implementation of Green IS practices (Shrivastava *et al.*, 2013). To date, the discussion about the competitive potential of Green IS has been largely anecdotal and lacks in empirical evidence (Jenkin *et al.*, 2011).

The IS research community has only lately started providing assistance to organizations so that they can progress towards environmental sustainability and respond to the challenges of climate change (Dao *et al.*, 2011; Molla *et al.*, 2011). Although scholars of management research have already paid a great deal of attention to corporate sustainability and the significance of Green IS has been widely acknowledged by practitioners and academics (Mithas *et al.*, 2010; Bengtsson & Ågerfalk, 2011), the strategic aspects of Green IS have hardly been analyzed by the IS research community (Jenkin *et al.*, 2011). Watson *et al.* (2010) urge the IS research community to clarify the role of IS and to engage decisively in the investigation of IS capabilities that have the potential to make business and manufacturing processes more environmentally friendly.

As described in Section 2, the focus of the research discipline has shifted from *first wave* Green IT practices with an internal orientation, targeting operational cost reductions, to enterprise-wide *second wave* Green IS initiatives with an external market perspective, aiming at the creation of competitive advantages through innovation and differentiation. Unfortunately, current Green IS practices are implemented in an unorganized and unstructured manner while neither being aligned with strategic goals nor being integrated with corporate level strategies (Harmon *et al.*, 2010; Lubin & Esty, 2010). As a consequence, Green IS strategies are now required to foster technological product and process innovations that

advance corporate sustainability and create new market opportunities (Harmon & Demirkan, 2011).

For the identification of potential gaps in the Green IS research discipline, this thesis builds on a comprehensive literature review of 98 research papers conducted by Tushi *et al.* (2014), which reflects the current state of the field (Table 4). The majority of articles apply an organizational-level research perspective (Jenkin *et al.*, 2011; Tushi *et al.*, 2014). While most articles are of a conceptual nature, the few empirical studies mainly build on exemplary investigations of current practices based on case studies and surveys (Jenkin *et al.*, 2011; Tushi *et al.*, 2014). Lei & Ngei (2013) demonstrate in another literature review that numerous articles have analyzed the motivational factors that drive the adoption of Green IS.

However, as illustrated in Section 6.2 and Appendix B, many empirical research articles do not fulfill the highest standards of rigorous research (Jenkin *et al.*, 2011) and only a few exceptional articles have found their way into IS top-tier journals (e.g., Melville, 2010; Watson *et al.*, 2010; Dao *et al.*, 2011; Elliot, 2011; vom Brocke *et al.*, 2013b; Seidel *et al.*, 2013). For this reason, further high-quality empirical studies are urgently required (Brooks *et al.*, 2010).

Although several researchers have dealt with the question of what Green IT and Green IS are, theoretically grounded, clear and unambiguous definitions of the two concepts are still missing as a foundation for this immature research discipline (Brooks *et al.*, 2010). Tushi *et al.* (2014) also emphasize that the research field lacks theoretical frameworks to advance the cumulative IS research tradition.

Another crucial aspect which needs further investigation is the post-adoption phase of Green IS practices. Until now, empirical evidence for the positive impacts on competitiveness of far-reaching Green IS practices is still missing (Brooks *et al.*, 2010; Tushi *et al.*, 2014). This economic uncertainty is a main inhibitor of adopting enterprise-level Green IS initiatives (Dedrick, 2010; Krauss, 2010; Elliot, 2013).

Referring to the environmental competitive environmental strategies developed by Orsato (2006), Brooks *et al.* (2010) identify the creation of competitive advantages through alignment of Green IS strategies and the coherent implementation of Green IS initiatives as a new aspect which requires scholarly investigation. In particular, frameworks and recommendations for the concrete process of adopting Green IS are needed by executives. Consequently, Green IS strategy typologies should be developed by IS researchers while alignment frameworks are needed to assure strategic fit and coherence (Harmon & Demirkan, 2011; Jenkin *et al.*, 2011).

Table 4: Categorization of Green IS research publications and identification of research gaps (adopted from Tushi *et al.*, 2014).		
Category	**Topic**	**# of published articles**
Green IT and IS	What is Green IT/IS?	6
Environmental impact of IT and IS	How does IT affect environmental sustainability?	12
	How can Green IS help to promote environmental sustainability?	18
Motivation	Green IS for operational cost reduction	7
	Green IS for environmental sustainability	7
	Green IS for innovation and market differentiation*	-
	Green IS for regulatory compliance	2
Implementation stage	Pre-adoption	14
	Adoption	11
	Post-adoption	1
Initiatives	Technical solution	8
	Soft solution	9
Adoption level	Macro level	1
	Organizational level	7
	Individual level	7
Pre-implementation	Awareness	2
	Organizational readiness	3
	Organizational capability to adopt Green IS	3
	Green IS strategies*	-
Challenges	Cost of implementation	2
	Conflicts between sustainability and IT performance	1
	Alignment of IS and environmental strategies*	-
	Uncertainty with regard to economic impacts of Green IS initiatives*	-
	Siloed thinking due to departmental roles and responsibilities*	-
	Measurement of economic, environmental and IT performance impacts*	-
Others	Literature review	10
	Creation of business value and competitive advantage with corporate sustainability	1
	Unaddressed concerns	2
* Extensions based on research suggestions made by other authors, as explained in the text. Lines highlighted in grey = research gaps addressed in the scope of this thesis		

Concerning the negative and positive environmental impacts of IS, a clearly defined ownership is still missing in organizations. In many companies, the IT department is not accountable for the energy consumption of data center facilities and IT equipment in offices. On the other hand, the IS function is not considered when corporate sustainability initiatives are developed. To overcome this siloed thinking

which inhibits the optimization of firm-wide resource use and the advancement of corporate sustainability, the definition of roles, responsibilities and communication structures is required (Jenkin *et al.*, 2011).

Furthermore, a detailed understanding of the environmental and economic impact is mandatory to advance corporate sustainability. Accordingly, there is a need for performance measurement frameworks which allow for a holistic evaluation of different performance dimensions (Jenkin *et al.*, 2011; DeGarmo *et al.*, 2013).

Finally, the relationship between adopting Green IS strategies and practices and firm competitiveness has to be investigated. In management research, several articles have conceptually and empirically analyzed the impacts of environmental initiatives on the creation of competitive advantages (Shrivastava, 1995a; Orsato, 2006; Porter & Kramer, 2006; Berns *et al.*, 2009; Lubin & Esty, 2010). However, while management research can build on established concepts and theories, the competitiveness-related effects of adopting Green IS have not been assessed by IS researchers yet (Jenkin *et al.*, 2011).

5. Research Methodology

5.1 Research gaps & research goals

With reference to the first step of the research process (see 1.4), the description of the practical problem (Section 2 and Section 3), it can be concluded that Green IS are perceived as potential technological enablers of corporate sustainability while the adoption of far-reaching initiatives has been slow owing to prevailing economic uncertainties and due to the lack of appropriate management frameworks. For this reason, well-grounded conceptual research and empirical studies are required to generate practice-relevant insights:

- Identification of business challenges that arise from the new sustainability paradigm and evaluation of technology-related opportunities to meet these challenges (Chen *et al.*, 2008; Lubin & Esty, 2010).
- Practical recommendations on how to achieve a balance between negative environmental impacts of IT manufacturing, IT operations, and IT disposal, and positive impacts of Green IS as key enablers of a sustainable economy and society (Watson *et al.*, 2010).
- Reduction of the economic uncertainty regarding the business case of investing in Green IS initiatives (Dedrick, 2010).
- Development of frameworks for a holistic management of information systems for environmental sustainability (Brooks *et al.*, 2010).
- Definition of distinct environmental strategies for the IS function to leverage the competitive potential of Green IS practices; advice on how to align these strategies with corporate sustainability goals (Harmon *et al.*, 2010).
- Definition of roles and responsibilities at different organizational levels to leverage the firm-wide potential of Green IS and to assure a coherent implementation (Jenkin *et al.*, 2011).

As illustrated in the second step of the research process (see 1.4), the Green IS research stream has only recently emerged as a meaningful field within IS research and several issues have to be addressed to advance this discipline. Based on the extensive review of Green IS articles and related literature (Section 4), the following need for further research has been identified:

- There is a lack of meaningful theories and conceptual frameworks for sustainable information systems management in IS research. Although the new Green IS research discipline has demonstrated first significant achievements, the field needs to be rapidly advanced to address the most important challenge of the 21st century (Melville, 2010; vom Brocke *et al.*, 2013b; Tushi *et al.*, 2014).
- IS research has been criticized for not providing sufficient assistance to organizations in progressing towards environmental sustainability (Watson *et al.*, 2010). In this context, the cross-functional role of the CIO in fostering

enterprise-wide corporate sustainability initiatives has to be clarified (Melville, 2010).

- High levels of uncertainty concerning future technologies and the transformation of business activities towards markets that have yet to emerge inhibit far-reaching Green IS initiatives. In particular, empirical evidence regarding the economic effectiveness of Green IS initiatives is missing (Jain *et al.*, 2011; Elliot, 2013).
- Strategic aspects of Green IS have hardly been analyzed by the IS research community and there are no frameworks or guidelines on how the strategic potential of Green IS can be leveraged (Jenkin *et al.*, 2011; Corbett, 2013). In this context, a transdisciplinary research approach, which integrates knowledge and established concepts from Strategic Management Research, Corporate Sustainability Research, and Information Systems Research, is required (Shrivastava *et al.*, 2013).

In a seminal article published in the *MIS Quarterly*, Elliot (2011) presents a thorough analysis of environmental sustainability challenges and their significance for IS research. He emphasizes that business companies are the most important actors to induce a shift towards an environmentally sustainable economy and society. In a far-reaching review of 140 research articles from environmental, societal, governmental, and organizational literature he assesses the potential contributions IS research could make. He criticizes the narrow focus and limited scope of current research, which appears to be inadequate due to the complexity, transdisciplinarity, and multifaceted nature of environmental sustainability challenges. Elliot gives advice on how to advance the theoretical and practical knowledge in this important field.

To reveal how specific research gaps, identified by Elliot (2011), are addressed in this thesis, the relevant research gaps were structured and classified according to the four overarching research goals of this thesis (Section 1.3). In addition, the identified research gaps were matched with the six research articles of this thesis (B6, B7, B8, B9, C10 and C11). As a result, Table 5 gives a compact overview of how this research contributes to addressing practical and theoretical research gaps and how each of the six publications contributes to achieving the four high-level research goals which were formulated in Section 1.3.

Table 5: Selecting, classifying, and matching the identified research gaps with the four goals and six research articles of this thesis.

Research gap (identified by Elliot, 2011, pp. 221–223)	Research article (Section)					
	B6	**B7**	**B8**	**B9**	**C10**	**C11**
Research goal #1: Definition of terms and clarification of concepts (terminology)						
Gap 1.1: Lack of theoretical development in IS research.	X					
Gap 1.2: Much of the prior work is speculative and lacks theoretical grounding.	X		X			X
Gap 1.3: Need for a transdisciplinary approach at the conceptual level.		X		X		X
Research goal #2: Locate uncertainties and analyze organizational impacts (challenges arising)						
Gap 2.1: Analysis of the relevance of IS to address major challenges in environmental sustainability.	X					X
Gap 2.2: IS research should foster a holistic approach for a fundamental transformation of business towards sustainability.	X	X		X	X	
Gap 2.3: Analysis of the role of individuals and groups within organizations as catalysts of organizational change.			X			
Gap 2.4: Possible applications of IS to promote a shared understanding of environmental sustainability issues.			X			
Research goal #3: Understand cause-and-effect relationships (current responses)						
Gap 3.1: Development of academic theory based on observations of industry challenges and experiences.	X				X	
Gap 3.2: Investigation of technological developments and determination of the nature of their impact.	X			X		X
Gap 3.3: Practice-oriented research, e.g., identification of best practices in the scope of cross-sectional case studies.					X	
Gap 3.4: Need for a transdisciplinary approach at empirical levels.					X	X
Research goal #4: Guidance for the development of critical resources and capabilities and identification of possible implementation measures and initiatives (future actions)						
Gap 4.1: Reduction of the uncertainty with regard to the business case of environmental sustainability actions.						X
Gap 4.2: Efforts to increase organizational capabilities for technological innovations, which are perceived as key enablers for a sustainable development.					X	X
Gap 4.3: Tools for planning, implementing and evaluating organizational initiatives.	X	X		X	X	
Gap 4.4: Development of meaningful frameworks and models which are compelling to business.	X	X			X	

5.2 Research characteristics

The main goal of IS research is the development and communication of "knowledge concerning both the management of information technology and the use of information systems for managerial and organizational purposes" (Zmud, 1997, p. XXI). In this context, Gregory & Muntermann (2011, p. 2) emphasize that it is mandatory to "improve and ensure the practical relevance of our research while employing and maintaining a rigorous research approach to generate new theoretical insights." Applegate (1999) argues that assuring and balancing rigor and relevance is key to IS research. In this context, Benbasat & Zmud (1999) propose four specific aspects of relevant research:

a) Enduring or current organizational problem, challenge, or dilemma.
b) Implications can be put into practice to resolve problems or exploit opportunities.
c) Synthesis of existing research: classification or categorization.
d) Stimulation of critical thinking: challenge assumptions or identify emerging trends.

To assure the relevance of this research, these criteria were taken into account and each aspect is addressed by at least two of the six research articles (Part B & C).

With reference to the Green IS research stream, Melville (2010, p. 3) notices that "the IS perspective in research on environmental sustainability is nascent, despite the critical role of information systems in improving the natural environment and addressing climate change." This observation is confirmed by other researchers (e.g., Brooks *et al.*, 2010; Jenkin *et al.*, 2011; Ortwerth & Teuteberg, 2012; Tushi *et al.*, 2014) who argue that the evolving Green IS research stream is mainly based on descriptive and interpretative textual analyses while the discipline still lacks theory development, rigorous empirical studies, and applicable management frameworks. As a consequence, this thesis adds to the body of Green IS research by developing theoretically-grounded concepts and by delivering solution-oriented, applicable management frameworks, thus creating relevant knowledge for both academics and practitioners.

As revealed in the previous sections, the areas of environmental sustainability, strategic management, and IS research are intertwined. Whereas the business value of IT and IS has been studied extensively (Melville *et al.*, 2004; Wade & Hulland, 2004; Kohli & Grover, 2008), the contribution of Green IS to environmental goals, economic performance and long-term competitiveness is mainly discussed on a theoretical basis and there is still a lack of empirical evidence (Melville, 2010; Mithas *et al.*, 2010). IT and IS have the potential to drive environmental innovations and corporate environmentalism, but to do so, research and practice have to explore the strategic dimension of corporate sustainability transformations. The strategic

potential of Green IS can only be understood by transdisciplinary research involving the domains of environmental sustainability and strategic management (Shrivastava *et al.*, 2013). Schaltegger *et al.* (2013) differentiate between multi-, inter- and transdisciplinarity and refer to Lang *et al.* (2012, p. 27), who describe transdisciplinary research as "a) focusing on societally relevant problems; (b) enabling mutual learning processes among researchers from different disciplines, as well as actors outside from academia; and (c) aiming at creating knowledge that is solution-oriented, socially robust and transferable to both scientific and societal practice." Correspondingly, this thesis can be classified as transdisciplinary research.

Drawing on Elliot's (2011, p. 210) research classification scheme, this thesis focuses on a multifaceted research issue and can be characterized as a transdisciplinary study that includes the environment (environmental impacts of IT and IS, ecological footprint of organizations, products and services), economics (performance and competitiveness impacts), information systems (increased process efficiencies and information effectiveness through technology-enabled business transformation), and management (frameworks for organizational change and sustainability transformations). These multifaceted issues are addressed in the scope of twelve research questions, which are displayed in Table 6 in the overview of research articles (Section 5.4).

After having defined the research focus, the unit of analysis should be identified. Melville (2010, p. 14) explains that "by virtue of their dominance in the global economy, business organizations play a critical role in mitigating climate change and promoting environmental sustainability." In a similar vein, Elliot (2011, pp. 269–270) argues that "current business practices contribute to the problem of the deteriorating environment [...] [while] business is also the critical enabler of solutions. Companies possess the knowledge, resources, capabilities and reach to affect change within and across nations to an extent that is beyond individual governments and societies." Building on these important arguments, the chosen unit of analysis of this research is business organizations.

5.3 Research methods

To characterize the research methods that were used in the scope of this work, one can differentiate between empirical research, which assesses observations and relies on data, and non-empirical research, which focuses on ideas and concepts for building theories and frameworks (Alavi *et al.*, 1989). Chen & Hirschheim (2004) examined 1,893 articles from eight major IS journals, 60 percent of which could be classified as non-empirical while 40 percent built on empirical studies. The authors further explain that emerging research fields are usually dominated by non-empirical theory-building efforts while theory-testing empirical studies are more

prevalent in mature disciplines. This observation holds true for the immature Green IS research discipline (as described in Section 4.4). Such being the case, this thesis consists of four non-empirical, conceptual articles and two empirical studies. One of these empirical studies is of explorative theory-building nature while the other can be classified as theory-testing quantitative research, as illustrated in Table 7 in the overview of research articles (Section 5.4).

In addition, research can be classified as either behavioral- or design-oriented (Wilde & Hess, 2007). As described by Hevner *et al.* (2004, p. 75), "the behavioral-science paradigm seeks to develop and verify theories that explain or predict human or organizational behavior. The design-science paradigm seeks to extend the boundaries of human and organizational capabilities by creating new and innovative artifacts." While the justification and testing of theories (behavioral science) is aimed at truth, the central goal of building and evaluating artifacts (design science), such as constructs, models, methods, and instantiations, is utility. Obviously, both paradigms have their own raison d'être and can be seen as complementary (Hevner *et al.*, 2004). In line with this, this thesis consists of both behavioral- and design-oriented research articles.

Since the development of practice-oriented management frameworks is central to this research, the majority of articles can be assigned to the design-oriented paradigm (see Table 7). These articles are focused on defining constructs, which "represent a vocabulary of a domain and provide the means to describe problems", and on developing models, which "provide a basis to describe and explore the relationship between different constructs of interest" (Gregory & Muntermann, 2011, p. 4). This research corresponds to the guidelines of design science research, as articulated by Hevner *et al.* (2004, p. 82), by creating innovative and purposeful artifacts for specified problem domains which yield utility and solve unsolved problems. The utility of the artifacts has been evaluated through observational case studies in real-life business environments as well as through descriptive informed arguments from the IS research knowledge base. The constructs and models have been defined in a scientifically rigorous and formally representative way. As a consequence, they have become both coherent and internally consistent (Hevner *et al.*, 2004). Finally, the results have been communicated effectively to technical and managerial audiences, i.e., through both scientific and practitioner conferences, scholarly journals, as well as through industry projects and through a management-oriented book on sustainable information systems management which will be published subsequent to this thesis.

Four non-empirical articles are presented in Part B of this thesis (see Table 7). The first of these articles is a literature review, which is seen as a crucial first step towards conducting scholarly research to delineate the boundaries of the research

project, to identify and describe key concepts, and to motivate the distinct research topic (Webster & Watson, 2002). In addition, the literature review should exhibit four specific characteristics, as proposed by Levy & Ellis (2006, p. 182): "a) methodologically analyze and synthesize quality literature, b) provide a firm foundation to a research topic, c) provide a firm foundation to the selection of research methodology, and d) demonstrate that the proposed research contributes something new to the overall body of knowledge or advances the research field's knowledge-base." The literature review, which is presented in Section 6, derives well-grounded definitions for the concepts Green IT and Green IS and proposes a framework for the holistic management of IS-enabled environmental initiatives. These conceptual outcomes are complemented by a comprehensive list of Green IT measures and Green IS initiatives. The theoretical and managerial contributions of this work have been acknowledged with the AMCIS 2013 Best Paper Award.

Wilde & Hess (2007) classify IS research methods being applied in the German-speaking Wirtschaftsinformatik research community. They show that conceptual-deductive research represents around 10 percent of publications whereas argumentative-deductive analyses are the most prevalent type of research with 35 percent of publications. Referring to this classification scheme, the second non-empirical article (Section 7) can be classified as conceptual-deductive analysis. Drawing on strategic management theory and building on Orsato's (2009) competitive environmental strategies as well as Henderson & Venkatraman's (1993) Strategic Alignment Model (SAM), this article proposes a Strategic Green IS Alignment Framework.

The third article, which can be found in Section 8 in Part B of this thesis, utilizes an argumentative-deductive analysis as research method and applies the knowledge-based view to the Green IS strategic alignment context to identify critical roles and communication processes.

The fourth non-empirical article can be classified as conceptual-deductive analysis and builds on a multi-criteria decision analysis to evaluate the utility of established performance measurement and strategy implementation systems. The conceptually developed Sustainability BSC for the IT2Green-funded research project *Green IT Cockpit* is based on Kaplan & Norton's (1992) Balanced Scorecard (BSC) approach.

With regard to empirical studies, IS research builds either on the positivist (81 percent of studies published in major international IS journals) or the interpretivist (19 percent) paradigm (Chen & Hirschheim, 2004). Melville (2010) emphasizes that each of the two philosophical perspectives is beneficial in its own way to advance the knowledge in IS research. Positivist research usually draws on hypothetic-deductive theory and causal relationships that can be tested with quantitative methods to derive objective, value-free, generalizable results with intersubjective validity.

Interpretivist research, on the other hand, builds on empirical evidence from a non-deterministic perspective to understand specific human and social interactions in organizational contexts. As a consequence, researchers engage in social settings to conceive the viewpoint and interpretation of the observed actors, such as IS executives. Accordingly, case studies, which facilitate an in-depth understanding of a real-world situation, are a common qualitative method[1] for interpretivist research (Orlikowski & Baroudi, 1991; Chen & Hirschheim, 2004).

In addition to their philosophical assumptions, empirical studies can be classified concerning their fundamental approach to make empirical observations in a quantitative or qualitative manner (Venkatesh *et al.*, 2013). Interestingly, US-based IS research mainly builds on quantitative research methods (71%) whereas European journals also publish many qualitative articles (49%) (Becker & Niehaves, 2007). Until the 1990s, IS research was dominated by quantitative research, which focuses on numerical and statistical analyses to verify or falsify hypotheses which describe the relationship between clearly specified constructs (Sarker *et al.*, 2013). Qualitative research, on the contrary, builds on observations of social phenomena, interviews, and organizational documents. This type of research has gained in importance in the last two decades due to the "shift from technological to managerial and organizational issues" (Myers, 1997, p. 241) in IS research.

Kaplan & Duchon (1988) argue that the combination of both qualitative and quantitative research can result in rich and meaningful insights for IS research and practice. In this context, the authors argue that qualitative methods are useful for theory building while quantitative methods can be applied for theory testing. Consequently, the two empirical studies, which are presented in Part C of this thesis, follow an exploratory mixed method research approach (Venkatesh *et al.*, 2013), as illustrated in the overview in the following section (Table 7). The consolidation of the findings from these two contrasting empirical research approaches results in an in-depth understanding of the analyzed research topic.

The first empirical study (Section 10) is an exploratory, multiple-case study analysis, which draws on an interpretivist perspective and relies on the triangulation of qualitative data. Case research is particularly useful when "a phenomenon is broad and complex, when a holistic, in-depth investigation is needed, and when a phenomenon cannot be studied outside the context in which it occurs" (Dubé & Paré, 2003, p. 598). Since case studies can be exploratory, explanatory or descriptive, they can be applied to achieve various goals. In this thesis, case research is used to derive a typology of Green IS strategies in the scope of a theory-building approach (Eisenhardt, 1989). A typology "identifies multiple ideal profiles, each of

[1] It should be noted that positivist research can also make use of qualitative methods (Kaplan & Duchon, 1988). Likewise, qualitative case studies can draw on positivist, interpretivist, or critical philosophy (Dubé & Paré, 2004).

which describes a unique combination of attributes. These ideal profiles are theoretical abstractions thought to result in a specified level of outcome" (Guillemette & Paré, 2012, p. 531). Strategy typologies have received a lot of attention in strategic management theory, e.g., Porter's (1980) typology of generic strategies or Miles & Snow's (1978) typology of organizational strategies (Chan & Huff, 1992).

The second empirical study (Section 11) represents the positivist research tradition and evaluates quantitative data from a cross-sectional survey that was targeted at CIOs and top IS executives. To test the proposed research model, which hypothesizes specific cause-and-effect relationships between environmental firm orientation, Green IS strategies and practices, and firm competitiveness, the statistical technique of partial least squares structural equation modeling (PLS-SEM) is applied. This quantitative study provides detailed empirical insights into the relationship between the adoption of Green IS and the creation of competitive advantages and thus proves to be valuable to advance both, the theoretical understanding of underlying mechanisms and the implementation of IS-enabled sustainability initiatives in practice.

5.4 Overview of research articles

This section completes the introductory Part A of this research by providing an overview of the research articles that constitute the main body of this cumulative dissertation and by consolidating their specific methodological characteristics that were described in the previous section. In Table 6, the research questions, which have been formulated to address the identified research gaps (Section 5.1) and to achieve the declared goals of this research (Section 1.3), are assigned to specific research articles. In Table 7, the six research articles are classified according to the general type of research, the scientific orientation, the observational perspective, the utilized research method and the underlying theoretical assumptions. Finally, Table 8 provides a brief overview that contains the title, the publication outlet, and the authors of each of the six publications.

The four non-empirical articles will be presented in Part B (Sections 6–9) while the two empirical studies constitute Part C (Sections 10–11) of this thesis.

Table 6: Specific research questions addressed in the six research articles of this thesis.

Section	Research question	
Part B: Theory-based conceptual research		
B6	RQ B6.1:	How can the concepts of Green IT and Green IS be unambiguously defined on the basis of prevalent literature to clearly illustrate the differences between these two concepts?
	RQ B6.2:	How can IS-related environmental impact areas be classified to allow for a holistic and structured management of Green IS practices?
	RQ B6.3:	Which Green IT measures and Green IS initiatives can be identified in research and practice?
B7	RQ B7:	How can aspects of environmental sustainability be integrated into strategic IS alignment?
B8	RQ B8:	Which organizational actors are involved in the internal transfer of knowledge between organizational units being relevant for Green IS alignment?
B9	RQ B9:	How can economic, environmental, and IT performance impacts be integrated into a holistic performance management framework that prevents a one-sided focus on cost aspects?
Part C: Empirical research		
C10	RQ C10.1:	How can the concept of Green IS strategy be defined and which specific characteristics does it have?
	RQ C10.2:	What different types of Green IS strategies can be identified in a real-life context?
	RQ C10.3:	How do firms with distinct Green IS strategies conceive the role of Green IS within their organization?
C11	RQ C11.1:	Does corporate environmentalism lead to the adoption of Green IS?
	RQ C11.2:	Does the adoption of Green IS affect firm competitiveness?
	RQ C11.3:	How does the adoption of first-, second-, and third-degree Green IS practices generate business value and increase firm competitiveness?

Table 7: Classification of research articles and characteristics of the applied research methods.

Research article	Type of research	Scientific orientation	Observational perspective	Research method	Underlying theoretical assumptions
Part B: Theory-based, conceptual research					
B6	Non-empirical	Design	-	Literature review	Environmental sustainability in IS research
B7	Non-empirical	Design	-	Conceptual deductive analysis	Competitive Positioning, RBV, IS Strategy, IS/Business Alignment
B8	Non-empirical	Behavioral	-	Argumentative deductive analysis	KBV, IS/Business Alignment
B9	Non-empirical	Design	-	Conceptual deductive analysis	IS Performance Measurement, Balanced Scorecard
Part C: Empirical research					
C10	Qualitative empirical	Design	Interpretivism	Explorative multiple-case study analysis	Competitive Positioning, RBV, Strategic Management Theory
C11	Quantitative empirical	Behavioral	Positivism	Survey, PLS-SEM analysis	RBV, NRBV, IS Business Value, IS Strategy

Table 8: Overview of research articles.			
Section	**Title**	**Published in**	**Author(s)**
Part B: Theory-based conceptual research			
B6	Green IT and Green IS: Definition of Constructs and Overview of Current Practices	Proceedings of the 19th Americas Conference on Information Systems (AMCIS 2013), Chicago, USA *Best Paper Award*	**Loeser, F.**
B7	Aligning Green IS with Environmental Strategies: Development of a Conceptual Framework that Leverages Sustainability and Firm Competitiveness	Proceedings of the 17th Americas Conference on Information Systems (AMCIS 2011), Detroit, USA	**Loeser, F.**, Erek., K., Schmidt, N.-H., Zarnekow, R. & Kolbe, L. M.
B8	Shared Domain Knowledge in Strategic Green IS Alignment: An Analysis from the Knowledge-Based View	Proceedings of the 46th Hawaii International Conference on Systems Sciences (HICSS 2013), Maui, USA	**Loeser, F.**, Erek, K., Limbach, F. & Zarnekow, R.
B9	Information and Communication Technologies for Sustainable Manufacturing: Evaluating the Capabilities of ICT with a Sustainability Balanced Scorecard	Proceedings of the 10th Global Conference on Sustainable Manufacturing (GCSM 2012), Istanbul, Turkey	**Loeser, F.**, Grimm, D., Erek, K. & Zarnekow, R.
Part C: Empirical research			
C10	Towards a Typology of Green IS Strategies: Insights from Case Study Research	Proceedings of the 33rd International Conference on Information Systems (ICIS 2012), Orlando, USA	**Loeser, F.**, Erek, K. & Zarnekow, R.
C11	Enhancing Firm Competitiveness with Green IS: An Empirical Analysis of the Antecedents and Consequences of Adopting Green IS	Information Systems Journal's (ISJ's) Special Issue on Information Systems addressing the Challenges of Environmental Sustainability (original submission 15th August 2013; revision submitted on 31st March 2014; under review)	**Loeser, F.**, vom Brocke, J., Molla, A. Zarnekow, R. & Erek, K.

B. THEORY-BASED CONCEPTUAL RESEARCH

Table 9: Theory-based research articles.			
Section	**Title**	**Published in**	**Author(s)**
B6	Green IT and Green IS: Definition of Constructs and Overview of Current Practices	Proceedings of the 19th Americas Conference on Information Systems (AMCIS 2013), Chicago, USA *Best Paper Award*	**Loeser, F.**
B7	Aligning Green IS with Environmental Strategies: Development of a Conceptual Framework that Leverages Sustainability and Firm Competitiveness	Proceedings of the 17th Americas Conference on Information Systems (AMCIS 2011), Detroit, USA	**Loeser, F.**, Erek., K., Schmidt, N.-H., Zarnekow, R. & Kolbe, L. M.
B8	Shared Domain Knowledge in Strategic Green IS Alignment: An Analysis from the Knowledge-Based View	Proceedings of the 46th Hawaii International Conference on Systems Sciences (HICSS 2013), Maui, USA	**Loeser, F.**, Erek, K., Limbach, F. & Zarnekow, R.
B9	Information and Communication Technologies for Sustainable Manufacturing: Evaluating the Capabilities of ICT with a Sustainability Balanced Scorecard	Proceedings of the 10th Global Conference on Sustainable Manufacturing (GCSM 2012), Istanbul, Turkey	**Loeser, F.**, Grimm, D., Erek, K. & Zarnekow, R.

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

Title	Green IT and Green IS: Definition of Constructs and Overview of Current Practices
Authors	Fabian Loeser[1] [1] Institute of Information Systems Management, Technische Universität Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany
Published in	Proceedings of the 19th Americas Conference on Information Systems (AMCIS 2013), Chicago, USA
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.

6.1 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 & 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 *et al.*, 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 & Esty, 2010) and is associated with superior efficiency of production processes (Porter & van der Linde, 1995) and innovations that will change the competitive landscape and create future markets (Nidumolu *et al.*, 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 *et al.*, 2008).

Unfortunately, the lifecycle of IT equipment is associated with several negative environmental impacts (Elliot & 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 *et al.*, 2011; Watson *et al.*, 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 *et al.*, 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 *et al.*, 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 & 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.

6.2 Analyzing the status quo of Green IT and Green IS literature

6.2.1 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 10 presents an advanced analysis of search results.

Table 10: Classification of research results from the AIS eLibrary (AISeL).

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

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 10).

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 16). 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 10).

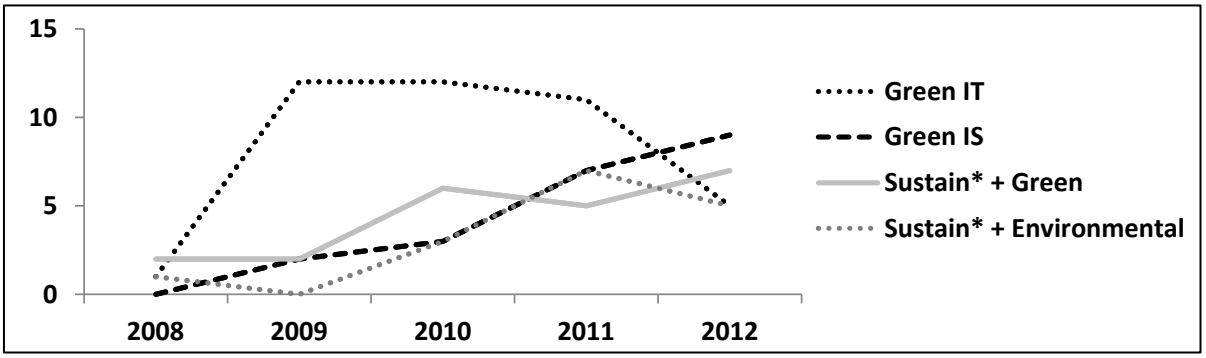

Figure 16: Number of publications in Green/Sustainable IT/IS research from 2008 to 2012.

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 10) 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 10 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.

6.2.2 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 B). 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 & Hirschheim, 2004) and their focus (Green IT or Green IS), as displayed in Table 11. 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 Appendix B.

Table 11: Research methods of the analyzed Green IT and Green IS articles.

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

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 B. 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 (February 15, 2013). 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 12.

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 12 and in Appendix B. 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.*, 2010) as well as enabling innovations for environmentally-friendly end products (Buchta *et al.*, 2007; Chen *et al.*, 2008).

Table 12: Most-cited Green IT/IS research papers.

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, informating (up and down) and transforming organizations, respectively.

Referring to this classification scheme, the most-cited definitions of Green IT and Green IS (Table 12) 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 13. 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.

Table 13: Functional impact areas of Green IT and 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

6.2.3 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 & 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 *et al.*, 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.*, 2010b, 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 & Weill, 1997; Ravichandran & 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:

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

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

- Reengineering of business and production processes.
- Implementation of IS-based environmental management systems (EMS).
- Innovations for environmental technologies in end user products and services.
- 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 & 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 17 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.*

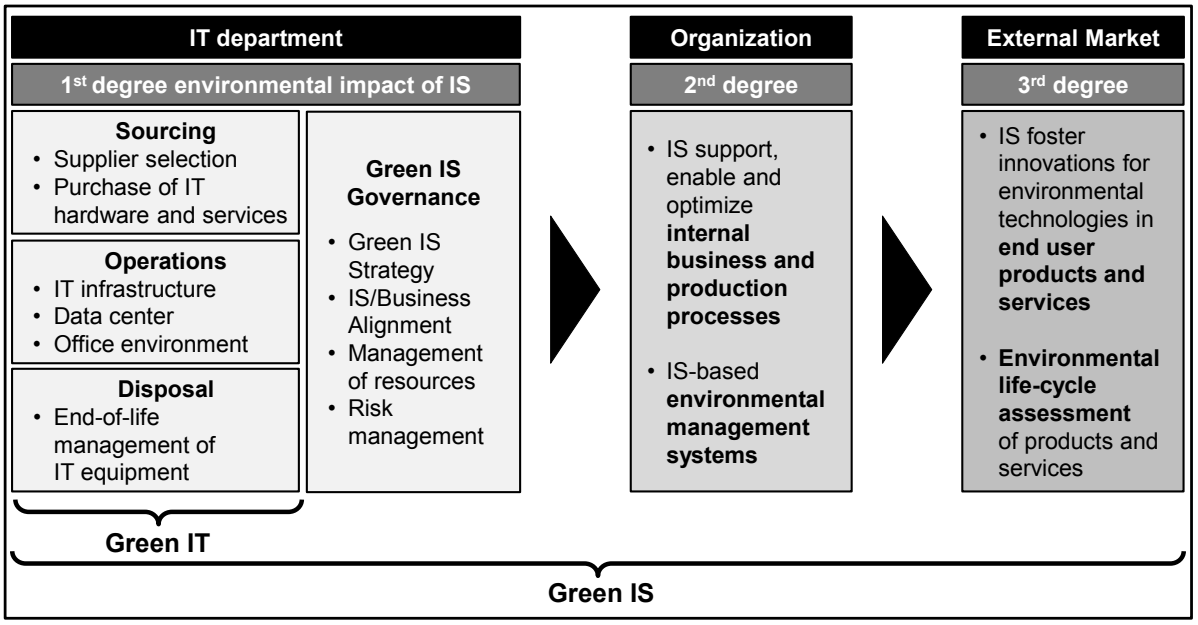

Figure 17: Scope of Green IT and Green IS.

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.*

(2010b). As elucidated in Figure 17, Green IT is an integral component of the encompassing concept of Green IS.

6.2.4 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 17), a wide range of literature from academics (e.g., Corbett, 2010; Molla *et al.*, 2011; Sayeed & Gill, 2011; Watson *et al.*, 2008) and practitioners (e.g., Krauss, 2010; Lamb, 2009; Murugesan, 2008; Ruth, 2009; Velte *et al.*, 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 14.

Table 14: Catalogue of Green IT measures.

Process	Scope	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 Operations	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

Table 14 (continued): Catalogue of Green IT measures.

Process	Scope	Focus	Measures and initiatives	
IT Operations	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

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 17) were analyzed in both, academic literature (e.g., Molla *et al.*, 2009; Fradley *et al.*, 2012; Ijab *et al.*, 2010) and practice-oriented reports (e.g., Krauss, 2010; Nunn & Bonecutter, 2009; World Economic Forum, 2008). These

Green IS initiatives were assigned to three areas: IT department, organization, and external market (see Table 15).

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.

Table 15: List of Green IS initiatives.

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)

Table 15 (continued): List of Green IS initiatives.		
Area	**Category**	**Green IS initiatives**
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

6.3 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.

7. Aligning Green IS with Environmental Strategies: Development of a Conceptual Framework that Leverages Sustainability and Firm Competitiveness

Title	Aligning Green IS* with Environmental Strategies: Development of a Conceptual Framework that Leverages Sustainability and Firm Competitiveness
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Published in	Proceedings of the 17th Americas Conference on Information Systems (AMCIS 2011), Detroit, USA
Abstract	Environmental technologies are becoming increasingly important for business firms to reduce environmental impacts and differentiate from competitors. In this paper, fundamental approaches of strategic management are presented and the strategic significance of sustainability initiatives and Green Information Systems (Green IS) is analyzed. Environmental strategies are introduced and the importance of strategically aligning the business, sustainability, and IS domain is highlighted. We argue that there is no consistent approach for aligning Green IS with sustainability goals and business objectives so far. To close this research gap, we integrate Green IS into the concept of IS strategy and develop the Strategic Green IS Alignment Framework (SGISAF), which could prove meaningful for both practitioners and academics. The SGISAF differentiates between an internal and an external perspective and comprises the domains Green IS and environmental sustainability. Four distinct Green IS alignment perspectives, which vary according to their competitive focus and their competitive advantage, are suggested.

* In the published article, the term *Green IT* was used synonymously for the concept of *Green IS*. At the time of publication (2011), unambiguous definitions of the concepts had not yet been published in IS research. To allow for consistency throughout the thesis, the term Green IT was substituted by the term Green IS. In addition, it was ensured that the use of the terms IT and IS is in accordance with the concepts defined in Part A of this thesis.

7.1 Introduction

Sustainability has emerged as relevant topic of strategic management during the last years – and it is supposed to become a game-changing megatrend (Lubin & Esty, 2010). However, business executives are struggling to identify sustainability-based sources of competitive advantage and to integrate environmental aspects into their corporate strategy. In addition, the strategic role of information systems (IS) still challenges executives. The IS strategy must be aligned with the business strategy to enhance firm competitiveness (Henderson & Venkatraman, 1993). Anyhow, IS/business alignment remains a major concern of Chief Information Officers (CIOs) and the necessity to consider environmental aspects of IS further increases the complexity of this strategic challenge (Avison *et al.*, 2004; Luftman, 2004). IT infrastructure responsible for substantial amounts of carbon dioxide emissions and the demand for data processing and storage capacities rises continuously. Even so, Green IS practices can enhance energy efficiency and the consequent application of green technologies can decrease IT-related carbon dioxide emissions. Green IS are acknowledged as strategic technologies that will play a fundamental role in reengineering business and production processes to reduce the environmental footprint of organizations (Watson *et al.*, 2010). Furthermore, Green IS practices induce considerable cost savings and often have a positive return on investment (Harmon *et al.*, 2010).

This paper illustrates how Green IS practices can increase IS value creation and firm competitiveness. To leverage the full potential of environmentally-friendly information systems, it is imperative to align the Green IS measures with the competitive environmental strategy. However, little research about Green IS alignment has been conducted so far.

To develop a Strategic Green IS Alignment Framework (SGISAF), which promotes the consideration of strategic aspects of environmental IS practices, the paper is structured as follows. First, we introduce the relevant research topics in the scope of a literature review. We define the term "Green IS" before we explain important approaches of strategic management and analyze the strategic relevance of sustainability for the creation of competitive advantage. Next, we illustrate the necessity of IS/business alignment and present the widely applied Strategic Alignment Model (SAM). On the basis of the literature review, we emphasize the need for the alignment of Green IS. Subsequently, we integrate Green IS into the concept of IS strategy. Then we conceptualize the SGISAF, which comprises four distinct Green IS alignment perspectives. The SGISAF is supposed to provide practitioners with an applicable framework for the strategic alignment of Green IS and to give researchers new insights concerning the strategic relevance of sustainability and IS.

7.2 Theoretical background and literature review

Green IS has become the latest buzzword in IS management although a common understanding of the coverage and scope is still missing in research and practice (Velte *et al.*, 2008). Amongst researchers the terms *green*, *eco-efficiency* and *sustainability* are widely used (Molla, 2009b). We apply the term *green* to specify the analysis and minimization of environmental impacts. This specification differs from the term *sustainability*, which is discussed later. The process of corporate *greening* can be understood as a first step towards the superior goal of sustainability. Harmon & Auseklis (2009) refer to Green IS as "the practice of maximizing the efficient use of computing resources to minimize environmental impact." In the scope of this research we define *Green IS* as follows:

Green IS is the systematic application of practices that enable the minimization of the environmental impact of IT infrastructure, support the superior goal of corporate sustainability, maximize efficiency and allow for company-wide emission reductions based on technological innovations.

Green IS is supposed to significantly decrease the environmental footprint of the IT industry and to foster ecological innovations in other industry sectors (Dutta & Mia, 2010). Nonetheless, one of the current key challenges of Green IS is to advance from uncoordinated cost-cutting investments to consistent Green IS strategies that leverage the full ecological potential of innovative environmental technologies (Harmon *et al.*, 2010; Olson, 2008).

7.2.1 Dominant approaches of strategic management

The fundamental objective of strategic management research is to identify how competitive advantage can be created and sustained (Teece *et al.*, 1997). Strategies determine the firm's market position and identify necessary key resources being required to assure long-term competitiveness. Porter (1996) emphasizes that strategy is always a question of choice, coming along with trade-off decisions. Different complementary approaches trying to identify the sources of competitive advantage have evolved during the last decades (Orsato, 2009). The most important framework of strategic management is the SWOT analysis, which is commonly used to identify the internal strengths and weaknesses of a firm and to reveal the opportunities and threats originating from the external environment (Andrews, 1971).

Porter's competitive positioning approach focuses on the company's external context and argues that business success depends on the attractiveness of the industry and the firm's relative position in that industry. To achieve competitive advantage, a firm necessitates pursuing a clear and focused strategy (Porter, 1980). Porter proposes

three distinct generic positioning strategies: the low-cost strategy, which aims at low prices and high sales volumes, the differentiation strategy, which targets unique products and premium pricing, and the focus strategy, which seeks for small but profitable market segments. The disregard of the structure and internal competencies of the firm in the scope of Porter's strategic positioning approach resulted in the development of the Resource-Based View (RBV), which can be seen as the dominant approach of strategic management today (Eisenhardt & Martin, 2000).

The RBV analyzes the significance of firm-specific resources and capabilities for the creation of competitive advantage. Grant (1991) distinguishes between tangible, intangible, and personnel-based resources while capabilities are organizational competencies, such as processes and business routines. Resources and capabilities should be the basis for the formulation of corporate strategy because they are the sources of competitive advantage and shape the firm’s permanent identity. Accordingly, Porter's strategic positioning approach is directed towards the external competitive environment whereas the RBV elucidates internal firm-specific sources of competitive advantage. Wade & Hulland (2004) emphasize that the consolidation of these complementary strategic approaches is appropriate and applied by numerous IS researchers.

7.2.2 Sustainability as a new dimension of corporate strategy

The most common definition of the term sustainability originates from the (WCED, 1987): "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Sustainable management considers the effects of business activity under consideration of the triple bottom line. It refers to a long-term process of simultaneously optimizing economic, ecological and social goals to ensure the enduring activity of business practices. Sustainability "is in the process of becoming a competitive and strategic issue" (Elkington, 1997) and it is supposed to cause fundamental shifts in the competitive landscape and create game-changing opportunities (Dutta & Mia, 2010). That is why organizations must advance from unfocused investments to consistent sustainability strategies being aligned with core business activities (Lubin & Esty, 2010). There is empirical evidence for a positive relationship between corporate responsibility and firm performance (Funk, 2003; Hart & Milstein, 2003; Klassen & McLaughlin, 1996) and Porter & van der Linde (1995) even claim that the efficient use of resources is a new paradigm, uniting environmentalism and competitiveness.

Economic and ecological value can be created in the internal domain by enhancing the efficiency of processes and material utilization, both resulting in cost savings and

emission reductions. In the external domain, sustainability can constitute a unique value proposition the customers are willing to pay for. Sustainability-related innovations can create new markets and enable differentiation while an improved firm reputation can increase the demand for products and services. Olson (2008) states that a "green strategy has the potential to significantly impact both top line revenue growth and bottom line cost savings." He emphasizes the crucial significance of aligning the sustainability strategy with the business, IS, and technology strategy. However, the value creation potential of sustainable business practices depends on the firm-specific context. Competitiveness and returns will only increase if the eco-investments are appreciated by internal or external stakeholders (Bieker, 2005).

Orsato (2009) proposes four generic, choice-based environmental competitive strategies which distinguish between the internal and the external domain of value creation and competitive advantage, which refers to the consolidation of the two leading strategic management approaches (Porter and the RBV) as explained above. He underlines that "strategy implies choice, priority, and focus" (Orsato, 2009), which implies that trade-off decisions have to be made. The environmental strategies are subdivided into two dimensions: in the "competitive advantage" dimension, firms can either pursuit a low-cost strategy by reducing their operational costs through environmental initiatives, or they can strive for competitive differentiation based on a superior, sustainability-related value proposition. The "competitive focus" dimension determines whether the environmental investments are targeted at internal organizational processes or at market-oriented products and services. On the basis of this classification, four different environmental strategies are defined, as illustrated in Table 16.

Table 16: Generic competitive environmental strategies (Orsato, 2009).

		Competitive focus	
Competitive advantage		Organizational processes	Products and services
	Low-cost	Eco-efficiency	Environmental cost leadership
	Differentiation	Beyond compliance leadership	Eco-branding

The *eco-efficiency* strategy aims at the minimization of waste, by-products and emissions. In this way, the production efficiency can be enhanced and costs can be reduced. Although initiatives that allow for a reduction of the environmental footprint and simultaneously come along with cost savings are attractive for virtually every firm, this strategy proves to be particularly appropriate for mass volume producers with intense industrial processing. The *beyond compliance leadership* strategy concentrates on organizational processes as well, but the competitive

advantage is rooted in differentiation rather than in cost reductions. Firms pursuing this strategy even approve unprofitable environmental initiatives to reduce their ecological footprint. The positive corporate image helps to attract new customers and to intensify the relationships with established ones. In contrast, the *eco-branding* strategy refers to a competitive focus on products and services. This strategy strives for competitive differentiation based on ecological product characteristics. The customer must be willing to pay for this ecological differentiation. Hence reputation and credibility are important intangible assets associated with this strategy. In highly price-sensitive markets, the *environmental cost leadership* strategy can be a suitable approach. This strategy targets radical product innovations instead of incremental process enhancements. Substitution of decisive input materials or new business practices can significantly change markets and competitive conditions.

7.2.3 Strategic IS/business alignment

For many years already, IS/business alignment is a major concern of business executives and the number one topic of CIOs (Luftman, 2004). Many firms are not able to leverage the full potential of their IS due to a lack of alignment between the IS and their business goals. Firms that have a high degree of alignment achieve to apply IS for strategic purposes, to position themselves strategically in the market, and to leverage their core competencies with the help of the latest technologies (Ravichandran & Lertwongsatien, 2005). Strategic alignment can result in superior strategies due to the fact that the "alignment process and its outcomes constitute a unique firm asset capable of producing IS-based competitive advantage" (Kearns & Lederer, 2003). Avison *et al.* (2004) underline that "firms cannot be competitive if their business and information technology strategies are not aligned."

Henderson & Venkatraman (1993) developed the Strategic Alignment Model (SAM), which is the most widely applied alignment concept in academic research and practice (Tarafdar & Qrunfleh, 2009). The SAM differentiates between four domains of alignment: business strategy, IT strategy, organizational infrastructure and processes, and IT infrastructure and processes. The alignment of these four domains is achieved by the utilization of two established concepts of strategic management: strategic fit, which describes the interrelation between the external environment and the internal structure of the organization, and functional integration, which addresses the harmonization of the business and the functional domains respectively. The externally-oriented strategies are determined by their scope, specific competencies and governance principles while the internally-oriented domains specify the provisioning of infrastructure and processes and the development of required functional architectures and skills. The four domains of the

SAM must be balanced to achieve strategic IT/business alignment. To do so, Henderson & Venkatraman, (1993) developed a system of cross-domain relationships, which are denominated alignment perspectives. Within the SAM, four dominant alignment perspectives are explained: strategy execution, technology transformation, competitive potential, and service level.

7.2.4 Findings and motivation

As revealed by theoretical and empirical research, Green IS practices can indeed have the capability to leverage firm competitiveness. By implementing consistent Green IS initiatives, competitive advantage can be created and thus Green IS should be understood as an integral part of IS strategy. IS-based environmental initiatives can support low-cost strategies or facilitate competitive differentiation. However, the interrelation of business strategy, sustainability goals and IS constitutes a complex challenge. Even so, linking and aligning these strategic domains promises great opportunities for environmental protection and economic progress. Regardless, Green IS initiatives are considered recently as a means to reduce costs and risks whereas technology-based overall strategies aimed at the creation of competitive advantage and sustainable, profitable growth can hardly be found.

Aligned Green IS strategies are essential because they can contribute to the achievement of sustainability targets of corporations. Firm competitiveness can be improved through environmental commitment that differentiates from competitors and enhanced efficiency that comes along with higher productivity. To leverage the full potential of Green IS, a company requires a clear strategic orientation and alignment between its sustainability and IS strategy. Executives need a sound rationale that conducts their sustainability initiatives for setting priorities in line with the company's core business. Non-aligned environmental activities do neither lead to increased competitiveness nor to the optimal reduction of the firm's environmental footprint. The development of aligned Green IS strategies requires the appreciation of the impact that IS and corporate sustainability can have on firm competitiveness. That is why a framework for the alignment of business, sustainability and IS strategies is strongly needed.

7.3 Conceptualization of Green IS alignment

The concept of Green IS should be integrated into the theoretical framework of IS strategy to facilitate the linkage of environmental IS practices and the strategic context of the firm. The IS strategy expresses how the application of IS is supposed to fulfill the requirements of the organization by providing efficient IS processes and services to the business, by supporting the corporate goals, and by delivering value. Thus the IS strategy must refer to the specific competitive environment of the

enterprise and its business objectives. The IS strategy takes costs, risks and opportunities of currently available and future information technologies into account and must assess their possible business impact (IT Governance Institute, 2005).

In line with Earl (1989) we propose a definition of IS strategy that consists of three basic items: technology strategy, systems strategy, and Green IS strategy. This concept of IS strategy is illustrated in Figure 18 and it is supposed to allow for a holistic IS management under consideration of strategic goals and environmental aspects. On the one hand, the systems strategy assures that the information systems and applications fulfill the requirements of the business. The respective systems requirements specify the technology strategy, which is aimed at the optimization of the IT architecture under consideration of efficiency and functionality. Business value and competitive advantage are created through efficient service provisioning, superior IT services that provide differentiation, and technological innovations that create IS-based business opportunities. On the other hand, the IS strategy is aligned with the sustainability strategy on the basis of the Green IS strategy. The Green IS strategy aims at enhancing the eco-efficiency of the IT infrastructure. The reduction goals concerning IT-related emissions are determined by the objectives of the corporate sustainability strategy. In this way, Green IS support the sustainability strategy by facilitating eco-efficiency and competitive differentiation. Furthermore, Green IS can create opportunities for environmental technology innovations, which can change prevalent business practices.

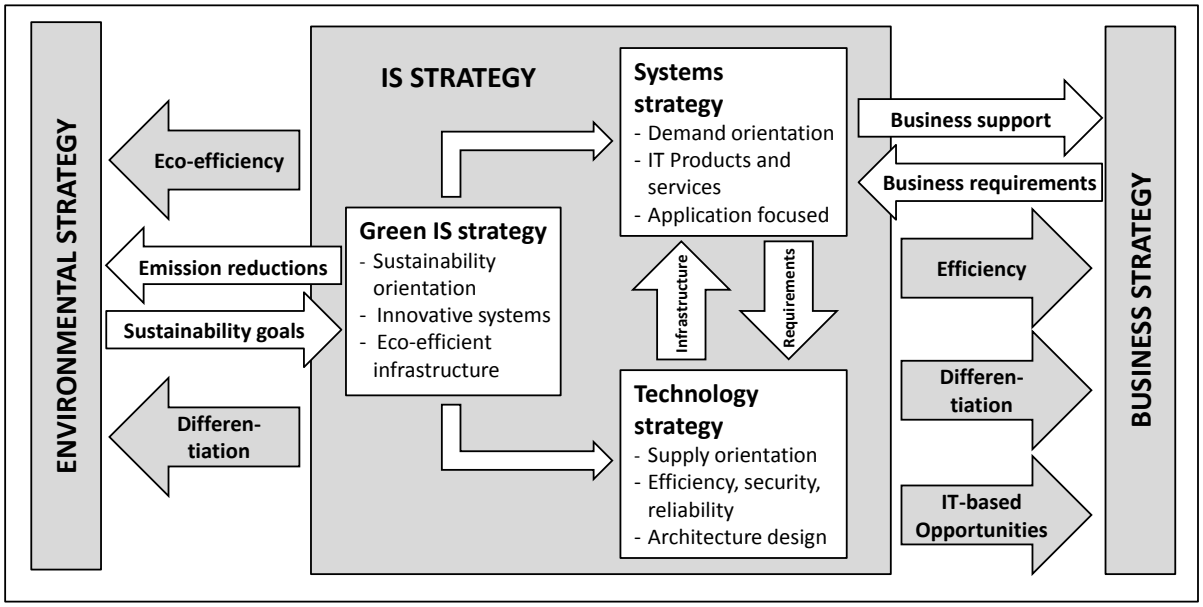

Figure 18: Conceptualization of IS strategy.

As discussed above, competitive advantage should be regarded from two dimensions: the internal dimension, where IS can enable cost-efficient business

processes, and the external dimension, where IS can be utilized to provide unique customer value (Henderson & Venkatraman, 1993). The IS organization should be effective and efficient in the provisioning of internal, standardized technology solutions while developing externally-focused distinctive solutions considering the strategic business context (Gartner, 2008).

7.3.1 The Strategic Green IS Alignment Framework (SGISAF)

It was highlighted above that Green IS implementations mainly consist of cost-saving measures currently while the strategic relevance is largely disregarded. The exploitation of the full competitive potential requires the strategic alignment of Green IS strategy and competitive environmental strategy. At this point we decided to refer to the generic environmental competitive strategies of Orsato (2009) that were already introduced in this paper. This generic, choice-based conceptual typology of environmental strategies corresponds closely to our understanding of business strategy, value creation, and competitive advantage based on environmental initiatives. Furthermore, the SGISAF is based on the fundamental logic and procedures of the SAM (Henderson & Venkatraman, 1993), which proved to be useful for executives and investigators and which is in line with our distinction between internal and external sources of competitive advantage. The SAM has the purpose of aligning the IT and business domain whereas the proposed SGISAF is aimed at aligning the IS and sustainability domain.

The conceptualized SGISAF aims at the identification of sources of competitive advantage and thus aligns the externally-oriented Green IS and competitive environmental strategies. In analogy to the SAM, the SGISAF refers to the achievement of strategic fit and functional integration as displayed in Figure 19. Strategic fit describes the interrelation between externally-oriented strategies at business level and the internal structure of the organization. The SGISAF links uncoordinated Green IS measures at functional level to the strategies at competitive level.

The achievement of *strategic fit* removes the prevalent constraints of the strictly internal perspective of Green IS practices and connects Green IS with the strategic external perspective, thus integrating customer and stakeholder aspects and revealing sources of competitive advantage for product differentiation or low-cost strategies. Sustainability goals can only be achieved if the strategies are implemented on the basis of an appropriate IT and organizational infrastructure, which constitutes the basis for low-impact business processes. The process of *functional integration* between the Green IS and the environmental sustainability dimension considers the impact of Green IS concerning the sustainability strategy and vice versa, thus indicating how Green IS can leverage the competitive

sustainability strategy and how a sustainability-oriented infrastructure in conjunction with environmentally-friendly processes can increase the sustainability of business operations.

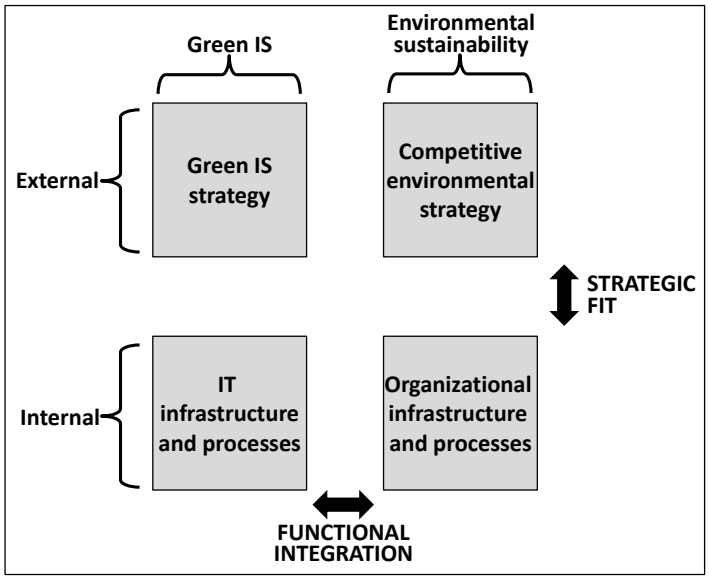

Figure 19: Components of the Strategic Green IS Alignment Framework (SGISAF).

Referring to the SAM, we argue that the four domains displayed in Figure 19 must be balanced to achieve strategic Green IS alignment. In analogy to the SAM (Henderson & Venkatraman, 1993), we identify four dominant alignment perspectives, which determine the cross-domain relationships and the specific characteristics of each domain. Each of these alignment perspectives corresponds to one of the previously introduced environmental strategies. The alignment logic of the four alignment perspectives is illustrated in Figure 20 and their main characteristics are summarized in Table 17.

The *Green IS for efficiency* alignment perspective corresponds to the *Eco-efficiency* environmental strategy. The business strategy is the driving force and promotes superior resource productivity. This strategy aims at achieving competitive advantage on the basis of a low-cost approach and focuses on the internal infrastructure and processes. As a consequence, the environmental strategy has a firm-wide scope and the efficiency of business operations is a major goal. Sustainability is regarded from a cost perspective and Green IS measures are implemented if they allow for superior efficiency, coming along with operational cost decreases. The environmental strategy corresponds to the business requirements and the IT infrastructure is guided by this strategy. The alignment logic reveals that environmental practices targeting the organizational infrastructure are determined by the competitive environmental strategy, which demands for

efficient business processes. This efficiency focus sets the terms for the implementation of Green IS practices.

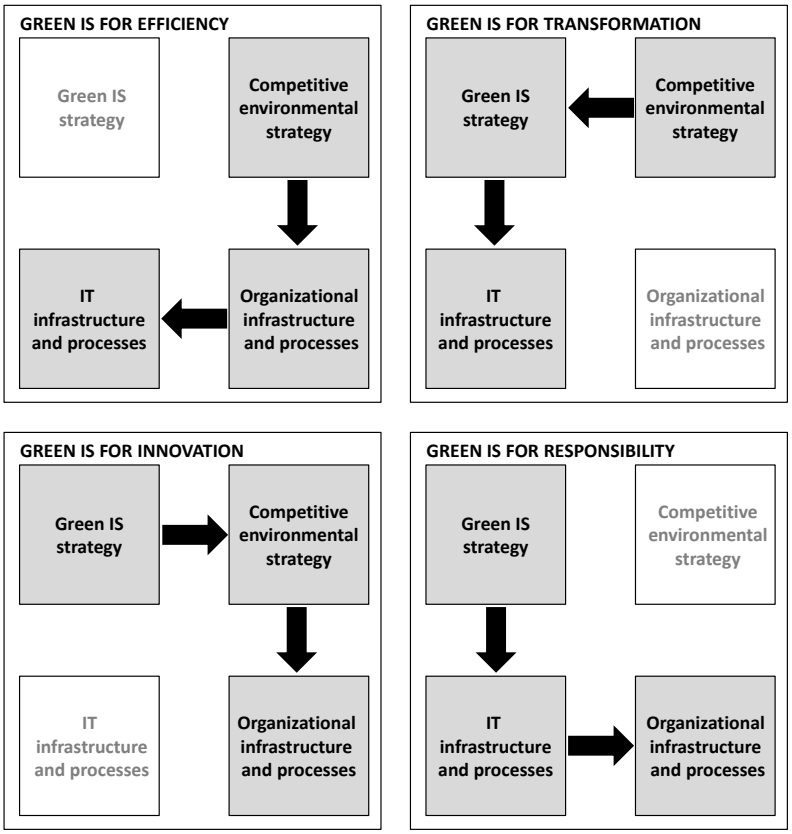

Figure 20: The four Green IS alignment perspectives.

The second alignment perspective, denominated *Green IS for transformation*, is driven by the *Eco-branding* competitive environmental strategy, which aims at product and service differentiation based on environmental attributes. These ecological products usually target niche markets and customers that are willing to pay for the costs of ecological differentiation. Green IS serves as crucial strategy enabler. Green IS-related opportunities are thoroughly considered by the top management. The sustainability management strives for environmental technology leadership and exploits the full environmental potential of the latest technologies. The IS function is responsible for the development of environmental technologies that facilitate a state-of-the-art IT infrastructure. Innovative IS solutions are an integral part of the product or service and the environmental characteristics are appreciated by the customers (e.g. provisioning of a CO2-neutral e-mail service). The alignment logic reveals that the Green IS strategy enables the competitive strategy on the basis of a specific IT infrastructure, which is not constrained by the organizational infrastructure.

The alignment perspective *Green IS for innovation* fits the *environmental cost leadership* strategy, which refers to a product focus while following a low-cost

strategy. This strategy is associated with radical product innovations instead of incremental process improvements and it is appropriate if the firm strives simultaneously for the lowest environmental impact and the lowest production costs within its competitive environment. This can only be accomplished through radical technological innovations, which are anticipated by a visionary top management that is committed to environmentalism and targets business leadership at the same time. As a result, the Green IS strategy should leverage innovations and drive the competitive environmental strategy. The top management seeks for business and sustainability opportunities which are based on innovative technologies. The IS function regards environmental technology trends and analyzes their impact for the business in close cooperation with the top management. IS influence the business and sustainability strategy as well as product characteristics while the environmental practices change the organizational processes fundamentally.

Table 17: The four Green IS alignment perspectives.

Competitive environmental strategy	Competitive advantage	Competitive focus	Objective of sustainability management	Objective of IS function	Performance criteria
Perspective 1: Green IS for efficiency					
Eco-efficiency	Low-cost	Internal processes	Support business strategy	Implement business strategy	Cost/service center
Perspective 2: Green IS for transformation					
Eco-branding	Differentiation	Products and services	Differentiate from competition	Develop green technologies	Environmental technology leadership
Perspective 3: Green IS for innovation					
Environmental cost leadership	Low-cost	Products and services	Become industry leader	Drive ecological innovations	Business leadership
Perspective 4: Green IS for responsibility					
Beyond compliance leadership	Differentiation	Internal processes	Fulfill stakeholder claims	Minimize environmental impact	Stakeholder satisfaction

The fourth alignment perspective is called *Green IS for responsibility*. It is associated with the *beyond compliance leadership* environmental strategy, which has an extended scope covering the entire range of internal processes with the goal of sustainability-based competitive differentiation. The key performance criteria are oriented towards stakeholder satisfaction while the IS function plays an important role for executive leadership. The top management and the sustainability management facilitate direction, analyze stakeholder claims and prioritize

investments. This Green IS strategy strives for a high quality, low-impact IT infrastructure that enhances the process efficiency of the whole organization. Green IS promote the extraordinary environmental dedication and even unprofitable investments that allow for further emission reductions are realized. This gives the firm a first mover advantage in the field of sustainability, shaping the shopping behavior of customers and resulting in an outstanding firm reputation.

7.4 Conclusions and further research

In this paper we analyzed the strategic impact as well as the underlying dimensions of Green IS. We pointed out that competitive advantage can be achieved by either lowering costs or providing differentiation. Practitioners must acknowledge that strategy is always a question of choice, coming along with trade-off decisions. A consistent Green IS strategy that creates sustainable competitive advantage necessitates the conjointly consideration of technological and environmental aspects. Such being the case, the topic of strategic Green IS alignment is highly relevant, especially because Green IS still consists of the implementation of uncoordinated measures while the strategic potential of environmental technologies is neglected. The presented framework for strategic Green IS alignment can help executives in developing a consistent Green IS strategy.

The proposed SGISAF distinguishes between the internal and external perspective, which are aligned by the concept of strategic fit, while the Green IS and environmental sustainability domain are aligned through functional integration. The four suggested Green IS alignment perspectives *Green IS for efficiency*, *Green IS for transformation*, *Green IS for innovation*, and *Green IS for responsibility* are selected according to the firm's competitive environmental strategy. These Green IS strategies differ with respect to competitive focus and competitive advantage and specify the characteristics, roles and objectives of the firm's Green IS management.

The conducted research can be seen as a first step towards a stringent approach of Green IS alignment. The major limitation of the SGISAF is that it is conceptualized on a theoretical basis exclusively. The framework is based on research findings and propositions of strategic management, IS management and corporate sustainability literature. To advance the applicability and validity of the suggested alignment procedure, the conceptual framework should be tested, refined and verified in the scope of an empirical investigation, for example on the basis of an extensive case study research.

8. Shared Domain Knowledge in Strategic Green IS Alignment: An Analysis from the Knowledge-Based View

Title	Shared Domain Knowledge in Strategic Green IS Alignment: An Analysis from the Knowledge-Based View
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Abstract	In this paper, we argue that the inclusion of environmental sustainability aspects increases the complexity of Information Systems (IS) alignment. The business value of IS and their potential to render firms more sustainable can only be leveraged if IS are strategically aligned. The literature from relevant academic disciplines is reviewed to lay a theoretical foundation. We define the term Green IS strategy, introduce a strategy typology, and integrate environmental aspects into Green IS alignment. The alignment process is determined by social aspects that are analyzed from the knowledge-based perspective in this research. We find that sharing of knowledge between the domains of business, IS, and sustainability is a premise for Green IS alignment. In this context, the importance of internally transferring tacit knowledge between different organizational actors on corporate, competitive and functional level is emphasized. Finally, we discuss implications for research and practice and make recommendations for further research.

8.1 Introduction

In the last years, the political and societal debate about climate change has intensified significantly. Business executives and politicians start to realize that the indispensable development towards a more sustainable economy will be the central principle of corporate management in the 21st century. Lubin & Esty (2010) identify sustainability as the next macro-economic 'megatrend' that will alter markets and business models. Sustainability-oriented management is expected to induce disruptive innovations, thus influencing market characteristics on a macro-economic scale. In the recent economic downturn, the G20 governments have invested $400 billion of their stimulus funds in clean technologies and sustainability initiatives (Lubin & Esty, 2010). But although the need for a fundamental transformation of economic activities is indisputable, the identification of effective measures proves to be challenging.

The environmental impact of information technology (IT) is addressed by the IS research community under the headline of *Green IT*. This stream of research mainly focuses on energy efficiency enhancements of initiatives that result in the reduction of operational costs and carbon dioxide emissions – and thus have a positive financial and environmental impact (Dao *et al.*, 2011). However, Green IT measures typically have a limited scope, whereas Green information systems (IS) initiatives have a broader potential. Green IS do not only address the negative environmental impacts of IT, but are seen as enablers for reductions of the environmental footprint of the entire organization by driving a transformation of the firm, e.g., through the reengineering of business and production processes (Watson *et al.*, 2010).

Apart from environmental aspects, IS are essential for business processes and strategy nowadays (Croteau & Bergeron, 2001). Indeed, companies can only benefit from the potential of IS, leading to improved organizational performance, if information systems are strategically aligned with the core business (Kearns & Sabherwal, 2007b). The alignment of IS and business strategy is a topic that is discussed by the IS community for a long time and it is one of the most challenging tasks for Chief Information Officers (CIOs) (Luftman & Ben Zvi, 2010). To leverage the potential of Green IS, the new challenges concerning environmental sustainability must also be considered in the IS strategy. Thus IS strategy must not only be aligned with the business strategy, but with the corporate sustainability strategy as well. This additional dimension of strategic alignment makes the challenge of effective and efficient deployment of IS even more difficult. Since this topic has not been addressed by the IS research community until now, we formulate the following research question:

RQ1: How can aspects of environmental sustainability be integrated into strategic IS alignment?

The effectiveness of strategic alignment has been studied under the theoretical lens of the knowledge-based view due to the fact that IS alignment has a social and an intellectual dimension (Reich & Benbasat, 2000). In this context, it is argued that strategic alignment is closely linked to knowledge transfer and sharing of domain knowledge. Alignment requires the internal transfer of knowledge from IT executives to business executives and vice versa, resulting in a shared understanding of business, sustainability, and IS. Referring to this, we define our second research question:

RQ2: Which organizational actors are involved in the internal transfer of knowledge between organizational units being relevant for Green IS alignment?

To answer these research questions, the paper is structured as follows. After the introduction we lay the theoretical foundation for analyzing Green IS alignment. We discuss strategic aspects of sustainable management and propose a definition for the term *Green IS strategy*. We then introduce a typology of four distinct Green IS strategies that was developed in prior research and assists IS and business executives to conceive the competitive potential of Green IS. Next, we integrate aspects of environmental sustainability into the process of strategic alignment and identify domains and management levels being relevant for the alignment of Green IS, thus addressing RQ1. In section three, we review extant literature referring to the concept of strategic IS alignment from the knowledge-based view. We introduce the concepts of internal knowledge transfer and shared domain knowledge. Next, we present enablers of alignment that refer to the social dimension of this process. Based on these theoretical insights and referring to RQ2, we analyze the specific characteristics inherent to Green IS alignment. We classify this research and identify organizational roles that are involved in the Green IS alignment process. We consolidate our insights from the theoretical discussion and formulate propositions that describe characteristics of Green IS alignment on corporate, competitive, and functional level. Finally, we summarize the results of this work, discuss implications for research and practice, and indicate areas of further research.

8.2 Theoretical background

8.2.1 Environmental sustainability in Strategic Management Research

Sustainable management practices regard the impacts of the firm under consideration of the triple bottom line, referring to a long-term process of simultaneously optimizing economic, environmental and social outcomes to ensure the enduring activity of business operations. Sustainability "is in the process of

becoming a competitive and strategic issue" (Elkington, 1997, p. 41). Corporate sustainability has gained in importance for companies due to rising pressure from stakeholders (Harmon & Auseklis, 2009), but most organizations regard sustainability as a complex challenge without recognizing related opportunities (Baumgartner, 2006). Environmental issues are associated with risk reduction and cost-cutting, but technology-related overall strategies that create competitive advantages and sustainable, profitable growth, can hardly be found until now (Orsato, 2009).

Apart from the fact that sustainable business practices are an essential condition for the future of our society, sustainability-related innovations are appreciated by consumers who increasingly reflect this attitude in their preferences and buying behaviors (Lubin & Esty, 2010). Environmental commitment can differentiate a business firm from its competitors while enhanced efficiency of processes comes along with higher productivity and improved firm competitiveness (Orsato, 2009). There is empirical evidence for a positive relationship between corporate responsibility and firm performance (Funk, 2003).

Stead *et al.* (2004, p. 36) define sustainable strategic management (SSM) as "strategic management processes that are economically competitive, socially responsible, and in balance with the cycles of nature. [...] SSM strategies are integrative and designed to develop long-term competitive advantage of products and services by simultaneously enhancing the three dimensions of sustainability." The authors differentiate between strategies on corporate, competitive and functional level. They claim that corporate strategy should be guided by triple bottom line thinking and that sustainability strategies on competitive level should focus eco- and socio-efficiency. The sustainability goals are achieved by the implementation of SSM strategies, techniques and processes (such as life cycle analysis, triple bottom line accounting and sustainability reporting) on the functional level.

Olson (2008) emphasizes the crucial significance of aligning sustainability strategies with business, IT, and technology strategies. A holistic approach, involving various domains such as IT product and service design, supply chain optimization and reengineering of business processes, is required to make IS an important enabler of sustainability (Velte *et al.*, 2008). Thus IS strategies must consider the impact that Green IS can have on firm competitiveness and environmental sustainability.

8.2.2 Defining Green IS strategy

To facilitate a common understanding of the key terms, we now define 'Green IS strategy' and its underlying components. 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 & 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 *et al.*, 2009).

The term *Information Technology* (IT) is applied to describe computer hardware, software, and peripheral equipment (Ijab *et al.*, 2010). The concept of *Information Systems* (IS) "combines both the technical components and human activities within the organization as well as describing the process of managing the lifecycle of organizational IS practices" (Chen *et al.*, 2010b, p. 234). *IS* comprise Information and Communication Technologies (ICT) (such as physical servers, office computers and network devices), shared services (such as databases or storage), and business applications (such as ERP systems). Furthermore, *IS* include IT human resources (such as skills and knowledge), and the IT managerial capability for organizational core activities and business transformation (Ravichandran & Lertwongsatien, 2005).

Green IT practices are mostly focused on the IT energy consumption of data centers and computers in the office environment, whereas the cross-functional characteristics of *Green IS* facilitate environmental management systems and the reinvention of business and production processes (Dao *et al.*, 2011; Elliot, 2011). Molla & Abareshi (2011) argue that *Green IT* refers to the negative first-order environmental impact (production, use, and disposal of IT), whereas *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) as well (Hilty *et al.*, 2006). In line with Watson *et al.* (2010), we argue that *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.

To elucidate the difference between *Green IT* and *Green IS*, we provide some practical examples: Currently firms mainly focus on the implementation of mainstream *Green IT* measures (hardware procurement and energy-efficient operations) since the reduction of IT-based energy consumption is directly linked to cost savings (Bengtsson & Ågerfalk, 2011). *Green IS*, by contrast, promise a much greater, organization-wide potential to measure, monitor, report and reduce the firm's environmental footprint, but the transformation of the business with the help of Green IS requires a holistic long-term strategy (Molla *et al.*, 2011). *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, p. 208).

In the context of this research, we adopt an organization-centric conception of *IS strategy*, which is defined by Chen *et al.* (2010b, p. 233) as "an organizational perspective on the investment in, deployment, use, and management of information systems." In this conception, IS strategy has an organization-wide scope, is an integral part of corporate strategy, and is not limited to specific business units. It can support competitive strategies as well as it can shape them (Henderson & Venkatraman, 1993), depending on the role of IS within the organization. This role depends on the shared view and managerial perception of IS infrastructure and capabilities while the specific business requirements are fulfilled through dynamic alignment. In line with Chen *et al.* (2010b) and Elliot (2011) we define Green IS strategy as follows:

Green IS strategy is the organizational perspective on the investment in, deployment, use and management of information systems (IS) in order to minimize the negative environmental impacts of IS, IS-enabled products and services, and business operations.

8.2.3 Integrating aspects of environmental sustainability into strategic IS alignment

Based on these theoretical insights, we now address our first research question. For achieving alignment of Green IS strategies, we propose to extend IS/business alignment by the integration of sustainability aspects. In section 8.2.1, three relevant alignment domains (business, Green IS, environmental sustainability) and three levels of strategic management (corporate, competitive, functional) were identified. This results in nine strategic fields. As presented in Figure 21, Green IS must take into account the business domain as well as the environmental sustainability of the organization and its products.

	BUSINESS DOMAIN	GREEN IS	ENVIRONMENTAL SUSTAINABILITY
CORPORATE LEVEL	Corporate Strategy	Organization-wide Role of Green IS	Corporate Environmental Footprint
COMPETITIVE LEVEL	Competitive Strategy	IS-related Product Characteristics	Sustainable End Products
FUNCTIONAL LEVEL	Business & Manufacturing Processes	IS-enabled Processes	Internal Process Efficiency

Figure 21: Domains and Levels of Green IS Alignment.

The corporate strategy level is the overarching construct of the corporation that facilitates strategic direction. Corporate strategy envisions a long-term perspective

of corporate development and gives guidance for decision-making. The corporate sustainability strategy focuses on the environmental footprint of the entire organization, formulates a sustainable long-term vision and determines the attitude of the corporate management towards environmental topics. Its goal is to integrate the triple bottom line thinking into all levels of the organization and it defines the major goals of the corporation with reference to sustainability. The strategies at corporate level strongly shape values and mindsets – and thus influence corporate culture and public perception of the organization. The Green IS strategy at corporate level defines the organization-wide role of Green IS. As explained above, this role is determined by the perception of Green IS through the corporate management.

The competitive strategies of the business units strive for the achievement of competitive advantage through specific positioning in the target markets under consideration of competitors. Sustainability strategies at competitive level focus on the business case for cleaner production technologies and green products and are strongly context-dependent. Environmental measures that target internal processes can improve resource efficiency and reduce costs whereas market-oriented green products can enhance revenues and profitability through product differentiation. Green IS strategies at this level can either support the business strategy in a reactive manner or they can shape the business strategy proactively. The focus of distinct Green IS strategies differs widely.

While competitive strategies determine a firm's position in a specific market, the actual value is created inside the firm, guided by its functional strategies. On this level, firm-specific resources and capabilities constitute the basis for the competitive advantages that are accentuated and focused by the higher-order strategies. Functional strategies determine the operations and processes of the different departments of the firm. The major goal of functional strategies is the achievement of effectiveness and efficiency. Sustainability strategies can foster redesigning of business and manufacturing processes. This increases the production efficiency and decreases resource consumption and waste disposal costs. Differentiation can be enabled through Design for Environment. This approach aims at reducing the product's environmental footprint, which can represent a unique customer value for both ethical and economic reasons (Albino *et al.*, 2009). Green IS can enhance resource efficiency of internal business and production processes through automation, material management, and travel reductions. Moreover, processes can be redesigned with innovative technologies under the premise of superior efficiency. In this way, the environmental footprint of the organization can be decreased. On the other hand, technological innovations have found their way into numerous products, from traffic management systems to smart homes. These new technologies

decrease the environmental footprint of end products and facilitate differentiation from competitors (Orsato, 2009).

Obviously, the trend towards corporate sustainability adds a third dimension that must be considered in strategic IS alignment. For this alignment, the corporate, competitive and functional levels of strategic management are relevant and must be addressed by Green IS strategies.

8.2.4 Introducing a typology of Green IS strategies

To illustrate how Green IS can be deployed in a strategic way, we now introduce a typology of Green IS strategies (Loeser *et al.*, 2011). This typology consists of four generic Green IS strategies which address corporate, competitive and functional level. These generic strategies outline four different approaches of defining the organization-wide role of Green IS and can guide the formulation of strategic targets for Green IS under consideration of different firm contexts. The characteristics of the distinct Green IS strategies are illustrated in Table 18.

Table 18: Typology of Green IS Strategies (Loeser *et al.*, 2011).

	Green IS for Efficiency	**Green IS for Innovation**	**Green IS for Trans-formation**	**Green IS for Credibility**
Corporate level: Organizational perspective on Green IS	Green IS are used to reduce costs	Green IS are used to achieve environmental technology lead-ership	Green IS are used to achieve business leadership	Green IS are used to improve stakeholder satisfaction
Competitive level: Strategic goal of Green IS	Implement business strategy	Foster innovation	Reengineering of business processes	Minimize environmental impacts
Functional level: Sources of competitive advantage based on Green IS	IS support competitive strategies by enhancing internal process efficiency	IS improve environmental characteristics of product lifecycle	IS support environmental strategies by decreasing footprint of internal processes	IS improve footprint of the enterprise and of end products

The *Green IS for Efficiency* strategy corresponds to the organization-wide target of superior resource efficiency as part of a corporate sustainability strategy that seeks cost leadership. This is probably the most prevalent strategy at this moment and appears to be adequate for mass-volume producers with intense industrial processing in particular. Business success is imperative and profitability is an absolute necessity for all kind of environmental initiatives. Corporate management perceives environmental sustainability as a means to support the traditional core

business. The main goal of Green IS strategy on competitive level is to support and implement the prevalent business strategy. IS are not part of the end product and on functional level, Green IS measures aim to enhance the efficiency of internal processes to facilitate operational cost reductions.

The *Green IS for Innovation* strategy is appropriate for companies that strive for environmental technology leadership. The corporate sustainability strategy aims at environmental innovations which differentiate the firm from its competitors. At competitive level, the strategic goal is to develop products with superior ecological characteristics the customers are willing to pay for, i.e. products which have an exceptionally low environmental impact during their lifecycle based on environmental innovations. Green IS play a significant role at functional level to build IS-based capabilities for environmental management and innovation.

The *Green IS for Transformation* strategy aims at industry leadership with the help of a profound business transformation fundamentally based on environmentally-friendly processes which are enabled through Green IS initiatives. This strategy is reasonable for companies from the service industry where core business processes and products are based on IS. For these companies, IS are critical to the achievement of competitive advantage which aims at a business leadership position based on low cost and low environmental impacts. This is a suitable approach in highly price-sensitive markets. The competitive strategy is shaped by the organizational transformation which is driven by Green IS. On the functional level, this strategy seeks for business process reengineering that allows for a cost and environmental leadership position.

The *Green IS for Credibility* strategy aids companies that pursue sustainability with a more holistic approach. This strategy aims at becoming a "good corporate citizen" by taking the claims of internal and external stakeholders into account. Transparency and credibility are major goals of the company and the corporate reputation is understood as a valuable asset. The top management anticipates that the extraordinary dedication for sustainability leads to a first-mover advantage and pays off in the long-term. The competitive strategy is shaped by the opportunities that emerge from the consequent implementation of Green IS. Firms pursuing this strategy even invest in unprofitable Green IS initiatives with the goal of reducing first-, second-, and third-degree environmental impacts. Green IS are part of the end product and enable competitive differentiation. The positive corporate image helps to attract new customers and to intensify the relationships with existing ones.

8.3 Strategic alignment from the Knowledge-Based View

8.3.1 Knowledge transfer and shared domain knowledge

In the literature of strategic management and IS research, the knowledge-based view, which is related to the resource-based view (RBV), has recently gained in importance. This theory is rooted in concepts being studied in psychology, sociology, and evolutionary biology (Eisenhardt & Santos). Knowledge can be defined as "a justified belief that increases an entity's capacity for effective action" (Alavi & Leidner, 2001, p. 109). Knowledge is hold by individual employees and it is mandatory for the utilization of tangible resources within a business firm. Knowledge can represent a state of mind, an object, a process, a condition, or a capability.

The knowledge-based view considers knowledge as a unique firm resource and understands the internal transfer of knowledge between different business units as a unique capability. From this theoretical perspective, knowledge sharing between different domains is decisive to enhance the building of core competencies and strategic know-how (Alavi & Leidner, 2001). Grant (1996a, p. 375) explains that "at the heart of this theory is the idea that the primary role of the firm, and the essence of organizational capability, is the integration of knowledge." The integration of knowledge is understood as the sharing and combination of knowledge between different business units that facilitate the effective application and creation of new knowledge (Kearns & Sabherwal, 2007b). Since knowledge-based intangible resources can hardly be imitated, they can result in a long-term competitive advantage (Alavi & Leidner, 2001).

However, knowledge-based competitive advantage is not rooted in the knowledge itself but in the effective application of the knowledge. For this reason, knowledge transfer plays a critical role. According to Tsai (2001, p. 996), "organizational units can learn from each other and benefit from new knowledge developed by other units. [...] Organizational units are embedded in a network coordinated through processes of knowledge transfer and resource sharing." Argote *et al.* (2000, p. 151) state that "knowledge transfer in organizations is the process through which one unit (e.g. group, department, or division) is affected by the experience of another."

Grant (1996b) argues that the transferability of knowledge depends on the type of knowledge. Explicit knowledge refers to knowing about facts and can be shared through communication, whereas tacit knowledge, which is related to know how, can only be revealed through its application. Kearns & Lederer (2003) argue that tacit knowledge can be transferred among executives through the participation in strategic planning processes. The collaboration of executives from different domains of the same organization leads to the application of their tacit knowledge. The

outcome is the formulation of explicit strategies that are based on shared domain knowledge.

Nelson & Cooprider (1996) classify shared domain knowledge as mutual understanding of executives from different domains, which is characterized by appreciating the needs, constraints, and contribution of each other. Reich & Benbasat (2000, p. 86) define shared domain knowledge as "the ability of executives [from different domains], at a deep level, to understand and be able to participate in the others' key processes and to respect each other's unique contribution and challenges." In line with the three managerial levels that were identified as being relevant for Green IS alignment (section 8.2.3), Reich & Benbasat (2000) argue that domain knowledge should be shared by top managers, executives, and functional managers.

We conclude that shared domain knowledge is decisive for the formulation of strategies that address multiple domains of the business organization. Explicit knowledge can be shared through communication, whereas tacit knowledge can only be shared through its application, e.g., through the participation of executives from relevant domains in collaborative planning processes.

8.3.2 The social dimension of aligning IS and business strategy

Alignment between business strategy and IS strategy implies that IS support and leverage critical processes of the core business effectively (Avison *et al.*, 2004). Kearns & Lederer (2003) explain that the alignment process is a unique firm capability. As a consequence, IS alignment converts the infrastructure technologies, which are equally available to all firms, into a source of competitive advantage. Wade & Hulland (2004) underline the significance of internal relationships between the IS department and other organizational units of the firm.

Through reviewing the relevant literature, we identified and consolidated enablers of strategic alignment (see Table 19). It becomes obvious that the social dimension, the shared domain knowledge in particular, is of major significance for the effectiveness of strategic alignment between the IS and business domain.

Reich & Benbasat (2000, p. 82) explain that two different streams of research dealing with the alignment of business and IS can be found in the literature. The first approach focuses on analyzing the structure and applied methodologies of alignment (the intellectual dimension), whereas the second approach investigates "the actors in organizations, examining their values, communications with each other, and ultimately their understanding of each other's domains." In this research, we focus on shared domain knowledge, which refers to the second approach, the social dimension of strategic alignment. In this context, "strategic alignment of

information systems refers to the extent to which the IS mission, objectives, and plans support and are supported by the business mission, objectives, and plans" (Hirschheim & Sabherwal, 2001, p. 88).

Table 19: Enablers of IS/Business Alignment.

Source	Enabler of Strategic Alignment	Social Dimension
Luftman & Brier (1999)	Senior executive support for IS	X
	IS executives involved in strategy development	X
	IS executives understand the business	X
	Well-prioritized IS projects	
	Business/IS partnership	X
	IS demonstrates leadership	
Kearns & Lederer (2000)	Alignment as bilateral process	
	Communicate corporate strategy (mission statement, objectives, competitive strategies) to IS management	X
	Integrate IS planning with business planning	X
	Assure top management participation in IS planning	X
Kearns & Lederer (2003)	Knowledge sharing between CIO and CEO can uncover IS opportunities	X
	Collaborative organizational processes for IS and business planning	X
Rathnam *et al.* (2004)	Improve business strategy development process	
	Collaborative strategy development between IS and business departments	X
	Define when and how new technology is introduced into strategy development	X
	Focus business needs	X
	Include CIO at executive council	X
Tarafdar & Qrunfleh (2009)	Linking business and IS planning such that strategic IS plans support business plans	X
	Exploit IS-based strategic opportunities by scanning emerging technologies for new products/ markets	
	Proactive influence of CIO in strategic planning	X
	Formal and informal contact between CIO, CEO, COO and CFO	X

Kearns & Sabherwal (2007b) argue that knowledge sharing between the IT department and the corporate management is a necessary prerequisite for linking IS to the strategic targets of the business firm. In this context, they explain that shared domain knowledge is substantial for the understanding and appreciation of the opportunities that recent technologies and IS can provide to the core business. The success of sharing IS and business domain knowledge is determined by the competence, partnership, and communication between these domains. The

communication between IT and business executives is a crucial requirement for successful alignment and is determined by communication frequency, technologies, and information flows (Kashanchi & Toland, 2008).

8.4 Shared domain knowledge in strategic Green IS alignment

In line with our previous argumentation and according to the insights of Kearns & Lederer (2003) and Kearns & Sabherwal (2007b), we maintain that explicit knowledge can be transferred among business, sustainability, and IS domain via communication, whereas tacit knowledge must be transferred between organizational actors via processes that lead to the application of the knowledge, e.g., strategic planning processes that are conducted by executives from business, sustainability, and IS domain. Kearns & Lederer (2003, p. 5) explain that "this cross-participation is necessary to elucidate the tacit knowledge that often remains undiscovered and is not shared in the organizational knowledge base and to make this personal knowledge explicit at the organizational level. While explicit knowledge might be shared in other ways, tacit knowledge is linked to the individual and must be discovered through a knowledge sharing process."

These processes result in shared domain knowledge (Kearns & Sabherwal, 2007a) and the shared knowledge is expressed through explicit strategies that leverage the potential of Green IS by appreciating IS-related opportunities in a multidisciplinary and holistic way. The sharing of domain knowledge and the collaborative development of strategies is central to the alignment process. The outcomes are aligned strategies and a mutual understanding, which allows for an adequate implementation of strategies at functional level (Kearns & Sabherwal, 2007a).

Referring to research question 2, we now identify organizational actors at corporate, competitive and functional level that are relevant for the successful alignment of Green IS strategies (Carter *et al.*, 2011).

8.4.1 Relevant actors at the corporate level

On corporate level, the corporate strategy must integrate aspects of environmental sustainability and define the organization-wide role of IS. Thus knowledge sharing between the board of directors, the IS strategy committee and the sustainability strategy committee is mandatory to ensure organization-wide alignment between business, IS and environmental sustainability. The cooperation of the authorities from these three domains in formulating a shared vision is a prerequisite for a consistent long-term strategy (Kearns & Sabherwal, 2007a).

Table 20: Corporate Level: Board of directors.	
Role	**Responsibility**
Board of directors	• Ensure an effective strategic planning process • Ratify business, IS, and sustainability strategy • Ensure that sustainability initiatives and IS-based processes complement the business model and support strategic goals
IS strategy committee	• Provide strategy direction and the alignment of IS with business and sustainability issues • Verify strategy compliance
Sustainability committee	• Formulate a sustainability strategy • Define firm-wide, measurable sustainability goals • Promote dialogue with stakeholders

Reich & Benbasat (1996) argue that the mindset of top executives and a mutual understanding are more decisive than collective actions. They define long-term alignment as "the state in which [top] business and IT executives share a common vision of the way(s) in which IT will contribute to the success of the business unit" (Reich & Benbasat, 2000, p. 87). In the scope of an empirical study they found out that shared domain knowledge of the top management allows for a shared vision that results in long-term alignment (over five years). In line with Reich & Benbasat (2000) we encourage research on the alignment process on corporate level and develop our first and second proposition:

P1: Shared knowledge between the business, IS and sustainability domains results in a shared vision of the role and contribution of IS to the firm's business and environmental goals.

P2: A shared vision of the role and contribution of IS to the firm's business and environmental goals is positively associated with long-term Green IS alignment.

8.4.2 Relevant actors at the competitive level

On competitive level, the communication between the CEO and CIO is crucial to leverage the business value of IS through effective and efficient provisioning of services and processes. It is important that the CEO appreciates the opportunities that new technologies provide for innovative business practices while the CIO must understand the specific needs and requirements of the business (Ranganathan & Sethi, 2002). Equally, knowledge-sharing between CIO and CSO is important to assess the potential of IS in making the firm's processes and products more sustainable while raising awareness for environmental issues in the IT department.

Kearns & Lederer (2003, p. 5) explain that "CIO participation is indicated by attendance at business planning meetings, formulation of business goals, frequent

access to the CEO, and regular informal contacts with other members of top management; CEO participation is indicated by regular contacts with the CIO, involvement on an IT steering committee, knowledge about competitors' uses of IT, knowledge about IT opportunities within the firm, and treatment of IT as a strategic resource."

Table 21: Competitive Level: Executive management.

Role	Responsibility
CEO	• Align and integrate IS and sustainability strategy with business goals • Align IS operations with business processes • Cascade strategy and goals down into the organization
CIO	• Drive IS strategy development and execute against it, ensuring measurable value is delivered, currently and in the future • Educate executives on dependence on IS, IT-related costs, technology issues and insights, and IS capabilities
CSO	• Ensure the implementation of the sustainability strategy throughout the organization • Evaluate business case of sustainability initiatives • Promote sustainability issues and raise awareness among executives and employees

The sharing of domain knowledge through communication and planning processes at competitive level results in a mutual understanding of business, sustainability, and IS strategies, which are harmonized through the alignment process. The commitment towards business goals, environmental targets, and IS plans results in short-term alignment (one to two years) (Reich & Benbasat, 2000). The alignment at this level assures that the potential of IS-related opportunities to leverage competitive advantage (Kearns & Sabherwal, 2007a) and environmental sustainability are fully exploited. Based on these insights we formulate our third proposition:

P3: Collaborative planning processes between CEO, CIO, and CSO result in aligned strategies that leverage the potential of Green IS in the short term.

8.4.3 Relevant actors at the functional level

On functional level, steering committees for IS and sustainability should prioritize investments and monitor the implementation of sustainability initiatives. Cooperation between business executives and these steering committees enables the identification of environmental measures that are implemented through cross-functional teams. By doing so, innovative solutions can be developed and firm competitiveness can be increased through the creation of transdisciplinary

knowledge. Sustainability-related knowledge can be assimilated by the employees through information meetings and training.

Table 22: Functional Level: Supporting committees.

Role	Responsibility
Business executives	• Define the business requirements • Understand IS infrastructure and capabilities • Act as sponsor for sustainability projects
IS steering committee	• Define project priorities • Assess strategic fit of proposals • Perform portfolio reviews • Monitor relevance of latest developments in IT from a business perspective
Sustainability steering committee	• Identify suitable environmental and social initiatives • Provide relevant information to organizational units and encourage sharing of knowledge • Training of employees

The implementation success of the higher level strategies at functional level is dependent on IS-knowledgeable business executives and business-knowledgeable IT managers (Ranganathan & Sethi, 2002). We argue that the same is true for the aspects of environmental sustainability. For this reason, sustainability-specific knowledge must be transferred through training to business and IT managers to raise awareness. This leads us to our fourth proposition:

P4: Implementation success of Green IS strategies depends on business-, IS-, and sustainability-related knowledge among functional line managers.

The organizational roles presented in this section are recommendations and have to be adapted to the firm-specific context. Nonetheless, the organizational integration of IS- and sustainability-related roles with explicitly defined competences and responsibilities is of major significance to enable the alignment of these three interrelated domains. Internal transfer of knowledge between these domains must be facilitated through communication, specified information flows and clear responsibilities to facilitate shared domain knowledge.

8.5 Conclusions

The trend towards a more sustainable economy permeates all organizational levels and domains, and IS research and practice have become increasingly involved in this topic. Environmental sustainability can enhance profitability through superior

resource efficiency and competitive differentiation, but the alignment between business, IS and environmental strategy is a prerequisite for long-term success. This paper aimed at the integration of sustainability aspects into strategic IS alignment and at the identification of organizational actors that are relevant in this context.

We analyzed the social dimension of strategic alignment through the theoretical lens of the knowledge-based view and identified enablers of strategic alignment. We argue that strategic Green IS alignment affects the business, sustainability, and IS domain and is a necessary prerequisite for leveraging the full business and environmental potential of IS. We emphasize that sustainability adds a third dimension to the process of strategic alignment and state that three different levels of strategic management should be considered. It became obvious that the transfer of explicit and tacit knowledge is decisive for the creation of shared domain knowledge, which is an antecedent of strategic IS alignment. The collaboration in strategic planning processes, knowledge sharing and above all the relationship between executives from different domains are decisive for the success of strategic Green IS alignment. A mutual understanding enables the utilization of IS to advance the business with innovative technologies and to decrease the environmental footprint of the business firm.

The IS research community as well as practitioners have to acknowledge that corporate sustainability adds a new dimension to the already complex challenge of strategic alignment. We presented four distinct Green IS strategies that can guide strategic investments. Green IS strategies must be addressed on corporate, competitive and functional level and imply an internal transfer of knowledge between business executives, sustainability management and IT department. Only if knowledge is shared and applied collaboratively between these three domains, Green IS can improve long-term firm profitability and advance environmental sustainability of business practices.

To illustrate how this knowledge transfer can be facilitated, we presented specific actors and their responsibilities within the organization. On corporate level, the board of director has to collaborate with the IS and sustainability strategy committee to formulate a shared vision and a long-term strategy. The executive management, in particular the CEO, CIO and CSO, must align competitive strategies and set specific goals to leverage the business value and environmental potential of IS. The actual implementation of environmental initiatives must be accomplished and verified on functional level by executives and steering committees.

However, this research has some limitations. The findings have a limited generalizability because they are derived from theory without empirical evidence. Obviously, this field is of transdisciplinary nature and thus we propose further investigation of this topic through collaborative research of scholars from the

management and IS research community. We suggest further studies that examine our four propositions and our conclusions drawn from this theoretical analysis. Moreover, we assume that valuable insights can be gained through in-depth case studies which investigate roles and responsibilities involved in strategic IS/business alignment and corporate sustainability.

9. Information and Communication Technologies for Sustainable Manufacturing: Evaluating the Capabilities of ICT with a Sustainability Balanced Scorecard

Title	Information and Communication Technologies for Sustainable Manufacturing: Evaluating the Capabilities of ICT with a Sustainability Balanced Scorecard
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Abstract	Information and Communication Technologies (ICT) are regarded as crucial enablers of resource-efficient business and production processes which can shape the path towards a sustainable economy. However, resource efficiency gains of internal processes must be balanced against investment costs of sustainability initiatives, and against negative environmental impacts of ICT operations. To evaluate the multifaceted contribution to long-term corporate goals, the predominant focus on financial aspects is insufficient. Hence we analyze Performance Measurement Systems (PMS) that facilitate a differentiated assessment of ICT environmental initiatives. In the context of a research project aiming at the development of a management dashboard which displays ICT-induced carbon dioxide emissions with reference to business processes, prevailing PMS approaches are evaluated by an expert panel according to project-specific criteria. We identify the IT Balanced Scorecard (BSC) as suitable PMS and conceive a Sustainability BSC with project-specific perspectives, measures and relationships. The Sustainability BSC provides valuable information to different stakeholders, such as high-level executives, process owners and IT operations managers.

9.1 Introduction

In the last decades, findings of scientists and researchers revealed that global warming is caused by the continuously increasing man-made emissions of carbon dioxide (CO2). Moreover, the global production of goods is associated with the destruction of habitat and the depletion of rare resources. It is widely acknowledged that the growth of the human population is still accelerating. A slowdown could be achieved through advanced education and higher living standards in low-income countries – but higher living standards come along with higher levels of consumption as well, and a tenfold increase of the world economy would be necessary to facilitate basic amenities to the entire world population. This would have a serious impact on the planet's ecosystem (Hart, 1997). Thus the technology to produce goods and services will have to change dramatically to prevent a global collapse. Even so, this environmental challenge constitutes an enormous opportunity in the history of economic development. That is why innovative ICT, which enhance transparency by providing information and measuring the achievement of sustainability objectives, are urgently needed (Figge *et al.*, 2002).

Today, challenges that are linked to environmental and corporate sustainability are still disconnected from corporate long-term goals. Business firms miss opportunities, innovations and competitive advantages that could originate from more environmentally-friendly business practices. Companies perceive growing media attention and stakeholder pressure, but instead of implementing holistic strategies for rigorous improvements of business and manufacturing processes, they restrict their actions to uncoordinated environmental initiatives and media campaigns (Porter & Kramer, 2006).

The impact of ICT concerning environmental sustainability is contradictory. On the one hand, ICT account for 5.3 percent of worldwide power consumption and are responsible for 2 percent of global CO2 emissions – an amount that is equivalent to the emissions of the aviation industry (Molla & Abareshi, 2011). This direct, negative environmental impact of ICT is usually addressed under the headline of Green Information Technology (Green IT). On the other hand, ICT are seen as enablers of environmental sustainability that can help decreasing resource consumption, emissions and waste of a wide range of business and production processes (Hilty *et al.*, 2006). The efficiency of internal operations can be enhanced with the aid of ICT, thus changing the way how business is conducted or how goods are produced and delivered. Through ICT-based process reengineering, significant sustainability and performance improvements can be obtained (Sarker & Lee, 1998). Apart from redesigning processes, ICT can increase transparency and comparability, thus revealing optimization potentials. As a consequence, ICT play a crucial role in the quantification of the environmental footprint of organizations. Obviously, ICT

contribute to corporate sustainability in various ways – both positively and negatively. In this context, we argue that the prevalent one-sided focus on costs of IT service provisioning in business firms is inadequate.

However, the creation of business value and the environmental impact of ICT are difficult to evaluate. To address this research gap, the paper is structured as follows. After the introduction, we conduct a literature review on performance measurement systems, characterize traditional accounting measures and modern PMS, and introduce the most widely applied PMS. In the context of the research project *Green IT Cockpit*, we derive evaluation criteria, identify the IT-BSC as most suitable PMS for our *Green IT Cockpit*, and develop a project-specific Sustainability BSC with customized perspectives, measures and cause-and-effect-relationships. Finally, we discuss the insights and draw conclusions from this research.

9.2 Performance measurement systems

The famous management saying "you can't manage what you can't measure" (Peter Drucker, in: Park *et al.*, 2012, p. 129) is still true nowadays – and it has far-reaching implications for ICT value creation and organizational sustainability. Originally, this saying was related to costs: in the beginning of the 20th century, managers were not able to precisely define the costs being caused by specific business functions. Today, it is mandatory for the corporate accounting department to figure out the exact costs of each process that is a component of the value chain within a company (Neely *et al.*, 2005). Although a wide range of business processes is based on ICT nowadays, the ratio of costs and benefits is difficult to quantify. ICT have become indispensable and permeate all levels of business organizations, but their contribution to profitability, firm value and long-term success is difficult to measure. IT business value is defined as "the organizational performance impacts of information technology at both the intermediate process level and the organization-wide level, and comprising both efficiency impacts and competitive impacts" (Melville *et al.*, 2004, p. 287). Similarly, the environmental impacts of internal organizational processes are difficult to measure – and thus cannot be optimized with the goal of achieving superior resource efficiency that minimizes resource consumption, costs and negative environmental impacts. We consider the measurement of IT business value and the impact of ICT on organizational sustainability as important issues. In line with this, we aim at applying successful performance measurement concepts to these new areas.

Metrics and key performance indicators (KPIs) are the basis for Performance Measurement Systems (PMS). KPIs are measurement values being aggregated to facilitate transparency referring to the performance of specified objects. In this way, comparability of objects, e.g., sales volume of business firms in a particular industry

or the development of profit margins in the course of time, can be achieved. Accordingly, KPIs are meaningful only in relation to respective values, i.e., in a certain context. Through the comparison of values, optimization potentials can be identified. Due to the fact that individual metrics do only have a limited validity and significance, KPIs are consolidated in more complex systems which illustrate the relationships between the measures (Nudurupati *et al.*, 2011).

According to Neely, Gregory and Plats, a PMS can be defined "as a set of metrics used to quantify both the efficiency and effectiveness of actions" (Neely *et al.*, 2005, p. 1229). The main goal of a PMS is to describe a complex issue in an understandable, simple and manageable way. A PMS illustrates the organizational reality through an abstract model that can guide managerial decision-making. To do so, the model must describe decisive characteristics of the reality while reducing details to keep the complexity at a controllable level. PMS are used for planning and operational steering processes and display targeted and real values.

Individual performance measures can be related to quality, time, flexibility or costs (Neely *et al.*, 2005). Traditional accounting measures, which emerged in the early stages of the 20th century, are focused on costs. The most widely known of these financial accounting systems is Du Pont's Return on Investment (ROI) measure. Due to the fact that costs can only be analyzed after they occurred, cost-based measures are only adequate to analyze the past. The main goal of these traditional measures is to enhance productivity by decreasing costs and to revise the achievement of financial objectives. These systems are inflexible and target individual incentives instead of providing analyses and learning that enhance corporate competitiveness in the long-term (Lynch & Cross, 1991).

More sophisticated PMS emerged during the 1980s, but they are still in a state of continuous advancement. Contrarily to traditional accounting systems, these PMS target reiterative, future-oriented performance improvements. They take the business strategy into account and measure the achievement of strategic objectives that enable long-term competitiveness and success. By facilitating transparency through the illustration of cause-and-effect relationships, PMS help to operationalize abstract strategic targets into measureable operational goals. Hence modern PMS provide valuable information for steering of business operations and manufacturing processes. Clear presentation of figures and values renders decision-making fast, efficient and reliable (Braz *et al.*, 2011). Another important aspect of modern PMS is the orientation towards customers while future developments are considered – contrarily to the cost-focused, backward-oriented traditional accounting systems that are restricted to financial measures. Moreover, modern PMS illustrate the interdependencies between processes and activities while assessing their effectiveness and efficiency (Pun & White, 2005). Table 23 provides

an overview of the most significant characteristics and differences between traditional accounting measures and modern PMS.

Table 23: Characteristics of traditional accounting measures and modern performance management systems.

	Accounting Measures	Modern PMS
Focus	Financial indicators	Corporate strategy
Goal	Efficiency, reduction of costs	Competitiveness
Timeframe	Short-term profitability	Long-term corporate success
Orientation	Backward/past	Forward/future
Adaptation	Commonly accepted accounting measures	Flexible customization of measures and dimensions
Recipients	High-level executives; accountants	All organizational levels and functions; specific perspectives & aggregation levels
Outcomes	Achievement of financial targets (e.g. profitability)	Implementation of strategy throughout the organization

The most prominent traditional accounting scheme is that of Du Pont, which was developed in the year 1919. It is constructed as a hierarchical tree structure with the ROI as target measure at the top. The aim of this accounting measure is to maximize the money that is gained in relation to the money invested. With the ROI, the efficiency of single business units and of the corporation as a whole can be analyzed and compared (Neely *et al.*, 2005).

In the following, we provide an overview of the evolution of modern PMS and describe important features of them.

Performance Pyramid (Cross & Lynch, 1988)

- Also known as Strategic Measurement Analysis and Reporting Technique (SMART).
- Hierarchical structure with three levels: corporate management, executive management and steering of operations.
- Implementation of top-down and bottom-up performance measures.
- Links strategy and business operations, is user-oriented and provides advice for strategic direction (Folan & Browne, 2005; Hudson *et al.*, 2001; Pun & White, 2005).

Results & Determinants Matrix (Fitzgerald, 1991)

- The R&DM was developed in the context of a study that investigated the service industry.
- Determinants are categorized according to pre-defined dimensions; results are dependent on the determinants and illustrate the outcomes of the performance measurement (Folan & Browne, 2005).

Balanced Scorecard (Kaplan & Norton, 1992)

- The BSC has become the most well-known PMS (Kennerly & Neely, 2004).
- The BSC is a holistic PMS that aims at balancing different dimensions and perspectives throughout the entire organization (Kaplan & Norton, 1996).
- Besides the shareholder view, which is dominated by financial aspects, other perspectives, such as customer, internal processes, and learning and development, are taken into account.
- The implementation of the BSC is supported through specific processes which break the corporate vision and strategy down into measurable targets.
- The systematic operationalization of targets to derive manageable goals for business operations facilitates an efficient allocation of resources and enables strategic learning within the organization.

Cambridge Performance Measurement Process (Neely *et al.*, 1996)

- The CPMP describes a holistic method that includes the phases design, implementation, and application of the PMS (Pun & White, 2005).
- The CPMP is a conceptual approach that allows for a firm-specific customization of the PMS (Taticchi & Balachandran, 2008).

Consistent Performance Measurement System (Flapper *et al.*, 1996)

- The CPMS focuses on the relations and interdependencies between the performance measures.
- The development and implementation process consists of definition of measures, description of relationships, and fixation of target values.
- The CPMS is a conceptual approach that defines the implementation process.
- There is no advice for how to balance critical performance dimensions (Hudson *et al.*, 2001).

Integrated Performance Measurement System (Bititci *et al.*, 1997)

- The IPMS integrates existing frameworks and models into a new reference model.
- The IPMS proposes a proactive closed-loop control system that assures the implementation of strategy on all organizational levels and in all business processes and gives feedback through appropriate performance measurement (Taticchi & Balachandran, 2008).
- Various performance levels are modeled and integrated through cause-and-effect relationships by the IPMS.
- The IPMS can be integrated into existing PMS, but structured processes to define goals and to support planning, development and implementation of strategy are missing (Hudson *et al.*, 2001).

Comparative Business Scorecard (Kanji, 1998)

- The CBS is also known as "Kanji's Business Scorecard".
- The CBS helps executives to identify success factors for business excellence (Kanji & Sá, 2002).
- The perspectives of the BSC were modified and aim at the maximization of stakeholder value, process excellence, organizational learning, and fulfillment of stakeholder claims (Kanji & Sá, 2002).
- The four perspectives are arranged as a loop that facilitates a process of continuous improvement.

Dynamic Performance Measurement System (Bititci *et al.*, 2000)

- The DPMS is based on the previously described IPMS and extends its reference model by integrating dynamic change processes (Taticchi & Balachandran, 2008).
- Particular emphasis is placed on the deployment of IT-based management tools.

IT Balanced Scorecard (van Grembergen, 2004)

- The IT-BSC is a derivate of the BSC, being customized to meet the requirements of measuring the performance and business value of IT services.
- In the literature, different perspectives for implementing strategy with the help of IT and measuring IT performance are proposed (van Grembergen & Van Bruggen, 1997; Martinsons *et al.*, 1999).
- Van Grembergen (2004) proposes four perspectives. 1) Business contribution: the main goal is that the firm receives a reasonable business value from its IT investments – thus costs must be controlled, business value must be evaluated, and innovative capabilities must be provided. 2) User orientation: this perspective analyses the satisfaction of users concerning the provision of IT services. 3) Operational excellence: the effectiveness and efficiency of IT services through IT service development and operations is measured. 4) Future orientation: by scanning emerging technologies, business opportunities can be identified and future challenges can be met through the adequate development of expertise of IT staff.

9.3 Research project Green IT Cockpit

The literature review on traditional and modern performance measurement systems was used for selecting a PMS that appears suitable for the research project *Green IT Cockpit*. This project is being realized by Technische Universität Berlin (research institute), Umweltbundesamt (public authority), Axel Springer AG (major business enterprise), and Time Kontor AG (small enterprise). Associated partners are Microsoft and the competence center Green IT-BB. The goal of this project is the development of a management dashboard which provides information for business

executives through the measurement and analysis of IT-related CO2 emissions. By facilitating transparency of energy consumption with reference to business processes, the energy efficiency of IT operations and the effectiveness of business processes can be enhanced. To display the IT-related energy consumption of business processes, the power consumption of servers, network equipment, workstations and peripheral equipment is monitored and linked to the activities that constitute higher order, complex business process. The measured values are aggregated to key performance indicators (KPIs). These KPIs are arranged according to specific performance dimensions and visualized in the *Green IT Cockpit*.

9.3.1 PMS evaluation criteria

To come to a decision how the collected data should be presented in the *Green IT Cockpit*, the research team had to agree on a PMS that could serve as a starting point for a customized arrangement of KPIs. For this reason, the PMS that were introduced in the previous section were discussed by three research scientists from Technische Universität Berlin and two executives from each of the partner organizations. In a first step, the experts agreed on nine assessment criteria referring to the project-specific requirements of the *Green IT Cockpit*. These were applied for the evaluation of different PMS approaches. At this point, we give a brief description of the chosen assessment criteria:

a) Process orientation: enterprise management techniques have recently evolved into process-oriented methods (Pun & White, 2005). To guarantee effectiveness and efficiency of business processes, the process owners (executives) must obtain process-related information, such as process-specific performance measures.

b) Temporal orientation: assesses whether past-, present- and/or future-oriented aspects are considered by the PMS.

c) Diversity of perspectives: describes whether the PMS is capable of displaying different performance perspectives, such as financial performance, which can be judged by "hard" numbers, or customer satisfaction, which is rather described by non-quantifiable, "soft" measures (Hudson *et al.*, 2001).

d) Strategy alignment: a PMS should support the implementation of strategy throughout the organization by delivering measurable results regarding the success of strategic initiatives. Moreover, the PMS should facilitate data of operational processes referring to the creation of business value (Kaplan & Norton, 1992).

e) Simplicity: obviously, an uncomplicated development, an easy implementation, low operation costs and little utilization of manpower are

advantages of a simple PMS. The complexity of collecting and visualizing data is regarded as well.

f) Consolidation of data: numerous organizational levels have to be addressed by the PMS (Folan & Browne, 2005). Thus data must be aggregated through cause-and-effect relationships from low-level operational measures to high-level KPIs that provide information to executives.

g) Identification of potentials for improvement: a PMS that facilitates transparency and identifies deficits can give hints how the prevailing practices can be improved.

h) ICT orientation: this criterion assesses whether the PMS is appropriate to measure the performance of ICT.

i) IT-based implementation: examines if monitoring and data analysis of the PMS can be implemented through IT systems. Furthermore, the integration of the PMS into existing systems is taken into account.

These nine selected assessment criteria were weighted with a rating matrix (Figure 22) to allow for a project-specific evaluation of PMS.

Rating matrix for evaluation criteria											
	a	b	c	d	e	f	g	h	i	Σ	%
a		2	1	2	2	0	1	0	0	8	11%
b	0		0	1	0	0	0	0	0	1	1%
c	1	2		2	2	1	0	0	0	8	11%
d	0	1	0		0	0	0	0	0	1	1%
e	0	2	0	2		0	0	0	0	4	6%
f	2	2	1	2	2		1	2	2	14	19%
g	1	2	2	2	2	1		1	1	12	17%
h	2	2	2	2	2	0	1		1	12	17%
i	2	2	2	2	2	0	1	1		12	17%
										72	100%

Figure 22: Determining the weights of assessment criteria.

In this matrix, the rows and columns represent the assessment criteria (from *a* to *i*). A value of 0 signifies that the criterion of the vertical column is more important than that of the horizontal row, a value of 1 stands for equality while a value of 2 signifies that the criterion of the row is more important than that of the column. The first row, for example, refers to criterion *a* and must be read as follows: process orientation (*a*) is more important (value 2) than temporal orientation (*b*). It is as well more important than criteria *d* and *e*. Moreover, *a* is as important as (value 1) diversity of perspectives (*c*) and identification of potentials (*g*). Finally, *a* is less important (value 0) than criteria *f*, *h* and *i*.

The main goal of the *Green IT Cockpit* is to provide information with regard to ICT energy efficiency. To do so, data that refers to ICT performance and energy consumption is required. There are three interest groups that must be addressed by

the *Green IT Cockpit*: 1) executives need consolidated, meaningful KPIs that can guide their decision-making; 2) process owners require data that is linked directly to their business processes to be able to optimize them; 3) IT operations managers need measures that illustrate energy efficiency of their IT systems to improve sustainability of IT operations. Obviously, the ability to analyze data on different levels of IT management is crucial for the *Green IT Cockpit* to leverage the potential of sustainability-oriented ICT. As a consequence, *f* turned out to be the most important evaluation criterion with a weight of 19 percent.

Other essential characteristics are the capability of identifying optimization potentials, the orientation towards ICT, as well as the possibility to implement the PMS with the help of information technology. Each of these aspects has a weight of 17 percent. The process orientation is important because the *Green IT Cockpit* is aimed at quantifying the IT-based CO2 emissions referring to specific business processes (weight 11 percent). Equally important is the diversity of perspectives to provide valuable information to different recipients. The simplicity is of minor importance (6 percent) and the future orientation and strategy alignment do not play a role (1 percent) according to the judgment of the expert panel. Although the projection of results into the future and the harmonization with corporate strategy are desirable aspects, they are not in the scope of this research project.

9.3.2 Development of the Green IT Cockpit

		Performance Measurement System																	
Criterion	Weight	PP		R&DM		BSC		CPMP		CPMS		IPMS		DPMS		CBS		IT-BSC	
		P	W	P	W	P	W	P	W	P	W	P	W	P	W	P	W	P	W
a	11%	1	0,11	1	0,11	4	0,44	2	0,22	2	0,22	4	0,44	4	0,44	4	0,44	4	0,44
b	1%	2	0,03	2	0,03	4	0,06	2	0,03	2	0,03	3	0,04	4	0,06	4	0,06	4	0,06
c	11%	2	0,22	3	0,33	4	0,44	3	0,33	3	0,33	4	0,44	4	0,44	4	0,44	4	0,44
d	1%	4	0,06	3	0,04	4	0,06	4	0,06	4	0,06	4	0,06	4	0,06	4	0,06	4	0,06
e	6%	1	0,06	3	0,17	2	0,11	0	0,00	0	0,00	1	0,06	0	0,00	1	0,06	2	0,11
f	19%	3	0,58	3	0,58	4	0,78	2	0,39	3	0,58	4	0,78	4	0,78	4	0,78	4	0,78
g	17%	3	0,50	3	0,50	4	0,67	2	0,33	3	0,50	3	0,50	3	0,50	4	0,67	4	0,67
h	17%	2	0,33	1	0,17	2	0,33	2	0,33	2	0,33	2	0,33	3	0,50	2	0,33	4	0,67
i	17%	2	0,33	2	0,33	3	0,50	2	0,33	2	0,33	2	0,33	4	0,67	2	0,33	3	0,50
	Σ		2,22		2,26		3,39		2,03		2,39		2,99		3,44		3,17		3,72

Figure 23: Results of the evaluation of the selected PMS.

After having agreed on the previously described evaluation criteria and their weights, the expert panel assessed the PMS that were introduced in section 2 (see Figure 23). For every PMS, there are two columns. The P column displays the judgment of the experts under consideration of the evaluation aspects: "0 points" signifies that the PMS does not fulfill the criterion at all; "4 points" indicates that the requirement is thoroughly met. In the W column, the points are multiplied with the

weights of the respective criteria. In the last row, the sum of the weighted evaluation presents the final result. Apparently, the IT-BSC is the most adequate PMS for the *Green IT Cockpit*. The only shortcomings are: 1) the IT-BSC is a rather complex PMS, and 2) the implementation with the help of information systems is not trivial. After having decided to utilize the IT-BSC in the scope of this project, suitable perspectives had to be derived to customize the IT-BSC according to the requirements of the *Green IT Cockpit*. These perspectives facilitate a multi-dimensional measurement of performance and efficiency of ICT, and allow for a neat arrangement of KPIs. It was decided to integrate a financial, a business process, an ICT performance, and an environmental perspective. The research team analyzed and discussed KPIs from existent literature to select measures and indicators meeting the requirements of the *Green IT Cockpit*. The chosen KPIs were assigned to specific dimensions. The results are displayed in Figure 24.

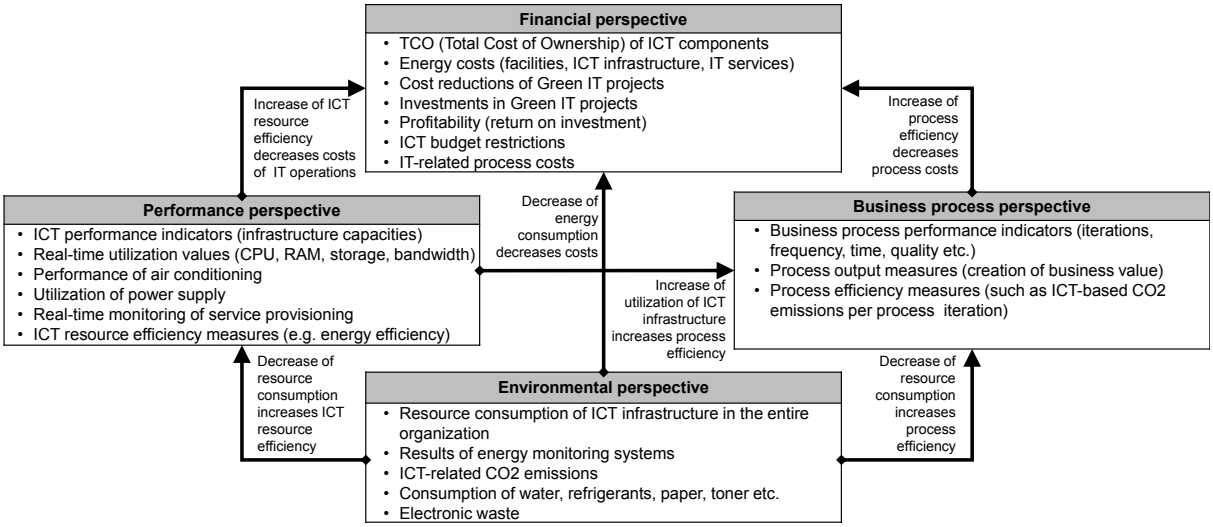

Figure 24: Sustainability BSC for the Green IT Cockpit.

The resource consumption of the ICT infrastructure is being quantified and analyzed in the *environmental perspective*. On the basis of the power consumption of specific hardware components, CO2 emissions can be derived. These emissions can be assigned to the deployment of ICT capacities, which are measured and displayed in the *performance perspective*. The output-oriented ICT performance measures are directly linked to the creation of IT services, which constitute the foundation for the execution of business processes. In this way, the IT-related CO2 emissions of specific business processes can be quantified. The process performance indicators are illustrated in the *business process perspective*. These three perspectives are all associated with the *financial perspective*, where the positive impact of energy efficient ICT infrastructure can be measured. The information provided can guide business executives in their decision-making processes concerning environmentally sustainable technologies.

9.4 Conclusions

In this paper, it was argued that both the creation of business value and the environmental impact of ICT are difficult to measure. Due to a lack of transparency, business executives can hardly leverage the potential of sustainable ICT although innovative technologies and reengineering of manufacturing and business processes offer substantial opportunities to decrease a firm's environmental footprint and to enable efficiency increases that enhance competitiveness. For this reason, we analyzed numerous PMS that assist executives in measuring and understanding the multifaceted impact of ICT on business value creation. However, these approaches do not integrate environmental sustainability, and linkages between ICT and efficiency of internal business processes are missing.

The research project *Green IT Cockpit* addresses this research gap. In this paper, we presented a part of the project results, evaluating modern PMS with multi-criteria decision analysis and selecting the IT-BSC as most suitable PMS. Subsequently, appropriate perspectives and KPIs were identified and linked through cause-and-effect relationships. By doing so, IT-related CO2 emissions could be mapped to IT performance while IT performance in turn is linked to the execution of business processes, and finally to financial measures. As a result, IT managers can analyze the energy efficiency of the infrastructure, process owners can quantify process-specific CO2 emissions, and high-level executives can base their investment decisions for sustainable ICT infrastructure and process reengineering initiatives on reliable data.

C. EMPIRICAL RESEARCH

Table 24: Empirical research articles.			
Section	**Title**	**Published in**	**Authors**
C10	Towards a Typology of Green IS Strategies: Insights from Case Study Research	Proceedings of the 33rd International Conference on Information Systems (ICIS 2012), Orlando, USA	**Loeser, F.**, Erek, K. & Zarnekow, R.
C11	Enhancing Firm Competitiveness with Green IS: An Empirical Analysis of the Antecedents and Consequences of Adopting Green IS	Information Systems Journal's (ISJ's) Special Issue on Information Systems addressing the Challenges of Environmental Sustainability (original submission 15th August 2013; revision submitted on 31st March 2014; under review)	**Loeser, F.**, vom Brocke, J., Molla, A. Zarnekow, R. & Erek, K.

10. Towards a Typology of Green IS Strategies: Insights from Exploratory Case Study Research

Title	Towards a Typology of Green IS Strategies: Insights from Case Study Research
Authors	Fabian Loeser[1], Koray Erek[1] & Ruediger Zarnekow[1] [1] Institute of Information Systems Management, Technische Universität Berlin, Straße des 17. Juni 135, 10623 Berlin, Germany
Published in	Proceedings of the 33rd International Conference on Information Systems (ICIS 2012), Orlando, USA
Abstract	In this paper we develop a typology of Green IS strategies and address two research questions: 1) What different types of Green IS strategies can be identified in a real-life context? 2) How do firms with distinct Green IS strategies conceive the role of Green IS within their organization? We begin with the a priori definition of "Green IS strategy" and conduct an exploratory case study that examines multinational companies from different industries. Across these cases, four distinct Green IS strategies are identified as a result of a within-case analysis and the emerging patterns are more closely defined using a cross-case analysis. Insights are compared with extant literature and findings are consolidated in five propositions that outline characteristics of Green IS strategies. These propositions guide the conceptualization of a typology of Green IS strategies which illustrates four generic strategies: Green IS for Efficiency, for Innovation, for Transformation, and for Credibility.

10.1 Introduction

Currently, a rising interest in the protection of the natural environment can be observed – due to resource depletion, industrial pollution, habitat destruction, population growth, and, in particular, because of the looming threat of climate change. Business executives have become aware of the environmental impact of their firms and their responsibilities, since stakeholders increasingly call for sustainable production methods and management practices (Albino *et al.*, 2009; Elliot, 2011). As stakeholders affect the achievement of the firm's objectives and determine both strategic success factors and competitive advantage, environmental issues should be considered in competitive strategies (Freeman & Reed, 1983; Stead *et al.*, 2004). A growing number of business leaders are beginning to meet these challenges – and to appreciate the opportunities that come along with sustainable development – by integrating environmental aspects into their corporate and competitive strategies (Dwyer, 2009; Dyllick & Hockerts, 2002; Watson *et al.*, 2010).

Porter (1980) argues that formulating competitive strategies leads to trade-off decisions and requires commitment and strategic positioning to enhance competitiveness. A firm that simultaneously pursues a low-cost approach while striving for unique product differentiation will reach neither of these goals – it is "stuck in the middle" and will be confronted with declining competitiveness and low profitability owing to the lack of strategic focus. The same is true for environmental strategies. To improve its competitiveness in the market, a firm requires a clear and consistent environmental strategy that either targets cost reduction through resource efficiency or aims at differentiation from competitors based on superior environmental product characteristics (Orsato, 2009). To incorporate aspects of environmental sustainability in the entire organization, sustainability must be addressed on the corporate, competitive, and functional level (Stead *et al.*, 2004). Focused sustainability strategies increase a firm's competitiveness since customers and other stakeholders, such as employees and shareholders that strive for the firm's profitability in the long-term, appreciate responsible business practices (Albino *et al.*, 2009; Freeman & Reed, 1983). Although sustainability has been identified as a key issue for corporate management, there is a high level of uncertainty with regard to the development of future technologies and the transformation of business activities towards markets that have yet to emerge (Elliot, 2011).

While scholars of management research have already given a remarkable amount of attention to environmental strategies and sustainable development, the strategic aspects of environmentally friendly Information Systems (IS) have hardly been analyzed by the IS community (Jenkin *et al.*, 2011). Recently, IS scholars have called for research within the academic field of Green IS, given the lack of meaningful

theories, conceptual frameworks, and above all, empirical evidence (Molla *et al.*, 2009). The significance and the achievable impact of Green Information Technology (IT) and Green IS have been widely acknowledged by both practitioners and IS scholars (Bengtsson & Ågerfalk, 2011). Nonetheless, IS research has been criticized for not providing sufficient assistance to organizations in progressing towards environmental sustainability and for not meeting the challenges of climate change (Molla *et al.*, 2011). Watson *et al.* (2010) urge the IS research community to clarify the role of IS and to engage decisively in the investigation of IS capabilities that have the potential to make business and manufacturing processes more resource-efficient and environmentally friendly.

Hu & Huang (2005) emphasize that the competitiveness of the firm increasingly depends on the harmony of business and IT strategy. Luftman & Brier (1999, p. 109) argue that "the alignment of information technology and business strategy to leverage the capabilities of IS and to transform the business has increased in importance over the past few years as firms strive for competitive advantage in a diverse and changing marketplace." IS can be an important enabler of organizational change and alignment can improve corporate efficiency, foster innovation in products and business solutions or strengthen the relationships with customers and suppliers (Weiss & Anderson, 2004). Obviously, the potential of innovative information systems to support the achievement of environmental targets can only unfold if the IS strategy is aligned with the environmental strategy of the firm. However, this topic has hardly been investigated by the IS research community.

Chen *et al.* (2010b) underline that business executives perceive IS as crucial for the achievement of their strategic targets. Nonetheless, current Green IT initiatives are restricted to reducing IT-based energy consumption, which is associated with operational cost decreases, although Green IS are crucial to "enable firms to develop capabilities to address sustainability issues, deliver sustainable value to stakeholders and gain sustained competitive advantage" (Dao *et al.*, 2011, p. 64). Apparently, there is a need for IS strategies that integrate aspects of environmental sustainability and support business and environmental targets while leveraging firm competitiveness.

To summarize our argumentation: Green IS have the potential to improve the environmental sustainability of business firms. These firms follow different strategic approaches to enhance their competitiveness. The potential of IS can only be leveraged if IS strategy is aligned with business and environmental strategies. Hence we assume that there should be different strategic approaches for managing IS to improve long-term competitiveness. With the goal of advancing the knowledge of strategic IS management in research and practice, concerning the integration of

environmental aspects and corporate goals into IS strategy, we formulate our first research question:

RQ1: What different types of Green IS strategies can be identified in a real-life context?

To address RQ1, we opted for exploratory case study research. We follow the advice of Eisenhardt (1989) for building theories from case study research and apply the methods proposed by Yin (2009). Furthermore, we consider the requirements for scientific rigor in IS case study research as postulated by Dubé & Paré (2003). The insights from this case research are compared with prevalent concepts and theories from IS and strategic management literature. The consolidated findings are used to guide our conceptualization of a typology of Green IS strategies.

The paper is structured as follows. After the introduction, we define the term Green IS strategy. Following this a priori definition, we explain the design of our exploratory case study in detail. Next, we conduct a within-case and a cross-case analysis, providing insights from four very different cases that demonstrate distinct Green IS strategies. Subsequently, we compare the emerging concepts from our empirical study with theories from extant literature. On the basis of these consolidated findings, we propose a conceptual typology of Green IS strategies. Finally, we discuss implications and provide suggestions for further research.

10.2 Conceptualizing Green IS strategy

Ijab *et al.* (2010) conducted a literature review for defining *Green IS* and found out that there is no clarity amongst IS researchers concerning the terms *Green IT*, *Green IS*, *Green ICT*, *Sustainable IT/ICT* and *IS for eco-sustainability*, which are sometimes used interchangeably. To clarify our research objective, we explain our understanding of the term *green*, we illustrate differences between the terms *IT* and *IS* as well as between *Green IT* and *Green IS*, and we introduce a specific concept of IS strategy that serves as foundation for our definition of *Green IS strategy*.

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 & 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 *et al.*, 2009).

The term *Information Technology* (*IT*) is applied to describe computer hardware, software, and peripheral equipment (Ijab *et al.*, 2010). The concept of *Information Systems* (*IS*) "combines both the technical components and human activities within the organization as well as describing the process of managing the lifecycle of

organizational IS practices" Chen *et al.* (2010b, p. 234). *IS* comprise *Information and Communication Technologies* (*ICT*) (such as physical servers, office computers and network devices), shared services (such as databases or storage), and business applications (such as ERP systems). Furthermore, *IS* include IT human resources (such as skills and knowledge), and the IT managerial capability for organizational core activities and business transformation (Broadbent & Weill, 1997; Ravichandran & Lertwongsatien, 2005). Chen *et al.* (2010b, p. 237) give a comprehensive definition of *IS* by stating that "*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."

Green IT practices are mostly focused on the IT energy consumption of corporate data centers and offices, whereas the cross-functional characteristics of *Green IS* enable environmental management systems and the reinvention of business and production processes (Dao *et al.*, 2011; Elliot, 2011). Molla & Abareshi (2011) argue that *Green IT* refers to the negative first-order environmental impact (production, use, and disposal of IT), whereas *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) as well (Hilty *et al.*, 2006). In line with Watson *et al.* (2010), we argue that the concept of *Green IT*, although often used amongst practitioners, is too limited because it is restricted to the lifecycle of IT, whereas *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.

To elucidate the difference between *Green IT* and *Green IS*, we provide some practical examples: Currently firms mainly focus on the implementation of mainstream Green IT measures (hardware procurement and energy-efficient operations) since the reduction of IT-based energy consumption is directly linked to cost savings. However, sustainable competitive advantages can hardly be achieved with these well-known operational measures (Bengtsson & Ågerfalk, 2011). Green IS, by contrast, promise a much greater, organization-wide potential to measure, monitor, report and reduce the firm's environmental footprint, but the transformation of the business with the help of Green IS requires a holistic long-term strategy (Molla *et al.*, 2011). 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).

Chen *et al.* (2010b) emphasize that *IS strategy* is an important field of research, and meaningful for practitioners as well. They analyze different streams of IS research which are related to IS strategy, such as research on Strategic Information Systems

Planning (SISP), IS alignment, and IS-based creation of competitive advantage. They find three conceptualizations of *IS strategy* in the literature that differ decisively from each other: 1) the *business-centric* conception of IS strategy as part of a competitive strategy, with the goal of supporting the business through a priori alignment to achieve a certain market position; 2) the *IS-centric* conception of IS strategy as a functional plan for effectively acquiring and building IS-assets and managing them efficiently, while IS and competitive strategy are aligned ex post; 3) the *organization-centric* conception of IS strategy which provides a common understanding throughout the organization of how IS should be utilized to achieve strategic goals.

In the context of this research, we adopt the *organization-centric* conception of *IS strategy* that is defined by Chen *et al.* (2010b, p. 235) as "an organizational perspective on the investment in, deployment, use, and management of information systems." In this conception, IS strategy has an organization-wide scope, is an integral part of corporate strategy, and is not limited to specific business units. It can support competitive strategies as well as shape them (Henderson & Venkatraman, 1993; Agarwal & Sambamurthy, 2002), depending on the role of IS within the organization. This role depends on the shared view and managerial perception of IS infrastructure and capabilities, while the specific business requirements are fulfilled through dynamic alignment. In line with Chen *et al.* (2010b, p. 237) and Elliot, 2011, p. 208) we define Green IS strategy as follows:

> *Green IS strategy is the organizational perspective on the investment in, deployment, use and management of information systems (IS) in order to minimize the negative environmental impacts of IS, IS-enabled products and services, and business operations.*

Under consideration of this definition of Green IS, we formulate our second research question:

RQ2: How do firms that follow a distinct Green IS strategy conceive the role of Green IS within their organization?

To answer our research questions RQ1 and RQ2, we follow the process of building theories from case study research that is described by Eisenhardt (1989). This seminal piece is the most-cited inductive approach for conducting exploratory case study research and recommends the definition of research questions and a priori constructs whereby no theory should be considered and no hypotheses should be formulated in advance because "preordained theoretical perspectives or propositions may bias and limit the findings" Eisenhardt (1989, p. 536). In line with this, we formulated RQ1 and RQ2 without hypothesizing specific relationships of

variables or outcomes. Further, we limited the literature review at this point to the a priori definition of the term "Green IS strategy".

10.3 Case study research design

Myers (1997, p. 241) states that "qualitative research methods become increasingly useful as the focus of information systems research shifts from technological to managerial and organizational issues." Since formulating Green IS strategies is a managerial issue that determines the role of IS throughout the organization, a qualitative research approach appears to be appropriate to address our research questions. Benbasat *et al.* (1987, p. 328) argue that "the relationship between information technology and corporate strategy is an area that could be explored further using a structured program of multiple case studies." For this reason, we decided to conduct case studies to investigate the chosen topic.

Case study research has become a widely acknowledged research strategy in IS research. Dubé & Paré (2003) analyzed 1691 articles from leading IS journals and found out that case study research is applied in 15 percent of all articles. Of those articles that use the case research method, 30 percent draw on exploratory case studies. Chan & Huff (1992, p. 194) suggest that "to obtain a rich and detailed understanding of strategy from multiple viewpoints, consider case studies [...]." Case study research has the advantage that data from multiple sources of evidence can be combined through triangulation (Dubé & Paré, 2003) and is particularly useful for IS strategy research which is linked to managerial perception, roles and complex interaction patterns of IS management (Benbasat *et al.*, 1987; Paré, 2004).

Regarding the case study research approach, we were mainly guided by the articles by Eisenhardt (1989), Yin (2009), Paré (2004), and Dubé & Paré (2003). Yin (2009, p. 18) defines a case study as "an empirical inquiry that investigates a contemporary phenomenon in depth and within real-life context [...]." Paré (2004) explains that "just as case research can be positivist, interpretive, or critical, positivist case study research can be descriptive, exploratory, or explanatory. Each of these three approaches can be either single or multiple-case studies." Our research can be classified as a positivist, exploratory multiple-case study. Eisenhardt (1989) illustrates a process for building theories from exploratory case study research which is particularly useful for the development of our typology of Green IS strategies. Consequently, our research was guided by Eisenhardt's work, while we followed the four steps that were proposed by Paré (2004) specifically for the IS research community (see Table 25). Furthermore, we considered the recommendations for scientific rigor in IS case study research of Dubé & Paré (2003).

Table 25: Exploratory case study approach used in this study referring to Paré's (2004) research framework.		
Steps	**Activities**	**Characteristics of the conducted research project**
1. Design of the case study	Definition of research questions	RQ1: What different types of Green IS strategies can be identified in a real-life context? RQ2: How do firms that follow a distinct Green IS strategy conceive the role of Green IS within their organization?
	Prior theorizing	Neither theory nor hypotheses – to retain theoretical flexibility.
	A priori constructs	Definition of Green IS strategy.
	Unit of analysis	Role and strategic goals of Green IS.
	Selection of cases	Multiple-case design, extreme sampling, selection of four cases.
	Case study protocol	Description of the research project, definition of objectives and scope, information sources, interview guidelines, and topics and structure of the case study reports.
2. Conduct of the case study	Data collection methods	Interviews, questionnaires, and internal documents.
	Data triangulation	Multiple sources of information were consolidated and results were compared to increase validity.
	Theoretical saturation	Key informants were interviewed and documents collected until theoretical saturation was reached.
3. Analysis of the case study evidence	Early steps in data analysis	Field notes were used to identify relevant categories. Interviews were transcribed and analyzed with open coding techniques. Information was structured and recorded in a project database.
	Within-case analysis	Explanation-building was used as dominant analytical strategy to identify specific Green IS strategies.
	Cross-case analysis	Differences of chosen constructs and dimensions were analyzed to illustrate distinct Green IS strategies.
4. Writing up the case report	Case study reports	Reports were written according to a standardized guideline and reviewed by interviewees in a feedback loop until final results were approved by all participants.

As displayed in Table 25, we started our exploratory case research with the definition of research questions RQ1 and RQ2 and defined the construct "Green IS strategy" a priori while not considering theory to minimize researcher bias. Throughout the whole investigative process, the researchers played a passive, neutral role. The unit of analysis, which is directly linked to our initial research questions, is the role and the strategic goals of Green IS in the investigated organizations (Dubé & Paré, 2003; Eisenhardt, 1989; Yin, 2009). In line with Sabherwal & Tsoumpas (1993), who studied a similar phenomenon, we base our research on a multiple-case study. Our case sampling strategy draws on the *extreme case* approach: we conducted 36 semi-structured interviews with executives from

eight international companies (headquarters based in Germany) in the scope of a cross-sectional research project.

To achieve a detailed picture of the role of Green IS within the studied organizations, different types of data collection were combined (Yin, 2009). Methodological triangulation was applied through semi-structured interviews, questionnaires and internal documents. The interviews were conducted with executives from both the IS and sustainability departments. Interview partners were selected using the snowball sampling strategy (Paré, 2004). Our initial interview partners identified further members within their organization that were of interest for our study, and they, in turn, identified others until additional interviews did not reveal any new information, which is an indicator that theoretical saturation is achieved (Eisenhardt, 1989). An outline of topics to be addressed was mailed to interview partners in advance. The 36 semi-structured interviews were conducted by two researchers to enhance accuracy and objectivity and lasted from 30 minutes to two hours (Dubé & Paré, 2003; Yin, 2009). Interviews were recorded, transcribed and analyzed using open coding techniques. Summaries of the reports were sent to the executives who provided feedback. The results were reviewed by the executives, using a feedback loop, until final reports were approved.

Referring to RQ1, we were searching for Green IS strategies that were as different as possible – and thus we selected four cases that reveal different Green IS strategies. The selected cases represent companies from different industries acting globally (see Table 26). All four companies have been listed in the 'Dow Jones Sustainability Index World' for at least three years, which implies that they are among the 10 percent environmentally top performing companies of their respective industry. Two of the companies (cases B and D) are worldwide sustainability leaders in their sector. All four companies publish detailed sustainability reports which have been rated A+ by the Global Reporting Initiative. The research process was guided by the agenda specified in our case study protocol where rules, procedures, and instruments were defined prior to data collection.

During the interviews the following topics were addressed:

- Corporate sustainability: environmental strategy and firm-wide goals; operationalization of sub-targets for the business units; measurement of environmental performance; environmental initiatives, projects and action plans; organizational roles and managerial responsibilities; internal and external communication; sustainability reports; industry characteristics.
- IT department: relevance of IS for the core business; fundamental approach for managing the IT department; perceived value of IS; support of internal processes; significance of IS for end products and customer services.
- Purpose of environmentally sustainable IS management: individual perception of this topic by the interviewee; environmental challenges relevant

to the IT department; firm-wide goals of Green IS; metrics and targets; measurement and goal achievement; effectiveness and efficiency of Green initiatives; cooperation between IT department and business units.

- Implementation of Green IT/IS measures: 1) source process (supplier management and policies for purchasing of IT hardware and services); 2) make process (data center operations and management of end user devices in the office environment); 3) deliver process (customer relationship and communications management).

In the questionnaire that was answered by the interviewees in a follow-up, the implementation of Green IT measures in the IT organization's source, make, and deliver processes, as well as inter-departmental Green IS initiatives, were addressed. Moreover, a wide range of internal documents, such as formalized descriptions of organizational structures, job roles, sourcing criteria, processes, environmental performance metrics and measures, as well as public documents, such as sustainability reports and company websites, were examined. Confidentiality was guaranteed and the descriptions of the case studies were anonymized for this paper.

Table 26: Characteristics of the four companies which are analyzed in this research paper

Case	A	B	C	D
Industry	Chemicals	Technology	Financial services	Software
Sales volume (2011)	> $ 40 bn	> $ 50 bn	Assets > $ 2 tn	> $ 10 bn
Number of employees	> 100,000	> 400,000	> 100,000	> 50,000
Interview partners	• Head of Data Center & IT Operations (1h) • Head of IT Operations & Green IT (1.5h) • Head of Procurement & Transport, Head of Procurement Hardware & Services (1h)	• Director of Sustainable IT (1.5h) • Advisor of Environmental Management (2h) • Head of Efficient Data Center (1.5h)	• Director Global Lead Eco-Efficient IT (2h) • Head of Corporate Social Responsibility (1.5h)	• Vice President Green IT (1h) • Vice President Sustainable Operations (1h) • IT Director for Global IT Clients (1h) • Senior Director of Data Center Operations (1h)

10.4 Case study analysis

To facilitate the answering of our research questions, the exploratory multiple-case analysis is focused on differences in strategic Green IS management. The goal is to identify distinct strategy types and to understand the organization-wide role of

Green IS. We conduct a within-case analysis with the dominant analytical strategy of explanation-building. This analysis technique is based on the description of the cases and is useful for exploratory case research (Paré, 2004).

10.4.1 Within-case analysis

Case A: Company A is a global player in the chemicals industry and produces pharmaceutical and medical products, chemicals for crop-protection, and materials such as polymers. Since the chemical industry has a significant environmental and social impact, the company is under increasing pressure from different stakeholder groups. Sustainability is considered as a long-term requirement for the legitimation of the business and is not treated as hype. However, company A is a mass-volume producer and the competitive pressure is high. Consequently, all environmental initiatives are directed towards efficiency enhancements of the production processes. One member of the executive board is responsible for environmental and social issues and a corporate sustainability board was established to embed sustainability throughout the organization. The internal IT organization develops and operates standardized solutions for executing business processes with "operational excellence". The IT department is managed as a cost center that provides internal services for the support of the core business. Green IS initiatives are only implemented if they have a positive return on investment in the mid-term. The cost pressure for the provisioning of IT services is intense since the corporate management demands top quartile prices as compared to the prices of the external market. IS are not part of the end product and only account for 0.6 percent of corporate CO_2 emissions. Green IS are understood as a means to reduce costs of IT and business operations and are initiated top-down. The "Green IT coordinator" is responsible for supporting the corporate efficiency and emission reductions goals. A Green IS strategy is not explicitly formulated since Green IS are understood as part of the corporate commitment towards sustainability. The main goal is to support business strategy and to enhance internal process efficiency, e.g., through facility management or teleconference systems.

Case B: Company B is a diversified technology company that serves global markets with energy technology, high-tech systems for the healthcare sector, industry automation technologies as well as mobility and infrastructure solutions. The competitiveness of company B heavily depends on innovation and technology leadership and sustainability has become the guiding principle for corporate strategy. In line with this, company B has incorporated organizational roles and structures for sustainability management. The Corporate Sustainability Officer (CSO) promotes sustainability at corporate management level; a board for sustainability takes responsibility for decision-making and the steering of

environmental initiatives while a specific sustainability council develops the sustainability strategy. Furthermore, an external expert panel provides feedback and advice to the executive board. The internal IT organization is managed as a cross-sector division and IS are perceived as important enablers for business and, above all, serve to foster innovation. The explicitly formulated Green IS strategy supports the values and goals of the corporate sustainability strategy and is an integral part of the organization-wide IS strategy. Green IS are managed with a holistic approach and have a broader scope than the usual Green IT measures. Company B already offers a continuously growing portfolio of energy-efficient products and succeeds in differentiating from competitors on the basis of these unique environmental product characteristics, which lead to reduced life-cycle costs and a smaller environmental footprint. The internal IT organization provides industry-specific solutions to the strategic business units. Green IS determine the characteristics of the end products and IS are a crucial enabler of innovation capabilities throughout the company. Furthermore, the IS organization aims at creating synergies among the different business units as a result of its cross-sector scope. Through cooperation between different divisions, internal processes were redesigned for a lower environmental impact. Examples are energy management systems for plant and production management, remote working practices and initiatives for ecological employee behavior, smart grid technology, and transport and fleet management systems. Green IS are not restricted to energy efficiency but perceived as enablers for firm-wide infrastructure and process management and for environmental product innovations that allow for competitive differentiation.

Case C: Company C is a leading international credit and investment bank that offers financial services to private and corporate clients. The financial services industry is currently characterized by consolidation and cost pressure while stakeholders are demanding more responsible business practices. Company C has installed an environmental steering panel at corporate level to formulate a vision. This panel receives advice from an environmental advisory board of external experts. The transformative vision of the company is to become carbon neutral within five years. The environmental operations panels develop concrete strategies for the different business units while environmental initiatives are implemented through so-called eco teams, which are supported by a specific project management office. IS have a significant impact on the CO_2 footprint of company C since all core business processes are based on IS – as are the majority of the financial services that are offered to the customers. Thus IS functionality and efficiency are critical to company C's competitiveness. Besides a business process redesign through Green IS, company C also uses Green IS to decrease its environmental footprint with a holistic energy management that is linked to the building automation systems. To achieve carbon neutrality for its services, company C has developed an ambitious

Green IS program, which includes highly efficient IT systems, raising awareness among employees, strict requirements for suppliers, recycling initiatives, travel reduction and real-time energy management of buildings.

Case D: Company D is a software company that offers enterprise resource planning and business intelligence solutions to customers worldwide. Its software solutions help companies to decrease their environmental footprint. Its clients are big companies around the globe, and many of them want to become more sustainable, such as companies from the financial services industry with a high dependence on software and IS. Sustainability has become the core component of company D's corporate strategy. It is embedded on all organizational levels through a CSO and through a sustainability committee, which consists of executive directors from all business units. The members of the sustainability committee are advocates for sustainability who disseminate an environmental mind-set throughout the whole company. By offering environmental management solutions and providing IT services to its customers, Green IS are obviously part of the end product and lead to differentiation from competitors. Company D appreciates the continuously growing market for sustainability-enabling solutions and develops important competencies based on its own experience and expertise in environmental management. Company D strives for minimizing its environmental impact by all means because it wants to be perceived in a positive way by its stakeholders. A good reputation is vital for the company and the employees are appreciated as the most valuable asset of the firm. Through an intense dialogue with its stakeholders, the company translates stakeholder claims into concrete company goals, which are implemented through Green IS – such as energy-efficient infrastructure and software solutions that facilitate detailed measurement for more sustainable business practices.

10.4.2 Cross-case analysis

The description of the role of Green IS in these four organizations already reveals that the approaches to managing Green IS strategically differ widely. The motivation for considering sustainability issues in the corporate strategy, the goals of Green IS, and the functional area of the company which is targeted by Green IS is different for each company. In addition, the significance of IS for the core business and the way of managing the IS department vary significantly – depending on the firm's end products and the relevance of IS for enabling internal processes.

Eisenhardt (1989) and Paré (2004) recommend consolidating the findings of the within-case analysis with a cross-case analysis, which facilitates a deeper understanding of the cases and accentuates the differences between them. By selecting specific categories that are relevant for the unit of analysis, the emerging patterns of explorative case study research can be sharpened by searching for

similarities and intergroup differences. To illustrate specific characteristics of the different Green IS strategies in the scope of a cross-case analysis, we contrast the four cases in Table 27. We consider the industry in which the firms are competing, their principal motivation for becoming more sustainable, the role, goals and focus of Green IS, as well as the fundamental approach to managing the IS department.

The cross-case analysis reveals that Green IS are of comparatively low importance for company A. The share of IS-related emissions is nearly negligible (0.6 percent of the company's CO2 footprint) because company A is active in a very energy-intensive processing industry. Moreover, Green IS are neither significant for company A's core business nor for the generation of competitive advantage since Green IS are hardly perceived by the firm's customers. The cost focus prevails and the potential for redesigning the manufacturing processes with the help of Green IS is small. The principal motivation for considering Green IS arises from stakeholders putting high pressure on companies from the chemicals industry, and thus several measures are taken to improve the corporate image.

Table 27: Cross-case analysis: Description of Green IS in companies A, B, C, and D.

Case	A	B	C	D
Industry	Chemicals	Technology	Financial services	Software
Driver of sustainability	Stakeholder pressure	Environmental product differentiation	Business and environmental leadership	Lead by example
Role of (Green) IS	Support business	Innovation driver	Enabler for business transformation	Core business
Major goal of Green IS	Cost efficiency	Technology leadership	Carbon neutrality	Encourage customers
Focus of Green IS	Business processes	High-tech products and business processes	Business processes and customer services	Sustainability-enhancing software solutions
Management approach for IS department	Cost center	Cross-sector division; realization of synergies	Cost center	Profit center

For company B, Green IS are important for environmental product innovation in particular. Similar to company A, the environmental impact of IS related to internal processes is relatively low (about 2 percent) because the manufacturing of high-tech products requires a great amount of energy and raw materials. However, the potential of Green IS to make the end products more efficient is extremely large – the products of the environmental portfolio helped company B's clients to save 300 million tons of CO2 emissions in 2011. Company B already generates 36 percent of

its sales volume with environmentally friendly high-tech products and thus Green IS are seen as crucial enablers for sustainable solutions that directly influence the company's competitiveness. Although the IS-based CO2 impact is relatively low, the internal business processes are reengineered with Green IS – primarily to acquire know-how that can be transferred to other business sectors. For example, an intelligent energy management system was implemented throughout the company and the know-how gained from this project could be applied to complex infrastructure solutions that are sold as a product of the company.

Although the Green IS strategy of company C is also focused on internal processes, the Green IS strategy is very different from the strategy of company A. The reason might be that the financial services industry does not produce physical goods and, as a consequence, firms from this industry have a comparatively low environmental impact. The CO2 emissions of company C mainly stem from the heating and air conditioning of office buildings, flight travel, and IS infrastructure. The financial services industry is being closely observed by stakeholders and, as a result, company C wants to improve its reputation – with the long-term goal of becoming carbon neutral. The core business processes are completely dependent on IS and due to this Green IS have great potential with regard to improving the environmental efficiency of business operations. Green IS are seen as a critical technology for this business transformation. In the interviews executives pointed out that the corporate management follows an environmental cost leadership approach and strives for superior environmentalism through cost-efficient, innovative business processes enabled by Green IS. Despite its importance for the business, the IS department is managed as a cost center to respond to industry-specific cost pressures. As stated in the interviews, a positive long-term return on investment is mandatory for the implementation of Green IS measures.

Company D has discovered the growth potential of the software market for environmental performance measurement and hence aims at becoming a first mover in this field. The management is aware of the impact that the company can have by sensitizing its customers to sustainability issues and decreasing environmental impacts through software solutions and business transformation. To encourage its customers, company D has to lead by example. For this reason, rigorous measurement of its own environmental and social performance is the basis for fulfilling the claims of its stakeholders and for achieving superior credibility. This is why sustainability is a crucial element of company D's corporate strategy, and Green IS are a major part of it.

10.5 Comparing empirical findings with extant literature

Eisenhardt (1989) underlines that it is particularly important in exploratory case research to link the results of the case study analysis to extant literature. To enhance the validity of our case study and to improve the generalizability, which is limited by the small number of cases, we compare the emerging patterns of Green IS strategies found in the multiple-case study with prevalent concepts of strategic, environmental and IS management literature. Based on these findings, we derive propositions that guide the conceptualization of a typology of Green IS strategies.

10.5.1 Environmental strategies

Strategic management literature distinguishes between three levels of strategy. Corporate strategy defines the vision, identity, business portfolio, and major long-term goals of the corporation and aims at exploiting distinctive competencies. Competitive strategies define concrete objectives for strategic business units striving for competitive advantages in specific market segments. Functional strategies support and implement the higher level strategies, and address efficiency and effectiveness targets of operations (Pearce & Robinson, 1991; Porter, 1987). Stead *et al.* (2004, p. 105) argue that sustainability aspects must be considered on these three strategy levels as well: "Sustainable Strategic Management strategies exist in a hierarchy at corporate, competitive, and functional levels of the firm [...] with the transcendent core value of sustainability underlying each strategy level."

As described in the case analysis, sustainability is a key component of the corporate strategy of all four companies that were studied. For company B and D, sustainability is a key aspect of competitive differentiation and thus an integral component of the competitive strategy, whereas companies A and C rather react to stakeholder pressures. On the functional level, companies B and D strive for the creation of unique, sustainability-related product characteristics, whereas companies A and C focus on resource efficiency. Obviously, the significance of Green IS for the strategic management of the firm depends on the core business and results in distinct manifestations: for companies B and D, Green IS are significant for their core business and their end products, for company C they are an enabler for business transformation while they are of minor importance for company A. Actually, companies B and D formulated an explicit Green IS strategy while companies A and C address the topic indirectly through their sustainability strategies.

Referring to our definition of an organization-wide Green IS strategy, we argue that Green IS must be considered on the three identified strategy levels as well. This brings us to our first proposition:

P1: Green IS strategies should address environmental and technical issues at the corporate, competitive, and functional level.

This proposition is used as a guiding principle for structuring the following sections that discuss the characteristics of environmental strategies referring to these specific organizational levels. Moreover, these three levels constitute the fundamental basis of the Green IS strategy typology that is developed later on.

10.5.1.1 Environmental strategy at the corporate level

To facilitate an environmentally sustainable orientation for the firm that is consistent with present and future needs of internal and external corporate stakeholders, organizations must balance their economic targets against their responsibilities by considering environmental aspects in decisions concerning sourcing criteria, production processes, product characteristics and technological innovations (Molla *et al.*, 2011). The corporate level sustainability strategy strongly shapes values and mindsets and, thus, influences corporate culture and the public perception of the organization.

Bieker (2005) develops four corporate environmental sustainability strategies that determine the fundamental attitude of the firm to stakeholders and the natural environment. The *efficient* strategy aims at the economic utilization of all kinds of resources, which is usually accompanied by cost efficiency, the *innovative* strategy strives for market-based opportunities through an ecological differentiation of products, the *transformative* strategy involves fundamental organizational changes and seeks for the creation of new markets, and the *credible* strategy focuses on improving the firm's reputation through good corporate citizenship. Corporate sustainability strategy depends significantly on external factors, such as pressure from stakeholders, legislation, competitors, brand image and firm reputation. For this reason, corporate management must consider the relationship between economic and environmental performance to ensure profitability in the long-term (Orsato, 2009; Schaltegger & Synnestvedt, 2002).

With regard to the multiple-case study, the corporate sustainability strategies followed by the four companies fit quite well with the generic corporate sustainability strategies that were identified by Bieker (2005). The underlying corporate sustainability goal of the four companies can be classified as follows: company A: efficiency; company B: innovation; company C: transformation; company D: credibility.

Benitez-Amado & Walczuch (2011) argue that Green IS are enablers of corporate environmental strategy and just as the IS strategy is dynamically aligned with the

corporate strategy, the Green IS strategy must be dynamically aligned with the corporate sustainability strategy. This brings us to our second proposition:

P2: Green IS strategy must be aligned with the corporate environmental strategy, which can be oriented towards efficiency, innovation, transformation, or credibility.

10.5.1.2 Environmental strategy at the competitive level

As Chen *et al.* (2010b, p. 242) state, "IS strategy can be developed to either support or alternatively drive a business strategy allowing for a dynamic form of alignment." Considering the business strategies at competitive level, Porter (1980) developed two generic market positioning strategies: differentiation and cost leadership. The differentiation strategy aims at creating products that offer superior value for customers, e.g., through innovative technologies, extraordinary quality or exceptional services. This strategy aims at brand image and high profit margins. The cost leadership strategy, on the contrary, aims at achieving economies of scale and the implementation of highly efficient processes to reach the lowest production costs within the respective industry. These strategies refer to the external environment and are widely accepted among scholars and practitioners. They prove to be relevant in IS research as well (Banker *et al.*, 2011).

Environmental strategies at the competitive level focus on the achievement of competitive advantages (Banerjee, 2001). The business case for cleaner production technologies and green products is strongly context-dependent. Environmental measures that target internal processes can improve resource efficiency and reduce costs, whereas market-oriented green products can enhance revenues and profitability. Environmental strategies can support market-oriented differentiation or cost leadership. Orsato (2009) proposes four generic, choice-based environmental competitive strategies, which distinguish between the internal and the external domain of value creation and competitive advantage. The environmental strategies are subdivided into two dimensions, competitive advantage (cost leadership vs. differentiation) and competitive focus (internal processes vs. market-oriented products), which results in a typology of four different strategies. This classification is useful to deepen our understanding of the competitive advantage that is targeted by the companies of our case study: company A and C implement Green IS measures to achieve cost leadership, whereas companies B and D use Green IS for product differentiation that determines their competitive advantage. This brings us to our third proposition:

P3: Green IS strategies can support cost leadership or competitive differentiation strategies.

10.5.1.3 Environmental strategy at the functional level

While competitive strategies determine a firm's position in a specific market, the actual value is created inside the firm, guided by its functional strategies. The Resource-Based View (RBV) explains the creation of competitive advantage on the basis of unique firm-specific internal resources and capabilities, which are the primary source of profit and provide direction for the firm's long-term strategy (Grant, 1991). Porter's positioning strategies and the RBV are complementary, and their consolidation is useful to gain an in-depth understanding of the contribution of IS to firm performance, considering the external and internal perspective of IS strategy (Wade & Hulland, 2004).

Environmental cost leadership strategies can be leveraged through redesigning business and manufacturing processes. Thus harmful input materials can be substituted and by-products can be recycled. This increases the production efficiency and decreases resource consumption and waste disposal costs. Environmental differentiation strategies can be enabled through Design for Environment. This approach aims at reducing the product's environmental footprint, which can represent a unique customer value for both ethical and economic reasons. Albino *et al.* (2009, p. 86) refer to a green product as "a product designed to minimize its environmental impacts during its whole life-cycle. In particular, non-renewable resource use is minimized, toxic materials are avoided and renewable resource use takes place in accordance with their rate of replenishment." In many cases, e.g., energy efficient IT infrastructure, lower resource consumption during the use phase pays off for the customer even if the initial investment made to buy the product is higher (Christmann, 2000). A growing number of companies not only focus on efficiency-based cost advantages, but also strive for competitive advantages based on ecological differentiation (Albino *et al.*, 2009).

These theoretical aspects match our empirical findings. While companies A and C focus their Green IS efforts on internal processes to support their environmental cost leadership strategies, companies B and D aim at ecological differentiation of their products with the help of Green IS.

P4: Green IS strategies can either support environmental cost leadership strategies by enhancing the efficiency of internal processes or they can promote environmental differentiation strategies through ecological product and service innovation.

10.5.2 Industry and firm characteristics determine the role of Green IS

The role of Green IS within the organization depends mainly on two factors: the environmental strategy on corporate, competitive, and functional level (Jenkin *et al.*, 2011) and the value creation and strategic impact of IS within the organization. Ravichandran & Lertwongsatien (2005) differentiate between IS operational and transformational competences. Melville *et al.* (2004, p. 287) define the business value of IS as "the organizational performance impacts of information systems at both the intermediate process level and the organization-wide level, and comprising both efficiency impacts and competitive impacts." This definition refers to two different dimensions of IS value creation: on the one hand, IS can enhance the internal efficiency of an organization, i.e., productivity of business processes can be increased and costs can be reduced; on the other hand, IS can effectively contribute to the achievement of strategic goals of the firm concerning the external market environment by leveraging its competitive advantage. This strategic impact fundamentally depends on the question of whether IS are part of the end product, and if so, whether they can allow for environmental product characteristics that differentiate them from those of the competitors. If Green IS are only applied internally, the competitive potential is limited to resource-efficient processes and IS-based capabilities for innovation (Bakos & Treacy, 1986; Buchta *et al.*, 2007; Melville *et al.*, 2004).

These theoretical aspects underpin the findings of our exploratory case study: the role of Green IS heavily depends on the environmental strategy and the core business of a firm. For company A, Green IS strategy is of minor significance because IS are not critical for its core business and Green IS do not affect the company's end products. Company C mainly focuses on internal process efficiency but Green IS are understood as key enabler for the transformation of the business. Companies B and D achieve competitive differentiation of their end products with the help of Green IS and thus Green IS strategy is crucially important.

The significance of IS obviously depends on the industry as well. In 2009, the average IS budget in relation to the total sales volume was at a level of 13 percent in the banking and financial services industry, at 9 percent in the professional services industry, at 6 percent in the manufacturing industry, and only at 1 percent in the chemicals industry (Gartner, 2009). Likewise, the environmental impact of IS depends on the specific industry. The environmental impact of IS can be differentiated into first-, second- and third-degree impacts.

The first-degree environmental impact of IS refers to the power consumption of data centers, office computers and network equipment and the resources used for production and disposal of IT equipment. The second-degree environmental impact refers to the effect that Green IS can have on internal business and production

processes, while the third-degree environmental impact describes the footprint of the end product, i.e., the resource consumption and emissions that are associated with the use phase of the product (Mingay & Di Maio, 2007; Hilty *et al.*, 2006). The environmental impact of IS differs significantly depending on the industry. In the manufacturing industry, the first-degree impact is only 2 percent on average, whereas the second-degree impact is about 60 percent and the third-degree impact of IS is more than 30 percent. In the financial services industry, the distribution is very different. Here, the first-degree impact accounts for nearly 70 percent whereas the second-degree impact is about 30 percent and the third-degree impact is at a level of 1 percent only (Mingay & Di Maio, 2007).

These findings advance our understanding of the underlying factors that influence Green IS strategy with regard to our case study. Company A is from the chemicals industry where the first-degree impact of IS is negligible, and neither are the production processes based on IS nor do IS determine the characteristics of the end products. Company B is a manufacturing company where the first-degree impact is low while the second-degree impact is considerable and, above all, the third-degree impact to make the end products more environmentally friendly is substantial. Thus company B primarily addresses the third-degree impact with its Green IS strategy. In Company C, which is from the financial services industry, the first-degree impact is significant, whereas the second- and third-degree impacts are of minor importance. In line with this, company C targets a business transformation with the help of Green IS. For company D, which is from the software industry, the first and the third-degree impact are decisive, while the second-degree impact is low. Consequently, company D follows a Green IS strategy that targets both the internal processes and the differentiation of the end products. This brings us to our fifth proposition:

P5: The role of Green IS depends on the significance of IS for the core business and on the first-, second- and third-degree environmental impact of IS.

10.6 Conceptualizing a Typology of Green IS Strategies

On the basis of the insights from the exploratory case study and the comparison of the findings with extant literature, we derived five propositions that describe specific characteristics of Green IS strategies. These are summarized in Table 28.

The characteristics of Green IS strategies that were identified were then used to guide our conceptualization of four generic Green IS strategies that are displayed in Table 29. Like the majority of researchers, we consider strategies as distinct types and thus develop a typology of Green IS strategies (Jenkin *et al.*, 2011). In line with

our definition, we regard Green IS strategy from an organizational perspective and argue that Green IS strategy should address environmental and technical issues at the corporate, competitive, and functional level. Thus we consider these three strategy levels as fundamental dimensions of our Green IS strategy typology (see Table 29). Corresponding to proposition 2, we use the generic corporate sustainability strategies identified by Bieker (2005) as overarching concept. According to this, we label our proposed strategies *Green IS for Efficiency*, *Green IS for Innovation*, *Green IS for Transformation*, and *Green IS for Credibility*. Proposition 3 describes the strategic goals of Green IS on the competitive level, while proposition 4 determines the sources of competitive advantage that are targeted by the Green IS strategy on the functional level. Proposition 5 guides decision makers in identifying an appropriate Green IS strategy that suits the specific requirements of their business.

Table 28: Proposed characteristics of Green IS strategies.

Definition of the term Green IS strategy	*Green IS strategy is the organizational perspective on the investment in, deployment, use and management of Green information systems (IS) in order to minimize the negative environmental impacts of IS, IS-enabled products and services, and business operations.*
Proposition 1	*Green IS strategies should address environmental and technical issues at the corporate, competitive, and functional level.*
Proposition 2	*Green IS strategy must be aligned with the corporate environmental strategy, which can be oriented towards efficiency, innovation, transformation, or credibility.*
Proposition 3	*Green IS strategies can support cost leadership or competitive differentiation strategies.*
Proposition 4	*Green IS strategies can either support environmental cost leadership strategies by enhancing the efficiency of internal processes or they can promote environmental differentiation strategies through ecological product and service innovation.*
Proposition 5	*The role of Green IS depends on the significance of IS for the core business and on the first-, second- and third-degree environmental impact of IS.*

At this point, we describe the four generic strategies that are presented in Table 29.

The *Green IS for Efficiency* strategy corresponds to the organization-wide target of superior resource efficiency as part of a corporate sustainability strategy that seeks cost leadership. This is probably the most prevalent strategy currently and appears to be adequate for mass-volume producers with intense industrial processing in particular. Business success is imperative and profitability is an absolute necessity for all kinds of environmental initiatives. Corporate management perceives environmental sustainability as a means to support the traditional core business. The main goal of Green IS strategy on the competitive level is to support and implement the prevalent business strategy. IS are not part of the end product and on

the functional level Green IS measures aim to enhance the efficiency of internal processes to facilitate operational cost reductions.

Table 29: Typology of Green IS strategies.

	Green IS for Efficiency	Green IS for Innovation	Green IS for Transformation	Green IS for Credibility
Corporate level: organizational perspective on Green IS	Green IS are used to reduce costs	Green IS are used to achieve environmental technology leadership	Green IS are used to achieve business leadership	Green IS are used to improve stakeholder satisfaction
Competitive level: strategic goal of Green IS	Implement business strategy	Foster innovation	Reengineering of business processes	Minimize environmental impacts
Functional level: sources of competitive advantage based on Green IS	IS support competitive strategies by enhancing internal process efficiency	IS improve environmental characteristics of product lifecycle	IS support environmental strategies by decreasing footprint of internal processes	IS improve footprint of the enterprise and of end products

The *Green IS for Innovation* strategy is appropriate for companies that strive for environmental technology leadership. The corporate sustainability strategy aims at environmental innovations which differentiate the firm from its competitors. At competitive level, the strategic goal is to develop products with superior ecological characteristics that customers are willing to pay for, i.e., products which have an exceptionally low environmental impact during their lifecycle based on environmental innovations. Green IS play a significant role at the functional level to build IS-based capabilities for environmental management and innovation.

The *Green IS for Transformation* strategy aims at industry leadership with the help of a profound business transformation fundamentally based on environmentally friendly processes which are enabled through Green IS initiatives. This strategy is reasonable for companies from the service industry where core business processes and products are based on IS. For these companies, IS are critical to the achievement of competitive advantage which aims at a business leadership position based on low cost and low environmental impacts. This is a suitable approach for markets that are highly price sensitive. The competitive strategy is shaped by the organizational transformation which is driven by Green IS. On the functional level, this strategy seeks for business process reengineering that allows for a cost and environmental leadership position.

The *Green IS for Credibility* strategy aids companies that pursue sustainability with a more holistic approach. This strategy aims at becoming a "good corporate citizen"

by taking into account the claims of internal and external stakeholders. Transparency and credibility are major goals of the company and the corporate reputation is understood as a valuable asset. The top management anticipates that the extraordinary dedication for sustainability leads to a first-mover advantage and pays off in the long term. The competitive strategy is shaped by the opportunities that emerge from the consistent implementation of Green IS. Firms pursuing this strategy even invest in unprofitable Green IS initiatives with the goal of reducing first-, second- and third-degree environmental impacts. Green IS are part of the end product and enable competitive differentiation. The positive corporate image helps to attract new customers and to intensify the relationships with existing ones.

As described in detail above, the four distinct Green IS strategies displayed in Table 29 were derived from the insights of the exploratory case study and the consolidation of these findings with theories from extant literature. Since the proposed strategies were developed on the basis of this multiple-case study, every case refers to one of the strategies. Company A, which is active in the chemicals industry, mainly focuses on increasing efficiency, while IS are seen as supportive enablers for the company's business strategy without strategic significance for its core business. Accordingly, the internal IT department is managed as a cost center. As a result, company A is a real-life example of a firm that implements a *Green IS for Efficiency* strategy.

The technology company presented in case B perceives Green IS as a means to drive environmental innovations that differentiate its industrial and consumer goods from that of competition. Following this *Green IS for Innovation* strategy obviously pays off for company B – more than a third of its sales stem from environmentally friendly automation and mobility technologies and energy-efficient consumer products.

The financial services company described in case C is a textbook example of a company that understands Green IS as strategic enabler of its business transformation towards corporate sustainability. Nonetheless, its business leadership position indisputably remains the firm's top priority. The implementation of a *Green IS for Transformation* strategy allows this company to defend its business leadership position while striving for carbon neutrality – specifically through a fundamental reengineering of business processes employing Green IS.

The approach followed by the software company of case D refers to the *Green IS for Credibility* strategy. This company acknowledges the significance of Green IS for its core business. The success of its environmental management software is closely linked to the firm's environmental performance. Company D relies on its own credibility to convince its customers of the importance of corporate sustainability – which is why the company claims to lead by example.

10.7 Discussion and conclusions

This paper has several implications for research and practice. Our study responds to the call for research from IS scholars who identified a lack of conceptual frameworks and empirical studies in this field. It adds to the body of knowledge on strategic aspects of Green IS, which have been insufficiently analyzed in the past despite their relevance for sustainable development and firm competitiveness. Although there has been much discussion in the IS research community about the possible contribution of Green IS to environmental sustainability, relatively little attention has been paid to the formulation of Green IS strategies. These strategies determine the potential of Green IS for decreasing environmental impacts and creating competitive advantages. The conceptualized Green IS typology could be meaningful to guide further research on this topic in the IS community.

The goal of this research was twofold: we wanted to find out what types of generic Green IS strategies can be identified in a real-life context and we aimed at conceptualizing a typology of Green IS strategies that describes the role of Green IS in the organization. We conceptualized Green IS strategy as the organizational perspective on IS that targets the minimization of environmental impacts. We proposed that Green IS strategy 1) should address environmental and technical issues at a corporate, competitive, and functional level; 2) must be aligned with environmental strategies; 3) can support cost leadership or differentiation; 4) can enhance efficiency of internal processes or drive ecological product innovation; 5) is determined by the significance of IS for the core business and the first-, second-, and third-degree environmental impacts.

These propositions guided our conceptualization of the Green IS strategy typology that illustrates four distinct strategies: *Green IS for Efficiency* is presumably the most prevalent strategy at present. It aims at the reduction of operational costs and supports the business strategy by enhancing the efficiency of internal processes. *Green IS for Innovation* is a strategy that helps firms to achieve environmental technology leadership by fostering innovations that decrease the environmental footprint of end products. The *Green IS for Transformation* strategy allows for business and environmental leadership through fundamental business process reengineering. A holistic approach of addressing environmental impacts of both the organization and the firm's end products is represented by the *Green IS for Credibility* strategy that is primarily oriented towards stakeholder satisfaction.

Although the four cases match the four archetypical Green IS strategies quite well, it must be acknowledged that the strategies outlined in Table 29 represent an ideal situation. In line with Orsato (2009), we argue that these choice-based strategies describe stylized appearances of Green IS that should help researchers and

practitioners to understand this complex issue by simplifying certain aspects. The boundaries between the distinct strategies are blurred in reality and not all cases found in a real-life context can be mapped to only one of these strategies. However, we believe that the description of these ideal strategies facilitates a strategic rationale for focused Green IS investments which follow a clear competitive logic. This rationale is the fundament for enhancing the economic and environmental value of Green IS.

An important implication for practitioners is that Green IS have a greater potential for leveraging firm competitiveness, compared with the mere implementation of efficiency-increasing measures that target operational cost reductions. However, this potential can only be leveraged if environmental aspects are addressed through corporate, competitive, and functional strategies. If Green IS are aligned with these strategies, they can unfold their potential to decrease the environmental impacts of IT operations, of firm-wide internal processes, and of the life cycle of end products. The characteristics of the industry and the organization-specific context determine whether the first-, second-, or third-degree of environmental impact is of particular relevance and can be addressed through Green IS. Besides these considerations, executives have to decide whether to strive for cost leadership or for environmental differentiation with the help of Green IS.

This research reveals that sustainability leaders already follow differentiated Green IS approaches and succeed in enhancing their competitiveness with distinct strategies. Green IS are not restricted to data center efficiency measures and energy-saving office computers but offer a wide range of applications from decreasing environmental impacts of business and production processes to competitive differentiation based on unique environmental characteristics of end products. Nonetheless, it must be acknowledged that there is no single best strategy – Green IS strategy comes along with positioning choices and trade-off decisions. To benefit from Green IS, executives have to carefully analyze the potential of Green IS under consideration of their specific organizational context. The presented Green IS typology can be used as a tool to guide this analysis and to assist the process of strategy formulation.

Although this research provides interesting insights, we recommend further investigation of this topic since this qualitative study only gives first indications and has a very limited generalizability. Propositions 1 to 5 should be tested with a statistically significant quantitative analysis based on survey data, and it should be investigated if other generic strategies can be identified. Furthermore, it would be of interest for the IS research community to study the contingency factors that influence the formulation of Green IS strategies. By means of a survey with an adequate sample size the distribution of the identified Green IS strategies could be

analyzed. A cross-industry analysis could deliver valuable insights by addressing the question whether dominant Green IS strategy types can be identified for specific industries.

11. Enhancing Firm Competitiveness with Green IS: An Empirical Analysis of the Antecedents and Consequences of Adopting Green IS

Title	Enhancing Firm Competitiveness with Green IS: An Empirical Analysis of the Antecedents and Consequences of Adopting Green IS
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Abstract	While researchers acknowledge that Green information systems (IS) are important technological enablers of corporate transformations which enhance environmental sustainability, business and information technology (IT) executives are uncertain about the business value of the attendant environmental technologies and cross-functional initiatives. This study seeks to clarify this issue by means of an empirical investigation of the antecedents and consequences of adopting Green IS. In particular, this research analyzes the interrelationships among IT executives' environmental orientation, Green IS strategies, Green IS practices, and firm competitiveness. In this context, five hypotheses that describe the relationships among these constructs are tested with structural equation modeling, using data from a global survey with 118 responses from CIOs and senior IT executives. The results indicate that environmental orientation has a significant impact on the adoption of Green IS strategies and practices. Most notably, the findings suggest a positive influence of Green IS practices on firm competitiveness. To provide detailed insights into this relationship, three types of Green IS practices and their effect on various aspects of firm competitiveness are examined. The results demonstrate that IT-related Green IS practices reduce costs, whereas IS-enabled process reengineering and environmental technologies for end-user products and services enhance corporate reputation and innovation capabilities. This study contributes to the body of knowledge in this new IS research stream, reduces the prevailing uncertainty concerning the business value of Green IS, offers guidance for Green IS strategy formulation and implementation, and helps to advance corporate environmentalism in practice.

11.1 Introduction

Information technology (IT) and information systems (IS) are enablers of the sustainable development of our economy and society. However, IT and IS can have both positive and negative environmental impacts (Melville, 2010; Watson *et al.*, 2010; Elliot, 2011). On the one hand, IT is part of the environmental problem (Dedrick, 2010), as the manufacturing of IT equipment requires rare and toxic resources and raises environmental and ethical issues because of questionable practices that can occur throughout the supply chain (Chen *et al.*, 2008). The worldwide use of IT consumes vast amounts of electricity, which causes significant carbon dioxide emissions, while the disposal of IT equipment generates e-waste that can have negative impacts on the natural environment (Elliot & Binney, 2008; Corbett, 2010). On the other hand, academics and practitioners argue that IS are part of the solution (Malhotra *et al.*, 2013) and that Green IS are important enablers of corporate sustainability (Watson *et al.*, 2008; Melville, 2010; Thambusamy & Salam, 2010). Green IS support cross-functional capabilities and can decrease organizations' environmental footprints through environmental management systems, supply chain innovations, and the reengineering of business and production processes (Benitez-Amado *et al.*, 2010). Moreover, Green IS are not restricted to organizational boundaries but also lead to innovative end-user products and services with reduced resource requirements throughout their lifecycles (Watson *et al.*, 2010; Harmon & Demirkan, 2011). Given these positive and negative outcomes, the transformation of organizations, products, and business models with the help of Green IS requires a far-reaching, long-term strategy (Dao *et al.*, 2011; Molla *et al.*, 2011).

This research investigates the role of IS in corporate environmentalism and sustainability management. Corporate environmentalism is "the organization-wide recognition of the legitimacy and importance of the biophysical environment in the formulation of organization strategy" (Banerjee, 2002, p. 181). To facilitate corporate environmentalism, corporate sustainability management "covers all systematic activities to measure, analyze and improve economic, social and environmental aspects of a company to (a) achieve a sustainable development of the organization and (b) enable the organization to create a relevant contribution to a sustainable development of the economy and society, now and for the future" (Schaltegger *et al.,* 2013, p. 219). In this context, this study analyzes how corporate environmentalism influences the adoption of Green IS and determines whether Green IS strategies and practices influence firms' competitiveness.

Business and IT executives are uncertain about how IS-enabled solutions can help them meet the challenges of environmental sustainability while obtaining economic benefits (Elliot, 2013). As previous studies have shown, CIOs are cautious about

investments in Green IS whose business value is unclear (Corbett, 2010; Dedrick, 2010; Bengtsson & Ågerfalk, 2011). While a wide range of Green IT practices help to reduce IT energy consumption in data centers and, thus, decrease operational costs, the business case for enterprise-level Green IS initiatives that enhance the resource efficiency of business and production processes is more difficult to determine (Molla & Abareshi, 2012). The long-term payoffs of Green innovations at the product level are often even less tangible because of unknowns about the development of customer preferences and future markets (Michaud & Llerena, 2010).

Researchers have investigated the antecedents, characteristics, and consequences of corporate sustainability management from many perspectives. Government regulations and stakeholder pressures were the major drivers of the first wave of corporate sustainability (Porter & van der Linde, 1995), but management perceptions are shifting from seeing regulation- and stakeholder-driven pollution prevention as a "necessary evil" to market-driven product innovations and technology changes that offer economic opportunities like resource efficiency, cost reduction, new customer value, and long-term profitability (Orsato, 2006; Ambec & Lanoie, 2008; Albino *et al.*, 2009). Green process innovations can increase resource efficiency throughout the company, thereby reducing operational costs and improving the corporate reputation by reducing the organization's environmental footprint (Chang, 2011). Customers are increasingly willing to pay more for environmentally friendly products, so Green product innovations can be differentiated from competitors' products, increasing profit margins (Dangelico & Pujari, 2010). Moreover, environmental product innovations can create new markets, increasing firm revenues (Albino *et al.*, 2009). In short, corporate environmentalism can enhance competitiveness through cost reductions, improved reputation, and increased innovation.

To be effective, corporate environmentalism requires structured corporate sustainability management, which Green IS can facilitate. Since corporate sustainability can result in competitive advantages, we also expect Green IS adoption to enhance competitiveness through operational cost reductions, Green product and process innovations, and a positive impact on corporate reputation. Because this expectation lacks empirical validation, this study seeks to answer two research questions:

RQ1: Does corporate environmentalism lead to the adoption of Green IS?

RQ2: Does the adoption of Green IS affect firm competitiveness?

This research gap is important because of the uncertainty concerning the business value of Green IS (Elliot, 2013), particularly with regard to its strategic long-term benefits (Shrivastava *et al.*, 2013). Therefore, we seek to provide scholars and

practitioners with applicable information by using quantitative empirical data to examine the contribution of Green IS strategies and practices to firm competitiveness. This study can be classified as transdisciplinary, solution-oriented exploratory research (Pinsonneault & Kraemer, 1993; Schaltegger *et al.*, 2013), as it concentrates on a new area of IS research and addresses correlative research questions to identify the relationships between certain constructs.

The remainder of the paper is structured as follows. The next section explains the theoretical background, synthesizes related research, and introduces fundamental concepts. Then the research model is developed by defining the latent constructs based on a literature review, and cause-and-effect relationships between the constructs are described through hypotheses, which specify the research model. Subsequently, empirical results are analyzed and the measurement and structural models are evaluated through structural equation modeling. The final section presents theoretical contributions, managerial implications, limitations, and suggestions for future research.

11.2 Theoretical background and related research

Since 2008 the negative environmental impacts associated with IT (computer hardware, software, and peripheral equipment) (Ijab *et al.*, 2010) have been addressed under the heading of Green IT (Jenkin *et al.*, 2011; Harmon & Demirkan, 2011), defined as "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" (Murugesan, 2008, p. 25). IS, on the other hand, 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.*, 2010b, p. 237). Therefore, Green IS is defined as "IS-enabled organizational practices and processes that improve environmental and economic performance" (Melville, 2010, p. 2). These definitions show that Green IT has a restricted view of technological issues (Dao *et al.*, 2011), whereas Green IS is a more comprehensive concept that includes the people, processes, and capabilities that address environmental sustainability in a holistic way. This understanding is in line with (Watson *et al.*, 2010, p. 24), who explain that "Green IS is inclusive of Green IT"; in other words, Green IT has a narrow focus and is part of the more far-reaching concept of Green IS. With reference to Murugesan (2008), Watson *et al.* (2010), and Chen *et al.* (2010b), we define the concept of Green IS as the investment in and deployment, use, and management of IS in order to minimize the negative environmental impacts of IT, business operations, and IS-enabled products and services.

The business value and competitive potential of IT and IS have been widely discussed in the IS research community (Melville *et al.*, 2004; Schryen, 2013). IT infrastructure resources, which are available to all companies, can create business value whereas firm-specific IS management capabilities are unique and have the potential to create competitive advantages (Wade & Hulland, 2004). However, the strategic alignment of the IS function with the core business that remains a major concern of business and IT executives (Luftman & Derksen, 2012) is made more complex by consideration of environmental sustainability and the assessment of the business value of Green IS and its contribution to firm competitiveness (Benitez-Amado & Walczuch, 2011; Loeser *et al.*, 2012).

IS researchers have argued that Green IS can lead to a firm's sustainability transformation, which results in strategic advantages and competitive benefits (Dao *et al.*, 2011; Seidel *et al.*, 2013; vom Brocke *et al.*, 2013a). Corbett (2010) explores the value dimensions of Green IT and Green IS and calls for a multi-dimensional value perspective that takes financial, environmental, ethical, and competitive effects into account. Corbett explains that Green IS can create value through efficient IT infrastructure, improved information for decision-making, collaboration tools, and sustainable products and services and differentiates between direct effects, such as reduced operational costs, and indirect effects, such as business process and product innovations or environmental reporting targeted at external stakeholders.

Benitez-Amado *et al.* (2010) find that technological and human IT resources have a positive impact on innovativeness, which has a positive effect on firms' Green management capabilities. In another study, Benitez-Amado & Walczuch (2011) identify IT management capabilities as enablers of proactive environmental strategies, which result in cost savings and improve corporate reputation. The authors argue that IS can support business intelligence to anticipate future sustainability trends and can drive product and process innovations through IT-enabled environmental technologies. However, they measure the IT capability with archival data without analyzing specific Green IS strategies or practices. Bengtsson & Ågerfalk (2011) case study indicates that IT can serve as a change agent in sustainability innovations, changing the behavior of employees through sustainability initiatives.

Thambusamy & Salam (2010) use theory to explain that IS-enabled automation of energy and waste management, as well as measurement, monitoring, and reporting of resource consumption with environmental IS, can improve process efficiencies and lower costs. In addition, IS-based environmental performance evaluations can support firms' decision-making processes, and reporting of environmental impacts can improve transparency and collaboration with internal and external stakeholders.

Furthermore, IS-enabled business- and production-process reengineering can reduce organizations' environmental footprints, and IS-based innovations can result in eco-friendly products that can be differentiated from competitors' products. In a similar vein, Harmon & Demirkan (2011) show that IT-related environmental measures can reduce costs, whereas innovative IS services can create customer and societal value, thus changing the competitive landscape. They explain that the first wave of Green IT was focused on internal infrastructure and process efficiencies, whereas the second wave of sustainable IS will induce disruptive innovations and new technologies that transform organizations' core business and encourage new business models, which will facilitate differentiation advantages. However, these assumptions have not been tested empirically.

11.3 Development of the research model

To address the two research questions, which refer to the antecedents and consequences of Green IS adoption, this study draws on Melville (2010) Belief-Action-Outcome (BAO) framework, which has been proposed for use in investigating the relationship between IS and environmental sustainability in organizational contexts (Figure 25).

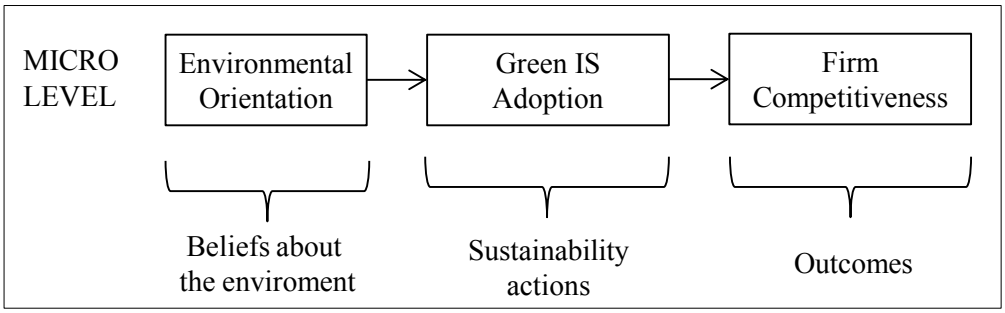


Figure 25: Structure of this study, with reference to Melville's (2010) Belief-Action-Outcome Framework.

The study can be framed as follows: The first research question is addressed by seeking to understand from a micro-economic, organizational perspective how executives' beliefs about the environment translate into concrete sustainability actions by adopting Green IS. In this context, we argue that a strategic approach is required in order to leverage the potential of Green IS. Therefore, we analyze the corporate sustainability actions in detail through two constructs, *Green IS strategy* and *Green IS practices*. To address the second research question, we evaluate the effect of Green IS strategies and practices on the outcome construct, *firm competitiveness*. Here we build on the Resource-Based View (RBV) (Wernerfelt, 1984; Barney, 1991), which has been widely applied to determine how IS can contribute to the creation of business value and competitive advantages through IT

resources and IS capabilities (Melville *et al.*, 2004; Wade & Hulland, 2004). Since the present research addresses aspects of environmental sustainability, the Natural-RBV (NRBV) (Hart, 1995) is particularly useful in determining the impact of Green IS on competitiveness while taking the natural environment into account.

11.3.1 Definition of constructs

The methodology for construct development is based on Lewis *et al.* (2005) recommendations and considers the advice of MacKenzie *et al.* (2011), as well as Urbach & Ahlemann (2010) guidelines for structural equation modeling. The first step of the model development involved performing a literature review to establish the basis for the definitions of the study's major constructs: *environmental orientation*, *Green IS strategy*, *Green IS practices*, and *firm competitiveness*.

11.3.1.1 Environmental Orientation

With its increasing significance for firm's competitiveness, corporate environmentalism has evolved from being a complementary management task into an integral part of strategic management activities (Schaltegger *et al.*, 2013). Certainly, the creation of competitive advantage is highly context-dependent, and uncoordinated environmental sustainability initiatives without strategic coherence are ineffective (Orsato, 2006). Previous studies (e.g., Chen *et al.*, 2010a; Butler, 2011; Molla & Abareshi, 2012) have analyzed the motivations for Green IS adoption. External pressures shape the personal beliefs of executives and result in sustainability actions (Melville, 2010; Gholami *et al.*, 2013). This phenomenon of corporate environmentalism has been studied through the concept of *environmental orientation*, which is defined as "the recognition by managers of the importance of environmental issues facing their firms" (Banerjee *et al.*, 2003, p. 106).

Table 30: Conceptualization of environmental orientation.

Construct	Definition	Description
Environmental Orientation	Executives' recognition of the importance of the environmental issues that face their firm (Banerjee *et al.*, 2003, p. 106).	A company's environmental orientation reflects its internal values, standards of ethical behavior, commitment to environmental protection, and relationships with external stakeholders (Banerjee *et al.*, 2003, p. 106). This concept is closely linked to organizational culture, which refers to a complex set of values, beliefs, and assumptions that define how a firm conducts its business (Barney, 1986). Environmental orientation guides executives' beliefs and actions and influences how a firm interacts with key stakeholders on issues related to the environment.

The historical development of a firm, organizational culture, top management's commitment and executives' personal experiences have an influence on environmental orientation (Barney, 1986; Banerjee *et al.*, 2003), which forms executives' beliefs about the environment and influences decision-making processes and the initiation of environmental actions (Gholami *et al.*, 2013). Hence, we conceptualize *environmental orientation* as an antecedent of Green IS adoption.

11.3.1.2 Green IS Strategy

Banerjee (2002, p. 182) emphasizes that "environmental concerns need to be translated into strategy if corporate greening is to occur" and explains that environmental strategies at a functional level are limited to the reduction of waste and emissions. Higher-level strategies, on the other hand, can facilitate competitive advantages by enabling low cost or differentiation strategies (Porter, 1980; Orsato, 2006). The distinction between corporate, business, and functional level strategies is common in strategic management research (Andrews, 1971) and is acknowledged among both IS and sustainability scholars (Stead *et al.*, 2004; Chen *et al.*, 2010b). We find that analyzing Green IS strategies at the corporate, competitive, and functional levels is useful in determining how IT executives' environmental orientation translates into sustainability actions. Accordingly, we conceptualize *Green IS strategy* by means of three sub-constructs: *Green IS strategy at the corporate level*, *Green IS strategy at the competitive level*, and *Green IS strategy at the functional level* (Table 31).

A Green IS strategy at the corporate level is characterized by business and IT executives' mutual understanding concerning future opportunities and challenges, as well as collaborative, cross-functional strategic planning processes. Green IS strategy at the corporate level articulates a shared vision by top management and IT executives and describes the fundamental role of Green IS in achieving organization-wide, long-term environmental objectives. This conception relates to corporate environmental sustainability strategies, defined as long-term visions formulated by the top management that outline the organization's attitude toward stakeholders and the natural environment (Stead *et al.*, 2004).

A Green IS strategy at the competitive level addresses the environmental and competitive characteristics of the company's core products and services. It leverages the potential of and opportunities for Green IS to enhance environmentalism and firm competitiveness through Green IS-induced innovation, differentiation, and superior resource efficiency of end-user products and services. This strategy is based on the concept of competitive-level environmental strategies that enhance the firm's product and service portfolio. Environmental competitive strategies are externally oriented and seek to establish the firm in a specific competitive position in a distinct

target market using the environmental aspects of products and services during their entire lifecycle (Porter, 1980; Stead *et al.*, 2004).

A Green IS strategy at the functional level, which is internally oriented, facilitates effective and efficient IS operations that support the implementation of environmental strategies throughout the organization. Concrete policies are defined at the functional level and result in the effective implementation of Green IS practices. Functional-level strategies are important in creating internal Green-IS-related resources and capabilities over time. These firm-specific assets, both tangible and intangible, lay the foundation for a company's productivity and innovative capacities (Barney, 1991). Green IS strategies at this level determine concrete action plans and affect business and production processes, and since they can increase the resource efficiency of internal operations, they enhance firm competitiveness (Grant, 1991).

Table 31: Conceptualization of Green IS strategy (with reference to Chen *et al.*, 2010b, p. 239).

Second-order construct	First-order constructs	Conceptual domain	Definition	Description
Green IS strategy	*Green IS strategy at the corporate level*	Organization-wide role of Green IS; organization-centric	Shared view of the role of Green IS in the organization	Green IS strategy at the corporate level describes a **perspective**: What is our view toward Green IS in the organization? *Desired strategic impact:* Provide a shared understanding of the potential of Green IS throughout the organization and guide fundamental Green IS investment decisions.
	Green IS strategy at the competitive level	Matching the potential of Green IS with the competitive position; business-centric	Use of Green IS to support competitive environmental strategies	Green IS strategy at the competitive level describes a **position**: How can Green IS be used to support a chosen environmental strategy and to enhance competitive advantage? *Desired strategic impact:* Support the implementation of competitive environmental strategies and ensure that the desired strategic position in competitive markets is achieved.
	Green IS strategy at the functional level	Intended course of action; IS-centric	Master plan of the Green IS function	Green IS strategy at the functional level describes a **plan**: What assets (staff, processes, infrastructure, applications, budget, etc.) are required for Green IS implementation and how should existing assets be allocated efficiently? *Desired strategic impact:* Give direction for the effective and efficient management of IS resources and capabilities.

For the conceptualization of Green IS strategy, we refer to Chen *et al.* (2010b), who review and consolidate numerous articles on IS strategy from leading IS journals. They identify three fundamental IS strategy concepts: "IS strategy as 1) the use of IS to support business strategy; 2) the master plan of the IS function; and 3) the shared view of the role of IS within the organization" Chen *et al.* (2010b, p. 239). These conceptualizations refer to strategy as a position, strategy as a plan, and strategy as a perspective (Mintzberg, 1987). We conceptualize *Green IS strategy* by means of these three strategy levels and define them as sub-constructs (Table 31).

11.3.1.3 Green IS Practices

The second construct that relates to the adoption of Green IS is *Green IS practices*. Because Green IS practices have a broad scope and address a wide range of IT-, business- and product-related environmental issues, we categorize the various kinds of Green IS practices according to their degrees of environmental impact. In line with Hilty *et al.* (2006), Gartner Research (2007), and Dedrick (2010), Green IS practices can be classified into first-degree IT effects, second-degree organizational effects, and third-degree product effects, each of which refers to a specific management area: IT departments, entire organizations, and end-user markets, respectively (Figure 26).

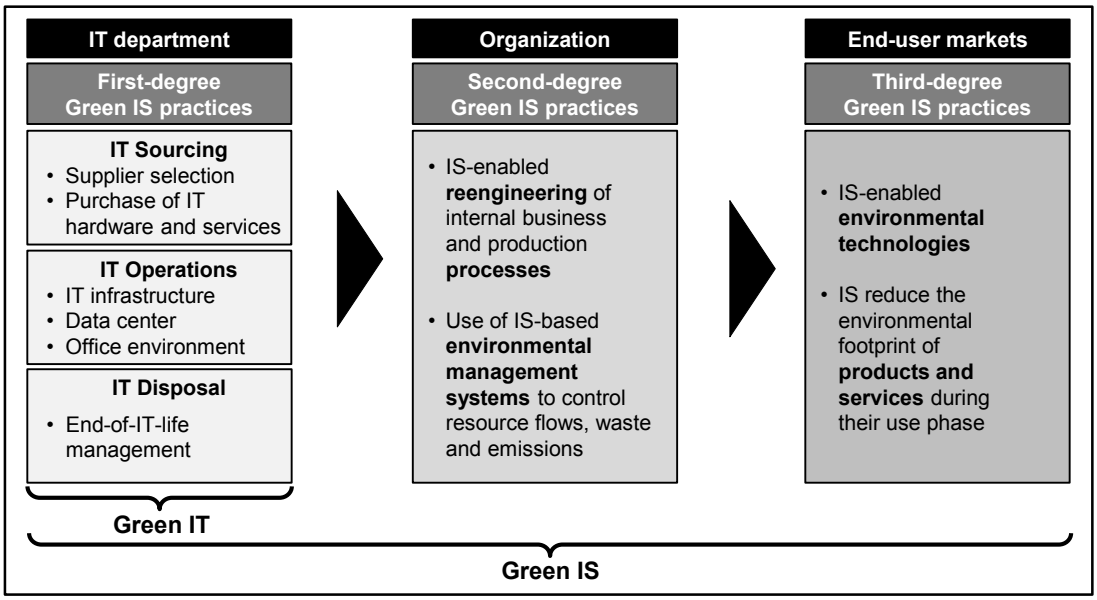


Figure 26: Classification of Green IS practices according to their degree of environmental impact (Loeser, 2013).

The distribution and the magnitude of these three degrees of environmental impact differ significantly from firm to firm and depend heavily on industry characteristics (Gartner Research, 2007). As a consequence, the importance of any one type of Green IS practice depends on the firm-specific context. Thus, we conceptualize the

Green IS practices construct through these three second-order constructs, whose particular dimensions are characterized through sub-constructs.

The first-degree environmental impacts of Green IS practices refer to IT-related issues, so these practices are usually referred to as Green IT practices (Murugesan, 2008). They aim at reducing the negative environmental effects associated with the manufacturing, use, and disposal of IT equipment (Dao *et al.*, 2011), so we conceptualize the construct *first-degree Green IS practices* by means of the sub-constructs *IT sourcing*, *IT operations*, and *IT disposal* (Park *et al.*, 2012) (Table 32). A comprehensive catalogue of seventy exemplary measures in Appendix C (Table 44) provides guidance to practitioners on how to decrease IT-related environmental impacts by means of these first-degree Green IS practices.

The second-degree environmental impacts of Green IS practices refer to the positive environmental impacts that can be achieved by decreasing the environmental effects of business operations and advancing corporate sustainability (Butler, 2011). Business and production processes' resource efficiency can be enhanced through IS-enabled process reengineering (Seidel *et al.*, 2013), and environmental management systems can quantify emissions and track resource flows (Corbett, 2010; Malhotra *et al.*, 2013), thereby uncovering opportunities for reducing business and production processes' consumption of resources (Benitez-Amado *et al.*, 2010). Hence, we conceptualize *second-degree Green IS practices* by means of the sub-constructs *process reengineering* and *environmental management systems*. Appendix C (Table 45) contains practical examples of these kinds of Green IS practices.

The third-degree environmental impacts of Green IS practices refer to end-user markets, where products and services are sold to customers. Green IS practices can foster innovations that decrease resource consumption, waste, and emissions during the use phase (Albino *et al.*, 2009) and thus reduce negative environmental impacts. The integration of IS functionalities can generate innovative end products and infrastructure solutions, such as building automation, smart-grid technologies, engine-control units, intelligent traffic management systems, and dematerialization initiatives that substitute physical products with digital services (e.g., books, music) (GeSI, 2008; Dangelico & Pujari, 2010; Butler, 2011). The corresponding *third-degree Green IS practices* sub-construct is *environmental technologies*, which is described in detail in Table 32, while exemplary initiatives are illustrated in Appendix C (Table 46).

Table 32: Conceptualization of Green IS practices.

Third-order construct	Second-order constructs	First-order constructs	Definition	Description
Green IS practices	First-degree Green IS practices ("Green IT")	IT sourcing	Environmentally friendly sourcing practices for IT hardware and services	Green IT initiatives that focus on the environmental assessment and auditing of suppliers and the selection of IT hardware and services according to predefined environmental criteria.
		IT operations	Green IT practices to decrease energy consumption by IT operations	Implementation of Green IT measures in the data center (e.g., server consolidation and virtualization, energy monitoring, air flow optimization) and in office environments (e.g., installing energy management software, raising user awareness of environmental issues, deploying energy-efficient desktop computers) to decrease energy consumption by IT operations.
		IT disposal	End-of-IT-Life management	Green IT practices that reduce e-waste by repairing, re-deploying, or disposing of outdated IT hardware in an environmentally friendly manner.
	Second-degree Green IS practices	Process re-engineering	IS-enabled reengineering of business and production processes	Green IS practices that enhance the resource efficiency of business and production processes through IS-enabled process reengineering and business transformation.
		Environmental management systems	Use of IS-based environmental management systems to control resource flows, waste and emissions	Use of IS-based environmental management systems that track resource flows, waste, and emissions to provide information for environmental control and sustainability-oriented decision-making. Furthermore, environmental management systems enhance transparency and provide aggregated information that can be communicated to external stakeholders through environmental reports.
	Third-degree Green IS practices	Environmental technologies	IS-enabled environmental technologies which reduce the footprint of products and services	Improvement of the environmental characteristics of end products and service with the help of Green IS. Examples are smart buildings, traffic management systems, smart grids, engine control units, and dematerialization through digital services.

11.3.1.4 Firm Competitiveness

According to Bansal & Roth (2000), implementation of sustainability initiatives can enhance firms' competitiveness. In keeping with the BAO framework, we conceptualize the outcome construct of the present research as *firm competitiveness*. Studies in the Green IT/IS research stream have built on the NRBV to determine the effects of Green IT and Green IS on the creation of business value and environmental sustainability (e.g., Benitez-Amado & Walczuch, 2011; Dao *et al.*, 2011; Molla & Abareshi, 2012). In the scope of the NRBV, Hart (1995) describes three capabilities of environmental management: pollution prevention, product stewardship, and sustainable development. According to Thambusamy & Salam (2010) and Corbett (2010), these environmental sustainability strategies can be leveraged with the aid of Green IS. Hence, the competitive benefits that are associated with these strategies constitute an appropriate outcome construct with which to evaluate the economic benefits of adopting Green IS.

Table 33: Conceptualization of firm competitiveness.

Second-order construct	First-order constructs	Definition	Description
Firm competitiveness	Cost reductions	Reduction of operational costs through superior resource efficiency	The competitiveness of business firms depends on their operational costs. Effective environmental management can reduce the required amounts of input materials and decrease the energy consumption of business and production processes. The enhanced resource efficiency of internal operations reduces costs (Porter & Linde, 1995; Ambec & Lanoie, 2008).
	Corporate reputation	Positive corporate image resulting from effective environmental management	Business firms that act in an ethical and responsible manner (corporate citizenship) can improve their reputations with internal and external stakeholders. A positive corporate reputation can improve employee retention rates and the firm's attractiveness to talented workers. Since firms increasingly depend on talented and knowledgeable employees, a good corporate reputation can enhance firm competitiveness. A positive corporate image also increases customer loyalty and attracts new customers, thus increasing sales and enhancing competitiveness (Sharma & Vredenburg, 1998; Bansal & Roth, 2000).
	Green innovations	Superior R&D leads to Green product and process innovations that differentiate the firm from competitors.	Environmental research and development (R&D) can give rise to Green product innovations that have a reduced environmental footprint during their lifecycles. Customers increasingly appreciate such environmentally friendly products and services, and they are willing to pay a price premium for them. Furthermore, the environmental characteristics of these products, such as lower fuel consumption during the use phase, can differentiate them from competitors, increasing the firm's competitiveness, profit margins, and sales volumes (Albino *et al.*, 2009; Chang, 2011).

The competitiveness dimension of corporate environmentalism is associated with benefits like lower costs resulting from enhanced resource efficiency of business operations, increased revenues that are due to a positive corporate reputation, and the creation of new markets (Chen *et al.*, 2010a; Thambusamy & Salam, 2010). Differentiation from competitors can also be achieved through innovative eco-products that can bring superior profit margins if customers perceive and value the products' superior environmental characteristics (Albino *et al.*, 2009; Dangelico & Pujari, 2010). Accordingly, we define *firm competitiveness* based on three sub-constructs: *cost reductions*, *corporate reputation*, and *Green innovations* (Table 33).

11.3.2 Higher-order construct models

Environmental orientation is a first-order construct that is measured with reflective indicators. The three other main constructs, *Green IS strategy*, *Green IS practices*, and *firm competitiveness*, are higher-order constructs, which are appropriate for modeling multidimensional latent variables while reducing a structural model's complexity (Wetzels *et al.*, 2009). The underlying dimensions of the higher-order constructs are modeled through lower-order constructs, which influence the higher-order constructs in a formative way. As Becker *et al.* (2012, p. 362) explain, "if a higher-order construct is formative, it is a combination of several specific dimensions into a general concept."

Green IS strategy is modeled as a reflective-formative second-order construct (Figure 27), which means that the three first-order constructs (*Green IS strategy at the corporate/competitive/functional level*) are underlying dimensions of this second-order construct, thus reflecting the theoretical understanding of levels of strategic management in prevalent research. The three first-order constructs, which represent facets of a Green IS strategy at specific management levels, are measured with reflective items and influence the higher-order construct in formative ways.

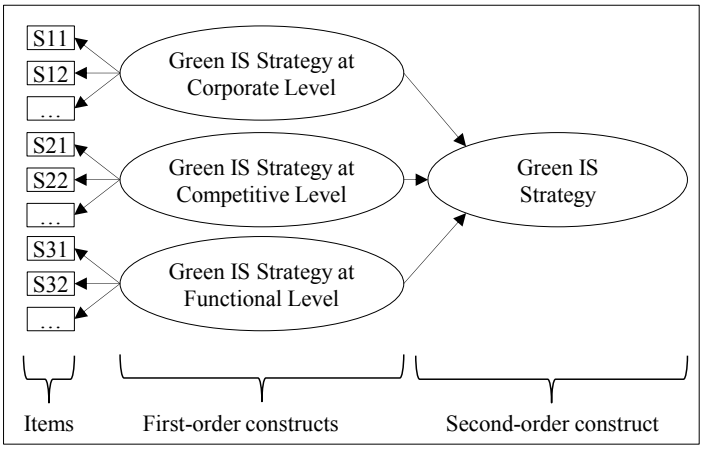


Figure 27: Illustration of the second-order construct Green IS strategy.

Similarly, the multidimensional higher-order construct *firm competitiveness* is modeled as reflective-formative second-order constructs, as displayed in Figure 27. The three first-order constructs *cost reductions*, *corporate reputation*, and *Green innovations* represent three aspects of *firm competitiveness*. Accordingly, they are modeled in a formative way, while the underlying first-order constructs are measured with reflective items (Figure 28) (Becker *et al.*, 2012).

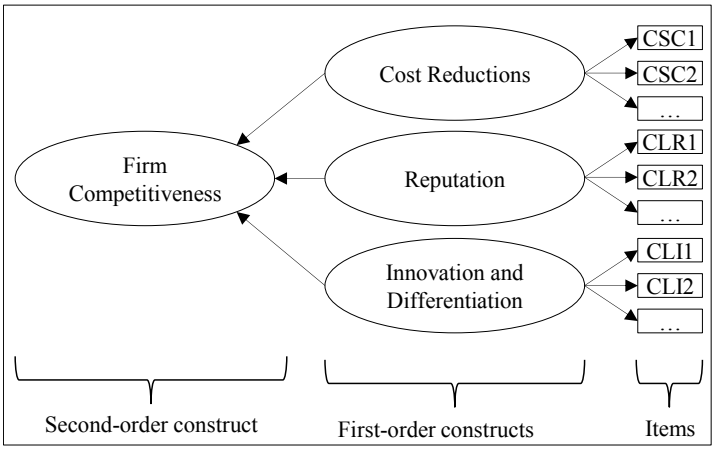


Figure 28: Illustration of the second-order construct firm competitiveness.

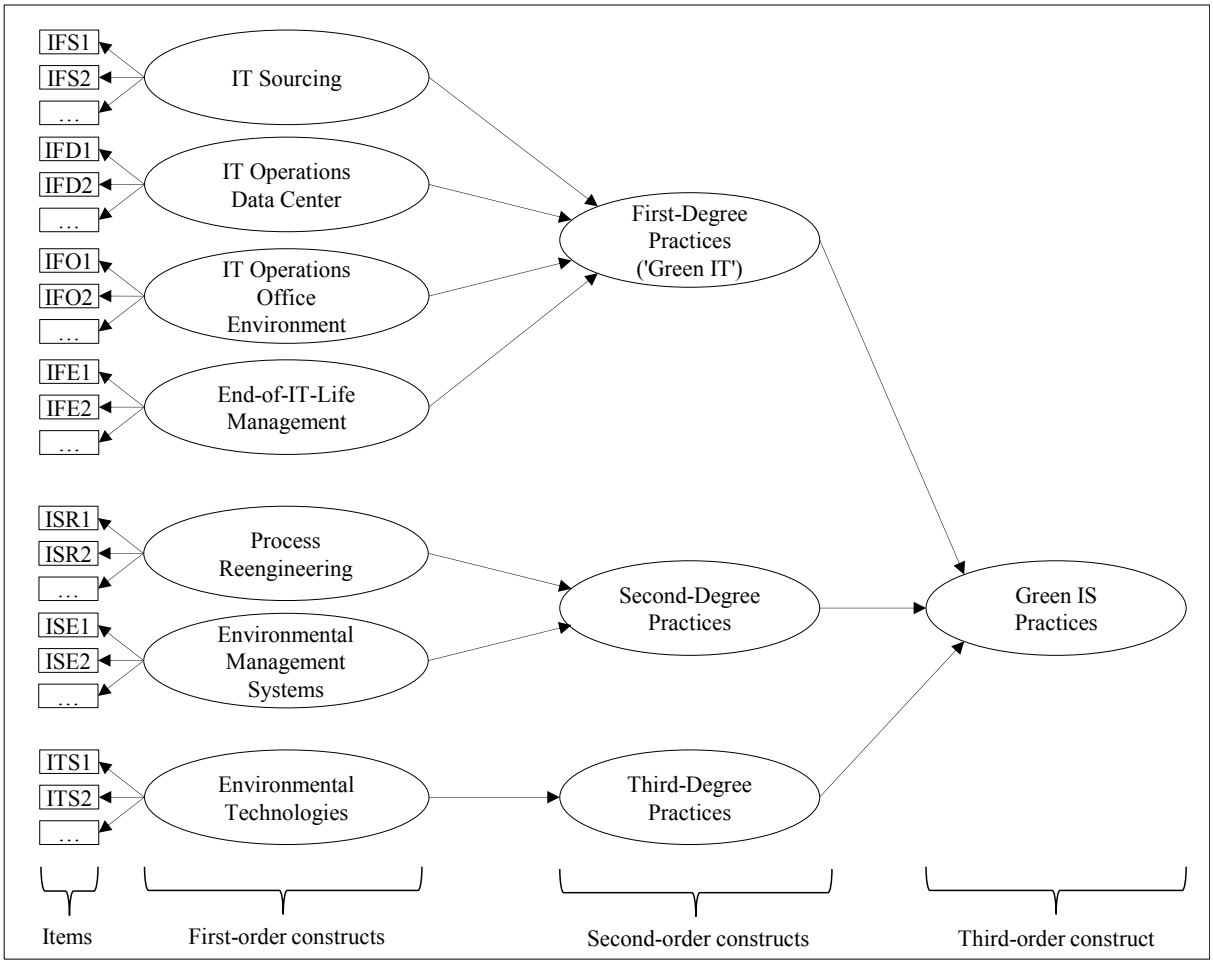


Figure 29: Illustration of the third-order construct Green IS practices.

The latent construct *Green IS practices* is modeled as a reflective-formative-formative third-order construct. The multidimensional construct *Green IS practices* is constituted of practices that address fundamentally different functional areas (IT department, organization, end-user markets; see Figure 26), which are modeled formatively as a result. Likewise, the second-order constructs are multidimensional because they are comprised of practices that are distinct from a managerial point of view—for example, IT sourcing practices are distinct from initiatives that address data center operations—which is why the second-order constructs are modeled with formative first-order constructs (Becker *et al.*, 2012). Like other first-order constructs, they are measured using reflective scales, as illustrated in Figure 29.

11.3.3 Specification of the research model

Referring to the BAO framework (Figure 25), the research model consists of three underlying dimensions: beliefs (*environmental orientation*), actions (*Green IS strategy* and *Green IS practices*), and outcomes (*firm competitiveness*). The first research question focuses on the relationship between environmental orientation and the adoption of Green IS. In line with Banerjee *et al.* (2003), we argue that IT executives' environmental orientation drives their concrete sustainability actions, such as the formulation of environmental strategies and the implementation of concrete environmental practices. Hence, we hypothesize:

H1: Environmental orientation is positively associated with Green IS strategy.

H2: Environmental orientation is positively associated with Green IS practices.

Next, we consider the relationship between Green IS strategy and Green IS practices, drawing on the RBV. Grant (1991) distinguishes among tangible, intangible, and personnel-based resources and defines capabilities as organizational competencies that describe the firm's ability to assemble, integrate, deploy, and combine resources. These capabilities facilitate the effective and efficient use of IS and firm assets (Watson *et al.*, 2008). The concept of Green IS strategy features the characteristics of such capabilities because it facilitates the effective combination and efficient management of technological infrastructure and IS-based environmental initiatives like Green IS practices. Hence, we hypothesize:

H3: Green IS strategy is positively associated with Green IS practices.

Concerning the relationship between Green IS practices and firm competitiveness, we argue that Green IS can facilitate environmental sustainability strategies that differentiate from competitors' strategies and create value through cost reductions, improved reputation, innovation, and growth (Thambusamy & Salam, 2010; Dao *et*

al., 2011). For example, Green IS practices can decrease the electricity costs of IT operations and reduce business and production processes' consumption of resources through efficiency enhancements through process reengineering. Moreover, Green IS can lower compliance costs by delivering necessary information through environmental management systems. Green IS can also deliver tools that enable a firm to implement effective environmental management that improves the firm's image and reputation. A positive corporate reputation can enhances competitiveness because it influences customers' preferences and purchasing behavior (Hart, 1995). Furthermore, IS are important enablers of R&D activities that are difficult for competitors to imitate (Benitez-Amado & Walczuch, 2011). Green IS practices can enhance long-term firm competitiveness through environmental technology innovations which alter products and services and thus differentiate from competitors (Corbett, 2010).

Brooks *et al.* (2010) also suggest that companies can use Green IS for strategic purposes, arguing that Green IS can facilitate the eco-efficiency of internal processes, decreasing costs; foster eco-innovations of Green products and services that allow for competitive differentiation; and promote eco-collaboration through customer and stakeholder integration, improving the firm's reputation. Therefore, we expect the implementation of Green IS practices to enhance firms' competiveness. Accordingly, we hypothesize:

H4: Green IS practices are positively associated with firm competitiveness.

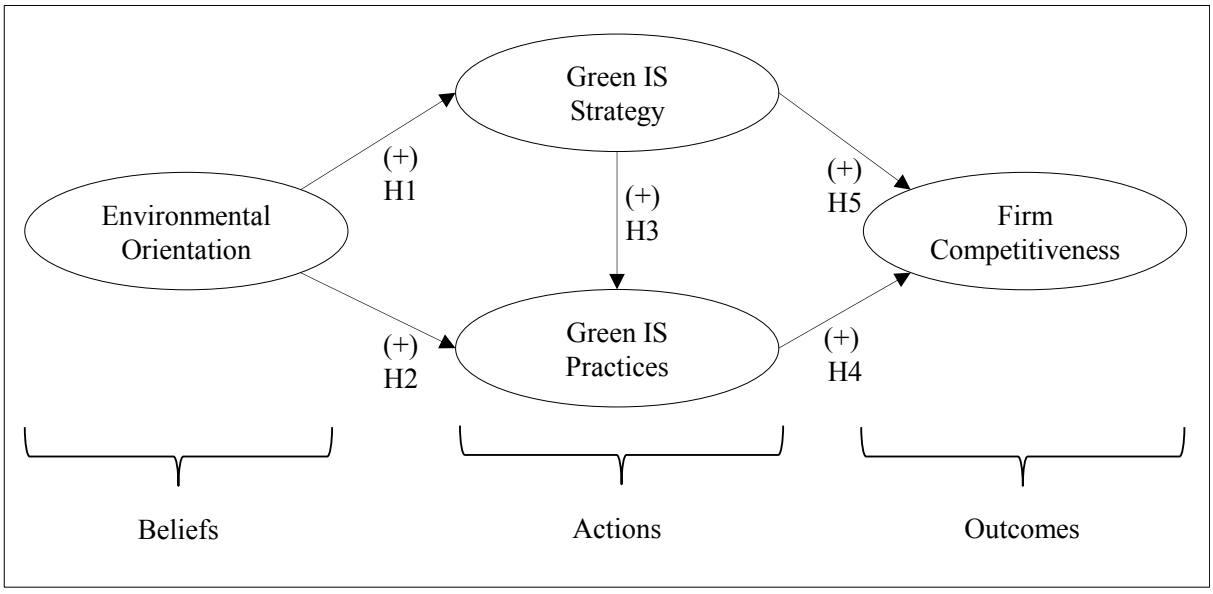


Figure 30: Research model.

Finally, the alignment of IS strategies with business goals is a firm-specific and unique capability that can be a source of competitive advantage (Kearns & Sabherwal, 2007b). Since Green IS strategies have to be aligned with corporate

business and sustainability goals and because they address different management levels of a company, they exhibit the characteristics of IS cross-functional organizational capabilities (Wade & Hulland, 2004). As these capabilities are deeply embedded in the organization and due to their elusive nature, they are unique, difficult to imitate, and can result in long-lasting competitive advantages (Sharma & Vredenburg, 1998). Accordingly, we hypothesize:

H5: Green IS strategy is positively associated with firm competitiveness.

These five hypotheses describe the cause-and-effect relationships between the latent constructs and specify the research model, as illustrated in Figure 30.

11.3.4 Instrument development

To collect empirical data to test the five research hypotheses and validate the research model, we designed an online survey, taking into account Fowler's (2009) recommendations and making use of Dillman's (2007) Tailored Design Method. In this context, we required a sophisticated measurement instrument, which was developed according to the guidelines of Lewis *et al.* (2005) and MacKenzie *et al.* (2011). Due to methodological considerations (Gefen *et al.*, 2000; Diamantopoulos & Siguaw, 2006) and the availability of empirically validated measures from prior research, all 14 first-order constructs where measured with reflective items on a common 7-point Likert scale, ranging from "strongly disagree" to "strongly agree".

As recommended by Urbach & Ahlemann (2010), we first identified potential items for the instrument by reviewing articles about empirical studies of similar research constructs. Although complete measurement scales could not be adapted to the research constructs, 248 fragments and single items suited the research model. In a second step, an analysis of the initial list of 248 items revealed that they did not cover all sub-dimensions of the construct domains. In particular, several aspects of the *Green IS strategy* and *Green IS practices* constructs were missing. Therefore, 22 new items were developed based on the construct definitions and descriptions (Lewis *et al.*, 2005; MacKenzie *et al.*, 2011). In a third step, we analyzed the quality and appropriateness of the 270 selected items. Three researchers from non-IS disciplines, each with a profound knowledge of quantitative studies and significant experience with SEM research, provided critical feedback, in response to which several items were revised. In a fourth step, a panel of five IS researchers, all of whom were familiar with key subject areas, participated in a rating procedure (MacKenzie *et al.*, 2011) to reduce the number of items to 89. In a fifth step, the measurement instrument was pretested with eleven researchers and practitioners who were familiar with the research topic to evaluate its appropriateness (Lewis *et al.*, 2005). The pretest and subsequent feedback helped to improve the structure and the design of the survey. Because the participants in the pretest criticized the length

of the survey, the sixth step was another round of item screening, in which the five IS research panelists once again evaluated the items' relevance using the content-validity-ratio-method proposed by Lewis *et al.* (2005). Based on this assessment, the final instrument contained 55 items (see Appendix D, Table 47).

11.4 Analysis of empirical results

11.4.1 Data collection and sample characteristics

The online survey was implemented with the open source software LimeSurvey. The empirical study focuses on large companies from highly developed countries as a target population, so we invited CIOs and high-level IT executives from companies with more than 250 employees in the US, Canada, Germany, Australia, and New Zealand to participate in the survey.

To invite these executives we used a database of 6,546 contact records for CIOs and high-level IT executives acquired from the Top IT Executives Database (5,899 records) (Applied Computer Research, Inc.), OneSource Australia (384 records), and our own research on CIOs of large German enterprises (263 records). This random sample features a company size distribution which is similar to the original population (see Table 48, Appendix E). After the initial invitation, four rounds of reminders were sent out with different formulations of the invitation text to improve the response rate (Sivo *et al.*, 2006). Our emails were undeliverable to 29.3 percent of the email addresses. Of the 4,628 invitations delivered, we received 169 responses for a response rate of 3.65 percent. Among these responses, 48 were incomplete, resulting in a final sample of 121 complete datasets.

Table 34: Characteristics of respondents' organizations [n = 118].

Annual company revenues [million USD]		Annual IT budget [million USD]		Number of employees		Number of IT staff	
< 50	22%	< 1	13%	251–1,000	40%	< 10	13%
50–250	31%	1–5	36%	1,001–5,000	25%	11–50	42%
251–1,000	17%	5.1–25	20%	5,001–25,000	27%	51–250	20%
1,001–5,000	17%	25.1–100	21%	25,001–100,000	5%	251–1,000	20%
5,001–25,000	8%	100.1–500	8%	> 100,000	3%	> 1,000	5%
> 25,000	4%	> 500	2%				

A first analysis of the standard deviation of the responses revealed 3 invalid data sets that included numerous arbitrary answers. We then searched for multivariate outliers by calculating the Mahalanobis d-squared values with SPSS and found that the remaining datasets were all within the accepted range. Thus, we ended up with

118 valid datasets. Table 34 lists the specific characteristics of the survey respondents.

The achieved response rate of 3.65 percent is low, despite our following of Sivo *et al.* (2006) suggestions for increasing response rates, such as considering feedback from colleagues and practitioners, continually improving invitation mails, sending several rounds of reminders, guaranteeing confidentiality, and providing an incentive for survey participants in the form of a management summary and an extensive catalogue of Green IT/IS measures. However, low response rates are not unusual for surveys that address senior executives (Anseel *et al.*, 2010; Messerschmidt & Hinz, 2013), and Ranchhod & Zhou (2001) emphasize that online surveys tend to have lower response rates than mail surveys do. An analysis of PLS-SEM articles published in *MIS Quarterly* revealed that studies with similar target respondent groups also yielded low response rates (e.g., Ravichandran & Rai, 2000; Enns *et al.*, 2003; Spears & Barki, 2010). Abareshi & Martin (2008) analyze 651 survey-based articles from leading IS journals and find that surveys directed at top managers, such as CIOs, yielded the lowest response rates, with an average value of 9 percent. The authors explain that "top managers are particularly difficult respondents from whom to gain data" (Abareshi & Martin, 2008, p. 7).

Urbach & Ahlemann (2010) emphasize that studies with low response rates do not necessarily yield less accurate results than studies with high response rates. According to Pinsonneault & Kraemer (1993), low survey response rates are problematic primarily for descriptive studies, but our research is exploratory in nature, focusing on the identification of cause-and-effect relationships (Goodhue *et al.*, 2012). However, we had to make sure that our dataset features external validity. Sivo *et al.* (2006, p. 352) say that, "when persons who respond differ substantially from those who do not, it becomes difficult to say how the entire sample would have responded." Therefore, we had to ensure that nonresponse bias is not an issue in our data. We applied three established post-hoc techniques to assess the possibility of a nonresponse bias (Furneaux & Wade, 2011).

The comparison of early and late respondents is the most widely applied method to test for nonresponse bias (Rogelberg & Stanton, 2007; Gefen *et al.*, 2011). Late respondents tend to resemble non-respondents, so a difference between early and late respondents would suggest a nonresponse bias. We compared the responses and demographic company characteristics from the first wave of participants to those from the last wave of respondents (linear extrapolation) using a two-tailed test (Armstrong & Overton, 1977). The tests were not significant at a 0.01 level, so they did not indicate a nonresponse bias. Second, the demographic characteristics of the respondents' organizations were compared to those of the sample from our contact record database (Sivo *et al.*, 2006). A chi-squared test of homogeneity did not

indicate a significant difference of company size distributions between the expected observations and the actually observed responses at the 0.05 level (see Table 48 in Appendix E). Third, we contacted 100 randomly selected non-respondents to learn their reasons for not participating in the survey, which is an established method for determining whether relevant patterns of nonresponse reasons emerge (Ravichandran & Rai, 2000; Rogelberg & Stanton, 2007). If dominant reasons for nonresponse are related to the topic of the survey (e.g., systematic disregard of environmental sustainability issues), the respondents would differ from the non-respondents, indicating a biased sample. As Table 49 (Appendix E) shows, 96 percent of the nonresponse reasons were not related to the topic of the survey. According to the results of these tests, there is no indication that a nonresponse bias exists, and it can be assumed that the dataset has external validity, despite a low response rate.

Next, we determined whether our sample of 118 datasets is large enough to test our complex structural model. The most widely applied minimum sample size rule for PLS-SEM is Chin & Newsted's (1999) "ten times rule," which states that "the sample size should be at least 10 times the number of incoming paths to the construct with the most incoming paths." Applied to our structural model, this rule of thumb postulates a minimum sample size of seventy responses. However, leading researchers and statisticians (Marcoulides & Saunders, 2006; Goodhue *et al.*, 2012; Hair *et al.*, 2013b) recommend conducting a more accurate assessment to ensure that the statistical power of the sample is sufficient to ensure statistical conclusion validity which "concerns the power to detect relationships that exist and determine with precision the magnitude of these relationships" (Sivo *et al.*, 2006, p. 354). Wetzels *et al.* (2009, p. 189) explain that "as a convention for behavioral research a value of 0.80 is used for power." Marcoulides *et al.* (2009) advise evaluating the number of predictors and the effect size of each multiple regression analysis of the structural model to calculate the statistical power with the help of Cohen (1988) power tables. Following this method, we calculated that, with n = 118 and a maximum of 7 predictors, we achieve the required statistical power of 80 percent for effect sizes larger than or equal to 0.18, with an error probability of less than 1 percent (GPower calculator, as suggested by Hair *et al.*, 2013b). Therefore, our sample has sufficient statistical power for our conclusions to be valid for all effect sizes that are larger than or equal to 0.18. We also conducted a more rigorous test that takes additional parameters of the entire model into account (http://www.danielsoper.com, as proposed by Gefen *et al.*, 2011). This test is based on the work of (Westland, 2010, p. 476), who proposes "two lower bounds on sample size in SEM, the first as a function of the ratio of indicator variables to latent variables, and the second as a function of minimum effect, power and significance." According to this sophisticated SEM sample size evaluation, we achieve statistical

power of 80 percent for effect sizes larger than or equal to 0.25 in our model with 55 observed and 14 latent variables. Therefore, we conclude that the sample has adequate power to detect medium to large effects, which is acceptable for exploratory research that aims at identifying relationships between theoretically derived constructs (Pinsonneault & Kraemer, 1993; Gefen *et al.*, 2011; Goodhue *et al.*, 2012).

To assess the potential for common method bias, which would indicate a systematic error of measurement, we conducted Harman's single-factor test, which involves performing an exploratory factor analysis with all independent and dependent variables in SPSS and analyzing the unrotated solution (Podsakoff *et al.*, 2003). The first factor that emerged explained 21.98 percent of the total variance. Since the first factor does not explain the majority of the variance, a common method bias is unlikely (Gefen *et al.*, 2011). Since Harman's single factor test has several methodological shortcomings (Podsakoff *et al.*, 2003), we conducted a second test by including a common method factor in the PLS model, as described by Liang *et al.* (2007). This test revealed that the average substantively explained variance of the indicators was 0.72, whereas the method-based variance was only 0.014, making the ratio of substantive variance to method variance 51:1. This high value suggests the absence of a common method bias.

11.4.2 Analysis technique

We used structural equation modeling (SEM) (Hair *et al.*, 2011) to test the latent multiple-indicator constructs (Figure 27 and Figure 29) and the hypothesized relationships that specify the research model (Figure 30). More specifically, we applied the multivariate analysis method of partial least squares structural equation modeling (PLS-SEM), which is an established technique in IS and strategic management research (Hair *et al.*, 2013a).

PLS-SEM is particularly useful in exploratory research settings, where the identification of relationships is the central purpose (Goodhue *et al.*, 2012; Ringle *et al.*, 2012). As a component-based approach, PLS-SEM is appropriate for testing higher-order constructs and complex research models (Urbach & Ahlemann, 2010). PLS-SEM is comprised of two levels of analysis: the measurement model, which evaluates the latent constructs' measurement scales, and the structural model, which assesses the direction and strength of the relationships between the constructs (Gefen *et al.*, 2000). The following analysis builds on the guidelines of Gefen *et al.* (2011) and Hair *et al.* (2013a).

11.4.3 Measurement model

A confirmatory factor analysis (CFA) was conducted with SmartPLS 2.0 to examine the psychometric properties of the measurement scales and to evaluate indicator reliability. The loadings for reflective measurement items should be higher than 0.707 (Chin, 1998), so we discarded three items from the analysis because their loadings did not reach this threshold (ITS1: 0.66, ISR5: 0.61, CR5: 0.56; see Table 47 in Appendix D). Next, we analyzed the cross-loadings of the measurement items and found that all items exhibited higher loadings on the constructs they were to measure than they did on any other constructs (see Table 51 in Appendix F).

To determine discriminant validity, we checked whether each construct shared more variance with its assigned measurement items than did any other constructs (Table 51). The Forner-Larcker criterion, which requires the average variance explained (AVE) of each latent construct to be greater than the construct's highest squared correlation with any other construct, was fulfilled for all constructs (Table 51). The AVEs are higher than 0.5 for all constructs, pointing to a high convergent validity. The composite reliability of all constructs was well above the 0.7 threshold, which indicates internal consistency reliability (Table 51).

11.4.4 Higher-order constructs

This research uses two second-order reflective-formative constructs (*Green IS strategy* and *firm competitiveness*) and one third-order reflective-formative-formative construct (*Green IS practices*), as illustrated in Figure 27 and Figure 29. The reflective measurement of the unidimensional first-order constructs was assessed in the previous section. Now we evaluate the structural model of the higher-order constructs (Hair *et al.*, 2013a). As recommended by Becker *et al.* (2012), we used the repeated indicator PLS-SEM approach to model the second-order reflective-formative constructs in SmartPLS 2.0. This approach can also be extended to third-order constructs. To evaluate the constructs, we assessed the path coefficients between the lower-order latent variables and the higher-order constructs (PLS algorithm, path weighting scheme, bootstrapping with 118 cases and 1,000 re-samples). All paths from the first- and second-order sub-constructs to the higher-order constructs showed weights considerably above the 0.2 threshold (Chin, 1998; Urbach & Ahlemann, 2010) and the positive relationships were significant at the 0.001 level (Table 52).

To test for possible multicollinearity between the formative indicators, we evaluated the Variance Inflation Factor (VIF) statistics with SPSS (Table 52). All VIFs were below the cut-off value of 5, which is recommended for formative models in PLS analyses (Diamantopoulos & Siguaw, 2006; Hair *et al.*, 2011). The significance of the paths from lower-order to higher-order constructs and the low multicollinearity

between the indicators demonstrate that the chosen lower-order constructs represent distinct facets of the higher-order constructs (Becker *et al.*, 2012).

11.4.5 Structural model

Next, the structural model (Figure 30) was assessed by testing the hypotheses and evaluating the predictive power of the model using a PLS algorithm (SmartPLS 2.0, path weighting scheme) and analyzing the significance of the path coefficients with a bootstrapping procedure (118 cases and 1,000 re-samples). The results of this assessment with PLS-SEM are shown in Figure 31.

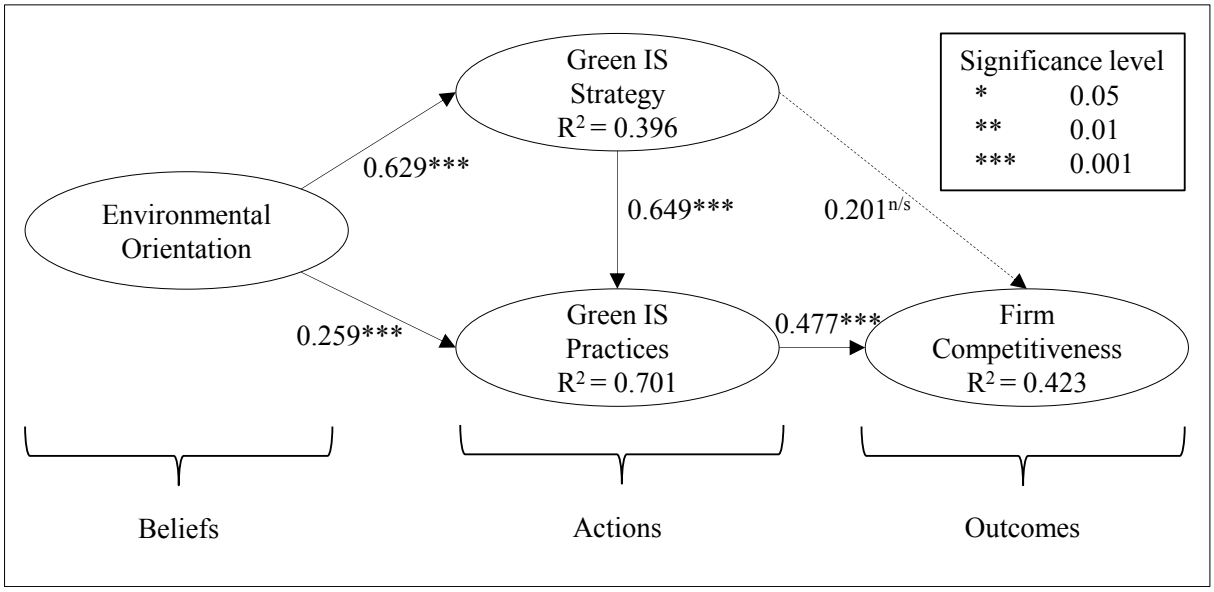


Figure 31: Assessment of the structural model with PLS-SEM (n = 118).

R^2 is the coefficient of determination, which describes the amount of a latent endogenous variable's variance that the model explains. R^2 values of 0.67, 0.33, and 0.19 are considered substantial, moderate, and weak, respectively (Chin, 1998; Urbach & Ahlemann, 2010). The model explains 42.3 percent (moderate) of the variance of the dependent outcome variable *firm competitiveness* through the endogenous latent variables *Green IS strategy* and *Green IS practices*. Furthermore, 70.1 percent (substantial) of the variance of *Green IS practices* are explained through *Green IS strategy* and the exogenous latent variable *environmental orientation*, and 39.6 percent (moderate) of *Green IS strategy* through *environmental orientation*.

We evaluated the hypotheses (Figure 30), referring to the paths in the structural model, using two-tailed tests based on a bootstrapping procedure. H1, H2, H3, and H4 proved to be significant at the $p < 0.001$ level. We rejected only H5 because the path from *Green IS strategy* to *firm competitiveness* was not significant. The path

coefficients, whose size indicates the strength of the relationship between the model's latent variables, are shown in Figure 31.

The effect size (f^2) indicates to what extent an independent latent variable contributes to explaining another dependent latent variable with regard to R^2 (Liang *et al.*, 2007). According to Cohen (1988), f^2 values from 0.02 but below 0.13 represent small effect sizes, those from 0.13 to below 0.26 represent moderate effect sizes, and values greater than 0.26 indicate large effect sizes (Wetzels *et al.*, 2009). The results show that *environmental orientation* has a large effect on *Green IS strategy* ($f^2 = 0.66$) and a moderate effect on *Green IS practices* ($f^2 = 0.13$). According to the PLS model, *Green IS strategy* has a large effect on *Green IS practices* ($f^2 = 0.83$), which, in turn, demonstrate a moderate effect on *firm competitiveness* ($f^2 = 0.13$), while *Green IS strategy* has almost no effect on it ($f^2 = 0.01$). However, in conjunction, *Green IS strategy* and *Green IS practices* explain a substantial amount of the variance of *firm competitiveness* (42.3%).

11.5 Discussion of findings

Hypotheses H1 and H2 posited that IT executives' environmental orientation has a positive influence on Green IS strategy and Green IS practices. The empirical results indicate that, although the path from *environmental orientation* to *Green IS practices* is significant, the causal relationship between the constructs is moderate ($\beta = 0.259$; $p < 0.001$; $f^2 = 0.13$). By comparison, the influence of *environmental orientation* on *Green IS strategy* is much more pronounced ($\beta = 0.629$; $p < 0.001$; $f^2 = 0.66$), so the environmental orientation, which influences executives' beliefs, has a strong effect on the formulation of Green IS strategies. H3 should also be discussed in this context. The impact of *Green IS strategy* on the implementation of *Green IS practices* is very large ($\beta = 0.649$; $p < 0.001$; $f^2 = 0.83$), so the results suggest a chain of causation from *environmental orientation* to *Green IS strategy* through to *Green IS practices*. Therefore, we used a Sobel test (MacKenzie *et al.*, 2011; MacKinnon *et al.*, 2012) to see whether *Green IS strategy* partially mediates the relationship between *environmental orientation* and *Green IS practices*, which proved to be significant at the 0.001 level. The indirect path ($\beta_{indirect} = 0.408$; $p < 0.001$) is more accentuated than the direct path from *environmental orientation* to *Green IS practices* ($\beta_{direct} = 0.259$; $p < 0.001$), showing that executives' environmental orientation is more likely to lead to environmental actions in the form of Green IS practices when Green IS strategies have been formulated than when they have not. This result indicates that sophisticated Green IS strategies that address the corporate, competitive, and functional levels are effective enablers of the implementation of far-reaching first-, second-, and third-degree Green IS practices.

The empirical results also support H4 and verify that *Green IS practices* has a positive influence on *firm competitiveness* ($\beta = 0.477$; $p < 0.001$). Although the substantial path weight indicates a strong relationship, the calculated effect size is moderate ($f^2 = 0.13$). The effect of *Green IS strategy* on *firm competitiveness* is small, and the path is not significant ($\beta = 0.201$; not significant, $f^2 = 0.01$), which leads to the rejection of H5. However, the two constructs *Green IS strategy* and *Green IS practices* together explain a considerable amount of the variance of *firm competitiveness* (42.3%). *Green IS strategy* appears to be a firm-specific managerial capability that combines Green IS resources in a unique way.

Because of the rejection of H5, despite *Green IS strategy*'s influencing *firm competitiveness*, we examined the relationships between *Green IS strategy*, *Green IS practices* and *firm competitiveness* in detail. Initially, it seemed that *Green IS strategy* has little effect on *firm competitiveness* ($\beta_{direct} = 0.201$; not significant, $f^2 = 0.01$), but this relationship changed considerably when we excluded *Green IS practices* from the model and the strong effect of *Green IS strategy* on *firm competitiveness* was revealed ($\beta_{without\ mediation} = 0.591$; $p < 0.001$; $f^2 = 0.54$). It appears as though the positive relationship between *Green IS strategy* and *firm competitiveness* changes from a significant path with a strong effect to an insignificant path with a small effect when the mediator *Green IS practices* is introduced. To verify that *Green IS practices* mediates the relationship between *Green IS strategy* and *firm competitiveness*, we conducted a Sobel test, which proved to be significant at the 0.001 level. The PLS model revealed that the indirect effect ($\beta_{indirect} = 0.309$; $p < 0.001$) is stronger than the direct effect, supporting our argument that *Green IS practices* partially mediates the positive relationship between *Green IS strategy* and *firm competitiveness*. These empirical results are in line with those of previous studies in related fields (e.g., Banerjee, 2002). To allow corporate environmentalism and sustainable management practices to occur, management must consistently translate Green IS strategies into sustainability actions in the form of Green IS practices. At the same time, Green IS strategies are unique IS management capabilities that are required in order for the firm to leverage the potential of Green IS practices through a firm-specific implementation of environmental technologies and initiatives.

11.5.1 Alternative models

In order to compare the proposed model to alternative models (Henseler & Sarstedt, 2013), we evaluated the global fit of our structural model by calculating the global goodness-of-fit (GoF) measure for PLS path models, as proposed by Wetzels *et al.* (2009). This measure, which is based on prior work of Cohen (1988) and Tenenhaus *et al.* (2005), is defined as the square root of the average communalities (which

equal the AVEs in Table 51), multiplied by the average effect sizes for R^2. The GoF of our model is 0.465, which indicates a good model fit. We tested as an alternative a model with a direct path from *environmental orientation* to *Green IS strategy* to *Green IS practices* through to *firm competitiveness*, which demonstrated a lower GoF of 0.455. Next, we tested the original structural model with the link between *Green IS strategy* and *Green IS practices* removed, which dropped the GoF to 0.427. We also tested several other models, but none demonstrated a better fit than the initially proposed model.

11.5.2 The effect of Green IS practices on firm competitiveness

To deepen our understanding of the positive relationship between Green IS practices and firm competitiveness, we conducted a detailed analysis of the paths between the sub-constructs that relate to the higher-order constructs of *Green IS practices* (*first-, second-,* and *third-degree Green IS practices*) (Figure 29) and *firm competitiveness* (*cost reductions*, *corporate reputation*, *Green innovations*) (Figure 27).

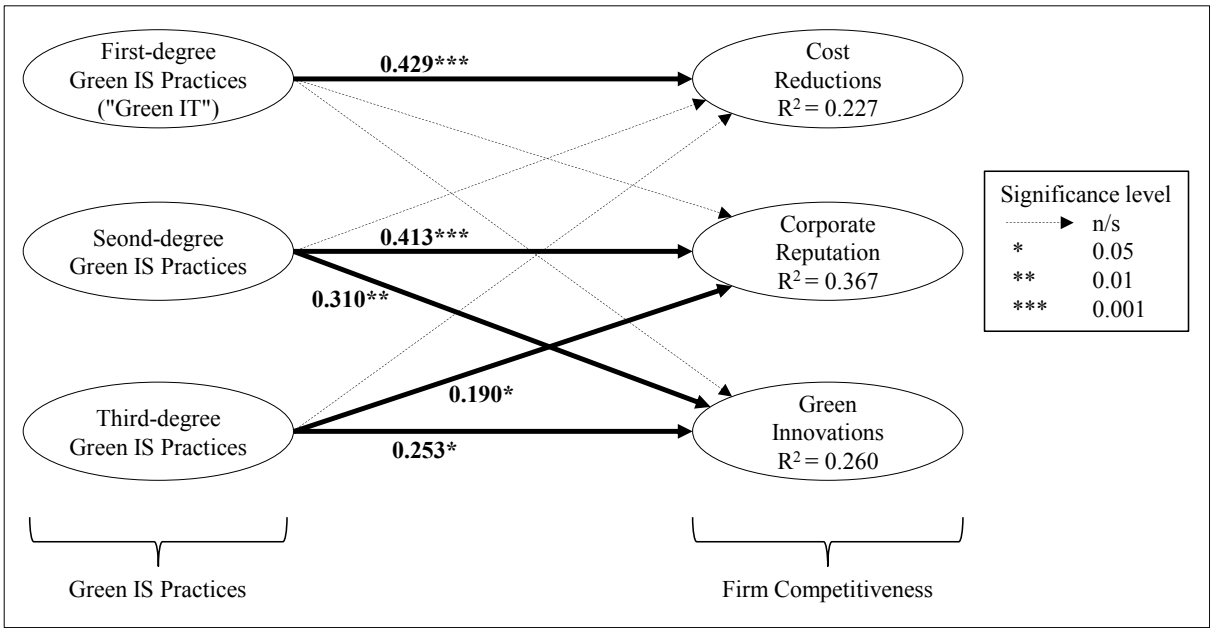


Figure 32: Relationships among the sub-constructs of Green IS practices and firm competitiveness.

As Figure 32 shows, *first-degree Green IS practices* has a moderately positive effect on *cost reductions* ($\beta = 0.429$; $p < 0.001$; $f^2 = 0.21$), while its impact on *corporate reputation* and *Green innovations* is not significant. By contrast, *second-degree Green IS practices* does not have a significant relationship with *cost reductions* but has a moderate effect on *corporate reputation* ($\beta = 0.413$; $p < 0.001$; $f^2 = 0.13$) and a small effect on *Green innovations* ($\beta = 0.310$; $p < 0.01$; $f^2 = 0.06$). Similarly, albeit less pronounced, *third-degree Green IS practices* demonstrates a small effect on

corporate reputation ($\beta = 0.190$; $p < 0.05$; $f^2 = 0.03$) and on *Green innovations* ($\beta = 0.253$; $p < 0.05$; $f^2 = 0.05$), but no significant impact on *cost reductions*.

These results empirically confirm the notion that first-degree Green IS practices ("Green IT"), which target the sourcing, operations, and disposal of IT equipment, not only decrease the need for hardware-specific raw materials, the consumption of electrical power, and the generation of e-waste, but also result in economic benefits in the form of cost reductions. However, because of their restricted focus on IT-related issues, these practices do not have a significant potential to enhance corporate reputation or induce Green innovations.

Second-degree Green IS practices, which target the entire organization by providing environmental management systems or fostering the IS-based reengineering of business and production processes, have a larger effect on corporate reputation. Although the first-degree environmental impact of IS (the direct impact of IT infrastructure) represents only a small proportion of a firm's environmental footprint in most industries (Gartner Research, 2007; Watson *et al.*, 2010), second-degree Green IS practices have a significant potential to enhance corporate reputation by reducing waste and emissions throughout the organization. Moreover, IS-based environmental management systems can facilitate monitoring of and reporting about the corporate footprint to internal and external stakeholders, which also has a positive effect on the reputation. The use of second-degree Green IS practices to transform the company's systems and processes can also strengthen the firm's environmental innovation capabilities, probably because of the expertise that emerges from using IS to employ resources efficiently and quantify environmental impacts throughout the product lifecycle. However, according to the empirical results, this effect is not pronounced, and we did not detect a significant impact of these practices on cost reductions. We expected that the IS-based redesign of internal processes would increase resource efficiency and reduce operational costs, but such was not the case.

We found a significant positive relationship between *third-degree Green IS practices* and *Green innovations*. The small effect size might be related to the restriction of IS-based environmental innovations like dematerialization initiatives and intelligent engine control units to certain product categories. Third-degree Green IS practices also affect the firm's reputation by supporting the development of environmentally friendly products, thus improving brand image and customer perceptions. However, the effect size is small, perhaps because eco-products have not yet reached the mainstream but remain a market niche.

11.6 Conclusion

IS researchers and IT executives alike are considering the rising concerns about climate change and environmental sustainability. IT organizations have already implemented numerous IT-focused Green IT measures that promise cost reductions and a short payback period (Harmon & Demirkan, 2011), but a wide range of Green IS practices remain that can facilitate substantial economic benefits and create competitive advantages. Many of these Green IS initiatives are cross-functional, rather than being bound to the IT domain, so they are more complex, require larger investments, and have less certain tangible payoffs in the long-term than do IT-focused Green measures, which inhibits their implementation (Dao *et al.*, 2011; Elliot, 2013). To contribute to the theoretical body of knowledge in this area and to advance the implementation of Green IS practices, this study analyzes the antecedents and consequences of adopting Green IS. We found that IT executives' environmental orientation leads to the formulation of Green IS strategies, which are translated into Green IS practices that have a significantly positive impact on the firms' competitiveness. The empirical results suggest that IT-focused Green IS practices reduce costs and that IS-enabled process reengineering and environmental technologies enhance corporate reputation and corporate innovation capabilities.

11.6.1 Theoretical contributions

This work contributes to the body of knowledge in IS research, particularly to the relatively new area of Green IT/IS research, in several ways. First, we answered the call for empirical studies that define the relationship between Green IS adoption and the creation of business value and firm competitiveness (e.g., Melville, 2010; Benitez-Amado & Walczuch, 2011; Jenkin *et al.*, 2011). Prior research has focused primarily on the environmental consequences of adopting Green IS (e.g., Chen *et al.*, 2008; Melville, 2010; Watson *et al.*, 2010; Butler, 2011) but has devoted little study to their economic impacts. To address this research gap, this study offers theoretical and empirical insights concerning the causal chain from environmental orientation, which affects executives' beliefs and decision-making processes, to the formulation of Green IS strategies and the implementation of Green IS practices, through to outcomes in the form of firm competitiveness.

Second, we defined the concept of Green IS as the investment in and deployment, use, and management of IS in order to minimize the negative environmental impacts of IT, business operations, and IS-enabled products and services. We systematically developed two further concepts, each of which represents a specific facet of Green IS adoption. To conceptualize *Green IS practices*, we differentiated among first-, second-, and third-degree Green IS practices, described their environmental impacts, management areas, and provided a wide range of

implementation examples. The concept *Green IS strategy*, on the other hand, refers to a firm-specific IS management capability through cross-functional synergies and IS-business partnerships (Wade & Hulland, 2004). In this context, we provided a detailed description of the characteristics of Green IS strategies at the corporate, competitive, and functional levels, which we hope will be useful for other researchers. The empirical findings underscore the significance of Green IS strategy as a managerial capability that allows a firm-specific combination of Green IS practices to leverage the potential of Green IS throughout the organization.

Third, we conceptualized numerous latent constructs that can be applied in similar or new research contexts. We developed and empirically validated a measurement instrument for these constructs that is comprised of a wide range of reflective measurement items. Since only a few empirical studies have been conducted in this research area, we hope that other researchers can benefit from this measurement instrument in order to develop additional empirical insights for this important field of research.

Fourth, our empirical analysis supports IS researchers' theoretical assumption that the adoption of Green IS has a positive impact on firm competitiveness (e.g., Brooks *et al.*, 2010; Benitez-Amado & Walczuch, 2011). We also found support for the suggestion that certain Green IS practices result in cost reductions, improved corporate reputation, and/or Green product and process innovations (Thambusamy & Salam, 2010; Corbett, 2010; Dao *et al.*, 2011). The results revealed a significantly positive relationship between first-degree Green IS practices ("Green IT") and cost reductions. In addition, we found a positive effect of second-degree Green IS practices (process reengineering and environmental management systems) and third-degree Green IS practices (IS-enabled environmental technologies which reduce the footprint of products and services) on corporate reputation and firm-specific environmental innovation capabilities. These empirical insights are particularly valuable for strategic IS and IT business value researchers.

11.6.2 Implications for management practice

This study's findings have several important implications for business and IT executives. First, the research's empirical results suggest to business managers that coherent Green IS investments generate business value and economic benefits. The adoption of Green IS not only contributes to environmental goals but also enhances the competitiveness of business firms through reduced operational costs, improved corporate reputations, and differentiation from competitors through superior innovation capabilities. By decreasing the uncertainty about the economic impacts of Green IS adoption, we motivate both business and IT executives to advance their environmental sustainability efforts.

Second, this research demonstrates that a holistic approach is required in order to advance Green IS adoption in an economically beneficial way. Many companies have implemented standard Green IT measures in their data centers and office environments (Park *et al.*, 2012), but Green IS have a more far-reaching potential that most companies have not exploited (Dao *et al.*, 2011). Green IS are key enablers of sound corporate sustainability management throughout the organization and can foster eco-innovations for end-user products and services. Business executives should cooperate more closely with IT executives in order to comprehend the technological potential of Green IS to advance the environmental management capabilities and market-oriented sustainability initiatives that result in competitive advantages. For their part, CIOs should conceive of the role of IS in a broader business and corporate sustainability context than is currently typical. Because of IT executives' cross-functional perspective that results from delivering technical solutions to a wide range of business units, CIOs are in a unique position to identify cross-functional synergies that can advance corporate sustainability initiatives (Clark, 2010). To leverage the environmental and economic potential of Green IS, CIOs should embed Green IS strategies at the corporate, competitive, and functional management levels. Depending on the firm-wide role of Green IS, strategies can be efficiency-driven, innovation-driven, stakeholder-driven, or transformation-driven (Loeser *et al.*, 2012). In this context, we advise IT executives on how Green IS strategies should be formulated as organizational perspectives (corporate level), as positions (competitive level), and as plans (functional level).

Third, we provide concrete guidance on how Green IS strategies can be translated into sustainability actions through Green IS practices that either target IT-related environmental impacts or reduce the firm-wide or product-specific ecological footprint (Figure 26). Appendix C provides an extensive catalogue of ninety-one exemplary Green IS practices that can be implemented. The catalogue categorizes measures that reduce first-degree IT environmental impacts according to specific functional areas, such as IT sourcing, IT operations in data centers and office environments, and IT disposal. Process reengineering initiatives and environmental management systems facilitate positive second-degree impacts by decreasing the resource use, waste, and emissions that are associated with business operations, and sustainable products and infrastructure solutions, which are based on technology-related environmental innovations, have positive third-degree impacts by reducing products' ecological footprints during their entire lifecycles. The firm-specific distribution of the three degrees of environmental impacts differs substantially among companies and among industries (Gartner Research, 2007), so we recommend close collaboration between IT and business executives in order to identify the areas where Green IS practices offer the largest potential to contribute to the organization's environmental goals.

Fourth, we decrease uncertainties concerning the economic benefits that the implementation of Green IS practices offers. The detailed empirical insights based on the classification of Green IS practices (Figure 26) reveal that IT-related first-degree Green IS practices can reduce costs, whereas second- and third-degree Green IS practices can enhance corporate reputations and Green product innovation capabilities. As a consequence, business and IT executives can focus their investments on initiatives that enhance particular facets of firm competitiveness. We emphasize that the competitive potential of Green IS is context-dependent and is influenced by customer preferences and stakeholder demands.

Finally, our analysis shows that the realization of the competitive potential of Green IS is complex and challenging. Environmental orientation, which is influenced by external factors and deeply embedded in the organizational culture, shapes executives' environmental beliefs, which either supports or does not support sustainability actions. When they occur, sustainability actions take place through the formulation of Green IS strategies, which are the prerequisite for a coherent implementation of Green IS practices. Green IS strategy and Green IS practices are complementary, and they enhance firm competitiveness only in conjunction with each other. A strategy without consequent implementation of activities and practices is as useless as uncoordinated implementation of activities and practices without the unifying constraint of a strategic focus.

11.6.3 Limitations and future research

Despite our efforts to ensure methodological rigor and thoroughly conducted analyses, this study has a few limitations. First, our survey generated a comparatively low response rate. Although low response rates are not unusual in empirical studies that target top executives, the generalizability of findings might be limited. Second, a larger number of datasets would have allowed us to test differences between companies of certain sizes, between industries, and between regions. Third, the cross-sectional data is limited to large organizations in the US, Canada, Australia, New Zealand, and Germany. The results might differ with data from small or medium-sized companies in other countries. Fourth, the empirical survey data is based on responses from single informants. A multiple-informant approach that included both business and IT executives would have offered findings related to specific functional areas. Fifth, this study relies on the responding executives' perceptions. Although we made use of relative performance measures that compared the respondent's company to competitors in the same industry, the consideration of quantitative financial data would have been more objective. Finally, because of the complexity of the research design, this study does not measure the environmental impacts of adopting Green IS or its contribution to sustainability

goals. Instead, it analyzes only the economic dimension, so its insights into the effectiveness of certain Green IS practices are restricted.

Future research should determine how Green IS strategies at the corporate, competitive, and functional management levels and the implementation maturity of first-, second-, and third-degree Green IS practices differ across industries and company sizes. Corresponding empirical insights would allow for detailed managerial recommendations under consideration of firm-specific contexts. As a consequence, advice for implementing Green IS practices with the largest possible competitive benefits could be given. Moreover, in-depth case studies could reveal how leading companies leverage the competitive potential of Green IS, thus providing examples for best practices. In addition, further research concerning second- and third-degree Green IS practices, such as process reengineering, environmental management systems, and IS-enabled Green products and services, is required. Researchers anticipate that Green IS could considerably advance environmental sustainability initiatives through technological innovations in these areas (Harmon & Demirkan, 2011). However, corresponding research is largely anecdotal and relies on theoretical assumptions (Jenkin *et al.*, 2011). To promote the adoption of Green IS to rapidly meet future sustainability challenges, further empirical insights are needed. In the area of IS business value research, the integration of performance measures that take environmental and social aspects into account (triple bottom line) should be advanced to prevent a unidimensional focus on economic goals.

Green IS can certainly drive environmental innovations and corporate sustainability, but to benefit from these opportunities, research and practice must explore the strategic dimension of corporate sustainability transformations. The potential of Green IS can be understood only if IS are analyzed using a transdisciplinary approach that involves the domains of environmental sustainability and strategic management (Dao *et al.*, 2011; Shrivastava *et al.*, 2013). Therefore, we call for additional transdisciplinary studies that empirically explore the potential of IS-enabled innovation and business transformations to advance sustainable development in business and society.

D. CONCLUSION

In Part D of this work, conclusions are drawn by consolidating the research results, insights and findings of this thesis. First, the twelve research questions that were formulated in the introductory Part A are briefly answered. Second, the theoretical contributions of this thesis are delineated by discussing how the research findings add to the body of knowledge of the nascent Green IS research discipline. Third, the management implications that arise from the empirical findings and the conceptualized frameworks are highlighted. Fourth, limitations of this research are discussed and areas of further research are identified. Finally, the fifth section describes with concluding statements how the four overarching research goals of this thesis were achieved.

12. Research Findings

This section briefly outlines the answers pertaining to the twelve research questions that were formulated in the introductory Part A of this thesis (Section 5.4, Table 6) to address the identified research gaps (Section 5.1, Table 5). These findings stem from the research that was conducted in the scope of the six research articles presented in Part B (theory-based conceptual research) and Part C (empirical research) of this thesis.

Findings from Part B – Sections 6–9

RQ B6.1: How can the concepts of Green IT and Green IS be unambiguously defined on the basis of prevalent literature to clearly illustrate the differences between these two concepts?

The clear definition of concepts is an important first step for the theoretical development of the Green IS research discipline. On the basis of an in-depth literature review and a concept analysis, the following definitions were proposed:

> 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.

RQ B6.2: How can IS-related environmental impact areas be classified to allow for a holistic and structured management of Green IS practices?

To holistically understand the ecological effects of Green IS practices, three specific degrees of environmental impacts should be taken into account. IT-related first-degree impacts delineate the negative environmental consequences of IT sourcing, IT operations, and IT disposal. The positive environmental effects of organizational IS-enabled sustainability solutions, such as process reengineering or environmental management systems, are subsumed as second-degree environmental impacts. Finally, IS-enabled environmental technologies can foster eco-innovations, which decrease the footprint of products and services during the entire lifecycle, thus inducing positive third-degree environmental impacts.

RQ B6.3: Which Green IT measures and Green IS initiatives can be identified in research and practice?

In the scope of the pre-study (Section 3) and the extensive literature review (Section 6), a catalogue of 70 Green IT measures, subdivided into IT sourcing, IT operations, and disposal of IT equipment, was developed (Table 14). In addition, a list of 41 Green IS initiatives, which were assigned to IT governance, to organization-wide environmental management systems and process optimization capabilities, or to the enabler function of IS for innovative end products and infrastructure solutions, was conceptualized (Table 15).

RQ B7: How can aspects of environmental sustainability be integrated into strategic IS alignment?

First, the concept of Green IS was integrated into the concept of IS strategy to allow a consideration of the strategic aspects of environmental sustainability (Figure 18). Next, Henderson & Venkatraman's (1993) Strategic Alignment Model as well as Orsato's (2006) competitive environmental strategies were adapted and integrated into a new Strategic Green IS Alignment Framework (SGISAF). The SGISAF differentiates between an internal and an external perspective and comprises the domains Green IS and environmental sustainability. In this context, four distinct Green IS alignment perspectives were suggested. These four alignment perspectives differ with regard to competitive focus, competitive advantage, targets of

sustainability management, goals of the IS function, and performance criteria. With this new alignment framework, the strategic aspects of IS-enabled environmental initiatives can be taken into consideration to leverage the competitive potential of Green IS.

RQ B8: *Which organizational actors are involved in the internal transfer of knowledge between organizational units being relevant for Green IS alignment?*

Explicit knowledge can be transferred among business, sustainability, and IS domains via communication whereas tacit knowledge must be transferred between organizational actors via processes that comprise the application of the tacit knowledge, e.g., strategic planning processes that are conducted collectively by business, sustainability, and IS executives. These processes result in shared domain knowledge, which is expressed through explicit strategies that leverage the potential of Green IS by appreciating IS-related business opportunities in a multidisciplinary and holistic way.

On the corporate level, the board of directors should collaborate with IS and sustainability strategy committees to formulate a shared vision as well as a long-term strategy. The executive management, in particular the CEO, CIO, and CSO, should ensure the alignment with competitive strategies and set specific targets that exploit the business value and environmental potential of Green IS. The accomplishment of the actual implementation of environmental initiatives should be verified on the functional level by corresponding functional managers and steering committees.

RQ B9: *How can economic, environmental, and IT performance impacts be integrated into a holistic performance management framework that prevents a one-sided focus on cost aspects?*

Kaplan & Norton's (1992) Balanced Scorecard (BSC) and its derivates, such as the IT BSC (van Grembergen, 2004) and the Sustainability BSC (Figge *et al.*, 2002), were identified as suitable performance measurement systems due to their flexibility, customizability, and multi-dimensionality. In the context of the industry-university project *Green IT Cockpit*, an IT-oriented Sustainability Balanced Scorecard was developed to provide aggregated information to high-level executives, process managers as well as directors of IT operations. As a consequence, four distinct perspectives were identified as being relevant (environmental perspective, IT performance perspective, business process perspective, and financial perspective). In addition, project-specific Key Performance Indicators (KIPs) were defined for each perspective and linked through cause-and-effect relationships. By doing so, IT-

related CO2 emissions could be mapped to IT performance while IT performance in turn was linked to the execution of business processes, and finally to financial success measures. The Sustainability BSC can be used to implement IT-related environmental strategies, to determine specific target values for high-level KPIs, and to identify appropriate measures to achieve these targets.

Findings from Part C – Sections 10–11

RQ C10.1: *How can the concept of Green IS strategy be defined and which specific characteristics does it have?*

The concept of Green IS strategy was defined as follows:

> **Green IS strategy** is the organizational perspective on the investment in, deployment, use and management of information systems (IS) in order to minimize the negative environmental impacts of IS, IS-enabled products and services, and business operations.

On the basis of empirical insights from case study research, which were consolidated with findings from extant literature, five distinct characteristics were proposed:

a) Green IS strategies should address environmental and technical issues at the corporate, competitive, and functional management level.
b) Green IS strategies must be aligned with environmental strategies.
c) Green IS strategies can support cost leadership or competitive differentiation strategies.
d) Green IS strategies can enhance the efficiency of internal processes, or drive ecological product innovations.
e) Green IS strategies are determined by the significance of IS for the core business and the first-, second-, and third-degree environmental impacts.

RQ C10.2: *What different types of Green IS strategies can be identified in a real-life context?*

By means of an exploratory multiple-case study research approach, a typology of Green IS strategies was derived from the empirical insights (Table 29). This typology comprises three specific management levels, which should be addressed through Green IS strategies. At the corporate level, these strategies delineate the organization-wide perspective on Green IS; at the competitive level, the market-oriented strategic goals are determined; and at the functional level, Green IS-related resources and capabilities that substantially affect firm competitiveness are developed, acquired, and managed. In the conceptualized typology, four distinct

strategies are proposed: *Green IS for Efficiency*, *Green IS for Innovation*, *Green IS for Transformation*, and *Green IS for Credibility*.

RQ C10.3: How do firms with distinct Green IS strategies conceive the role of Green IS within their organization?

Business firms that follow a *Green IS for Efficiency* strategy perceive Green IS primarily as a technological issue relating to the IT infrastructure. Accordingly, the reduction of operational costs of IS-based business processes is the main goal while the superordinate business strategy is the dominant driver in the alignment process. The *Green IS for Innovation* strategy, on the contrary, is associated with an externally- and product-oriented perspective. This strategy is suitable for companies who target an environmental technology leadership position, hence appreciating Green IS as key driver of eco-innovations. The *Green IS for Transformation* strategy is characterized by its internal focus. This strategy is appropriate for business firms who strive for a business leadership position that requires superior resource efficiency throughout the entire organization, enabled by a fundamental reengineering of production and business processes. Finally, the *Green IS for Credibility* strategy allows for a minimization of the environmental footprint of the entire organization and of its products and services. Accordingly, this strategy is aimed at occupying an undisputed environmental leadership position, coming along with an outright satisfaction of different stakeholder groups and involving a superior corporate reputation that becomes a valuable intangible asset, paying off through brand preferences of consumers and customer loyalty.

RQ C11.1: Does corporate environmentalism lead to the adoption of Green IS?

The empirical results indicate that the effect of environmental orientation on the adoption of Green IS practices is rather moderate. However, the influence of environmental firm orientation, which shapes the perception of executives, on the formulation of Green IS strategies is quite pronounced. In addition, Green IS strategies have a large impact on the implementation of Green IS practices. Accordingly, the empirical results suggest a chain of causation from environmental firm orientation to formulation of Green IS strategies to implementation of Green IS practices. Apparently, environmental orientation is more likely to lead to environmental actions in the form of Green IS practices when Green IS strategies have been formulated than when they have not. These findings indicate that sophisticated Green IS strategies that address the corporate, competitive, and functional levels are effective enablers of the implementation of far-reaching first-, second-, and third-degree Green IS practices.

RQ C11.2: Does the adoption of Green IS affect firm competitiveness?

The empirical data verify that the implementation of Green IS practices has a significant positive impact on the competitiveness of business firms whereas the effect of Green IS strategies on firm competitiveness turned out to be insignificant. However, the empirical results indicate a substantial indirect influence of Green IS strategies because these strategies mediate the positive relationship between Green IS practices and firm competitiveness. Green IS strategies show the characteristics of firm-specific managerial capabilities that combine Green IS resources in a unique way. Hence, executives should consistently translate Green IS strategies, which are required to leverage the strategic potential of environmental technologies, into sustainability actions in the form of Green IS practices to enhance the competitiveness of their organizations.

RQ C11.3: How does the adoption of first-, second-, and third-degree Green IS practices generate business value and increase firm competitiveness?

As discussed in Section 11.5.2, the empirical results show that first-degree Green IS practices ("Green IT"), which target IT sourcing, IT operations, and disposal of IT equipment, not only decrease negative environmental impacts by reducing the need for hardware-specific raw materials, the consumption of electrical power, and the generation of e-waste, but also result in economic benefits in the form of cost reductions.

Second-degree Green IS practices, which take the entire organization into consideration, can provide environmental management systems or foster IS-based reengineering of business and production processes. As a result, these Green IS practices enhance the reputation by reducing waste and emissions throughout the company. IS-based environmental management systems allow for a monitoring of and reporting about the corporate footprint to internal and external stakeholders while a transformation of the company's systems and processes can also strengthen the firm's environmental innovation capabilities.

Finally, third-degree Green IS practices have a positive impact on organizational Green innovation capabilities. In addition, these practices also affect the firm's reputation by supporting the development of environmentally-friendly products, thus improving brand image and customer perceptions. However, these effects are not particularly pronounced, perhaps because IS-based environmental innovations, such as dematerialization initiatives and intelligent engine control units, are restricted to certain product categories since these eco-products have not yet reached the mainstream but rather occupy niche markets.

13. Theoretical Contributions

As discussed in Section 4.4, the Green IS research discipline has only recently evolved as an important academic field within the wider context of IS research. To advance the theorization and the practical relevance of the discipline, Green IS scholars should:

1) Clarify central concepts, propose research frameworks, and develop meaningful theories.
2) Analyze strategic aspects of Green IS with a transdisciplinary approach to derive management frameworks and practice-oriented recommendations.
3) Empirically investigate the economic effects of Green IS adoption to decrease uncertainties that inhibit the implementation of Green IS initiatives.

Taking these research requirements into consideration, this thesis demonstrates the utility of a transdisciplinary research approach by integrating theories and concepts from strategic management, corporate sustainability, and IS research. Owing to their global reach and their significance in designing solutions for a more sustainable economy and society, business organizations were chosen as unit of analysis. Drawing on the aforementioned research requirements, this thesis fundamentally contributes to Green IS research in three areas.

First, theoretically-grounded and clear definitions of the concepts *Green IT* and *Green IS* are urgently needed as a foundation for this new research discipline. The definitions that were proposed in this thesis (see previous section) rely on a Green IS research framework that differentiates between three degrees of environmental impacts and thus demonstrates, how and in which areas Green IS initiatives can be implemented to advance corporate sustainability: in IT departments, throughout entire organizations, and in end user products and services (as outlined in Figure 17, Section 6.2.3).

A brief description of the three degrees of Green IS environmental impacts is presented in Table 35. This classification scheme was also the basis for compiling a comprehensive list of Green IT measures as well as a far-reaching catalogue of Green IS initiatives (Section 6.2.4). This synthesis of existing knowledge makes a substantial contribution to advance theory-building in the evolving Green IS research discipline. The well-grounded definitions of Green IT and Green IS as well as the conceptualized Green IS research framework can serve as a basis for future academic work in this new field. These theoretical contributions were honored by the IS research community with the AMCIS 2013 Best Paper Award.

Table 35: Environmental impacts of Green IS practices.		
Environmental impact	**Area**	**Description**
First-degree	IT sourcing	Sourcing practices for IT hardware and services that take environmental impacts of the entire lifecycle into account.
	IT operations	Green IT practices which decrease energy consumption of IT operations in data centers and office environments.
	IT disposal	Environmentally-friendly end-of-IT life management, including reuse, refurbishing and recycling of outdated IT hardware.
Second-degree	Process reengineering	IS-enabled reengineering of business and production processes to decrease enterprise-wide resource consumption.
	Environmental management systems	Use of IS-based environmental management systems to control and optimize resource flows, waste and emissions.
Third-degree	Environmental technologies	IS-enabled environmental technologies which reduce the footprint of products and services throughout their entire lifecycle.

Table 36: Conceptualization of Green IS strategy, drawing on Chen *et al.*'s (2010b, p. 239) IS strategy concept.			
Management Level	**Conceptual domain**	**Definition**	**Description**
Green IS strategy at the corporate level	Organization-wide role of Green IS; organization-centric	Shared view of the role of Green IS in the organization	Green IS strategy at the corporate level describes a **perspective**: What is our view toward Green IS in the organization? *Desired strategic impact:* Provide a shared understanding of the potential of Green IS throughout the organization and guide fundamental Green IS investment decisions.
Green IS strategy at the competitive level	Matching the potential of Green IS with the competitive position; business-centric	Use of Green IS to support competitive environmental strategies	Green IS strategy at the competitive level describes a **position**: How can Green IS be used to support a chosen environmental strategy and to enhance competitive advantage? *Desired strategic impact:* Support the implementation of competitive environmental strategies and ensure that the desired strategic position in competitive markets is achieved.
Green IS strategy at the functional level	Intended course of action; IS-centric	Master plan of the Green IS function	Green IS strategy at the functional level describes a **plan**: What assets (staff, processes, infrastructure, applications, budget, etc.) are required for Green IS implementation and how should existing assets be allocated efficiently? *Desired strategic impact:* Give direction for the effective and efficient management of IS resources and capabilities.

Second, this research adds to the body of knowledge concerning the strategic aspects of Green IS and responds to the call for research from IS scholars who identified a lack of practice-relevant conceptual frameworks in this field. Such frameworks are supposed to guide the implementation of Green IS initiatives, thus advancing corporate environmentalism.

The strategic aspects of Green IS have been insufficiently analyzed in the past despite their relevance for a sustainable development and firm competitiveness. To address this theoretical research gap, a concept of *Green IS strategy* with a detailed description of its characteristics at the corporate, competitive, and functional management level was systematically developed. This conceptualization (Table 36) is expected to be useful for academics who aim at investigating specific aspects of Green IS strategies.

Although there has been much discussion in the IS research community about the possible contribution of Green IS to environmental sustainability, relatively little attention has been paid to the formulation of specific Green IS strategies. Such strategies determine the potential of Green IS for decreasing environmental impacts and creating competitive advantages. The typology of Green IS strategies, which was conceptualized on the basis of empirical case study insights (see Table 29 in Section 10.6), makes a theoretical contribution by emphasizing that Green IS investments can support different strategic goals. Under consideration of Porter's (1980) theory of competitive positioning (cost advantage or differentiation) and building on the Resource-Based View, which is suitable to detect the internal sources of value creation through resources and capabilities, the presented strategy typology brings IS research to an in-depth understanding of the strategic potential of Green IS adoption and the competitive logic underlying far-reaching investment decisions.

The Strategic Green IS Alignment Framework (Section 7.3) distinguishes between an internal and an external perspective, both of which are aligned through the concept of strategic fit. Likewise, the Green IS and the environmental sustainability domain are aligned through the concept of functional integration. One of the four suggested Green IS alignment perspectives should be selected in accordance with the firm's competitive environmental strategy. This transdisciplinary research synthesizes theories and concepts from strategic management, corporate sustainability, and IS research. The proposed framework builds on Porter's (1980) competitive positioning approach, the Resource-Based View, Orsato's (2006) competitive environmental strategies, and Henderson & Venkatraman's (1993) Strategic Alignment Model. The results represent a first step towards a coherent alignment process which considers the strategic value of Green IS.

In this context, this research makes further theoretic contributions by analyzing the social dimension of strategic alignment through the theoretical lens of the

knowledge-based view, and by identifying social enablers of strategic alignment. It is emphasized that sustainability adds a third dimension to the process of strategic alignment and acknowledges that three different levels of strategic management should be considered by academics who investigate this topic. Further theoretical insights indicate that the transfer of explicit and tacit knowledge is decisive for the creation of shared domain knowledge, which is an antecedent of strategic IS alignment. The collaboration in strategic planning processes, knowledge sharing and, above all, the relationship between executives from different domains, are decisive for the success of strategic Green IS alignment. Mutual understanding enables the utilization of IS to advance the business with innovative technologies and to decrease the environmental footprint of the business firm. The analysis emphasized the appropriateness of applying a transdisciplinary research approach and the findings suggest that strategic Green IS alignment affects the business, sustainability, and IS domain. Strategic Green IS alignment is found to be a necessary prerequisite for leveraging the full business and environmental potential of Green IS.

In addition, this thesis demonstrates that performance measurement frameworks, which consider different performance dimensions, are useful to understand the multi-dimensional impacts of environmental initiatives. The development of an IT-related Sustainability Balanced Scorecard, which integrates an environmental perspective, an IT performance perspective, a business process perspective, and a financial perspective, contributes to the understanding of the economic, environmental, and technical impact dimensions of Green IT initiatives.

Third, this thesis provides empirical evidence concerning the economic performance and competitive impacts with regard to the post-adoption phase of Green IS initiatives. The presented empirical results (Section 11.5) give insights into the causal chain from environmental orientation, which affects executives' beliefs and decision-making processes, to the formulation of Green IS strategies and the implementation of Green IS practices, through to economic impacts in the form of firm competitiveness. The empirical analysis supports the assumption that the adoption of Green IS has a positive impact on firm competitiveness.

These effects on competitiveness of adopting Green IS practices were examined in detail (Section 11.5.2) and the results revealed a positive relationship between first-degree Green IS practices (IT sourcing, IT operations, IT disposal) and cost reductions. In addition, a positive effect of second-degree Green IS practices (process reengineering, environmental management systems) and third-degree Green IS practices (IS-enabled environmental technologies which reduce the footprint of products and services) on corporate reputation and firm-specific

environmental innovation capabilities was found. These empirical insights are particularly valuable for both SIS and IS business value researchers.

Finally, a measurement instrument for quantitative research, consisting of numerous latent constructs which could be applied in similar or new research contexts, was developed and empirically validated (see Section 11.3 and Appendix D). Due to the fact that only few empirical studies have been conducted in this research area, other researchers can benefit from this work by adopting the validated measurement instruments to generate further empirical insights, which are urgently needed in this new research discipline.

To sum up: this thesis has reflected the shift of the Green IS research discipline from efficiency-oriented Green IT measures, featuring an internal focus, to organization-wide Green IS initiatives, which also consider externally-oriented market aspects and target the creation of competitive advantages. In this context, central concepts were unambiguously defined, conceptual frameworks that take the strategic potential of Green IS into account were developed, and two empirical studies have generated unprecedented insights to advance the body of knowledge in the Green IS research discipline.

14. Management Implications

In Section 2 (Part A) of this thesis, the practical relevance of the research topic was described and the significance of Green IS as a technological enabler of corporate sustainability was delineated. As a consequence of the new challenges and opportunities that have been arising in this context, insights from IS research are required in the following areas:

1) Identification of IS-related environmental challenges and business opportunities.
2) Development of management frameworks to advance the implementation of Green IS initiatives.
3) Conceptualization of distinct strategies that leverage the strategic potential of Green IS under consideration of the firm's competitive context.

Since this thesis aims at delivering practice-relevant insights, these three areas were thoroughly addressed. The corresponding implications for managerial practice are outlined in this section.

First, this research investigated recent challenges faced by IS executives who are requested to simultaneously reduce IT environmental impacts while offering IS-enabled solutions that decrease the organization-wide ecological footprint. To facilitate a deeper understanding of how Green IS can affect the environment, three impact degrees and corresponding management areas were identified (Sections 1.2): IS executives should minimize IT-related first-degree impacts through responsible IT sourcing practices, energy-efficient IT operations, and eco-friendly end-of-IT-life management practices. IT departments should directly be accountable for these IT-induced first-degree impacts. Second-degree Green IS impacts describe the positive effects of firm-wide IS-enabled eco-initiatives that reduce the organizational footprint through environmental management systems and business process reengineering. In addition, IS-enabled infrastructure and product innovations can lower third-degree environmental impacts by decreasing resource consumption, emissions and waste during the entire lifecycle of end-user products and services.

The pre-study (Section 3) indicated that first Green IT measures have been implemented in data centers, but there is still ample room for improvement in office environments. In addition, most companies have not yet exploited the far-reaching potential of Green IS as key enablers of enterprise-wide sustainability initiatives. This research emphasizes that a holistic approach is required to advance Green IS adoption in an economically beneficial way. Business executives should cooperate more closely with IT executives in order to comprehend the technological potential of Green IS to advance the environmental management capabilities and market-

oriented sustainability initiatives that result in competitive advantages. Above all, structured planning, steering, management and control processes are still missing.

Furthermore, the pre-study delivered insights concerning the role of Green IS throughout the enterprise: the majority of respondents stated to have an internally-oriented perspective, focusing on the reduction of IT operational costs; about a third aimed at improving the corporate image; roughly ten percent were utilizing Green business process reengineering to achieve superior internal resource efficiency while a similar fraction strived for strengthening their innovation capabilities to gain a technology leadership position.

In relation to adopting cross-functional Green IS initiatives, the lack of clearly defined executive ownership concerning environmental impacts was identified as a major barrier. On the one hand, IT departments are often not accountable for the energy consumption of IT equipment operated in office environments, and sometimes they are not even charged for certain electricity loads of data center facilities, e.g., cooling and network infrastructure. On the other hand, the IS function is frequently ignored when corporate sustainability initiatives are developed. This departmental, siloed thinking inhibits the optimization of firm-wide resource use and the advancement of corporate sustainability. As a consequence, the definition of appropriate roles, responsibilities and communication structures is required. In Section 8.4, exemplary roles and responsibilities are described at the corporate, competitive, and functional management levels to assure a consistent formulation of Green IS strategies and their coherent translation into environmental practices.

> *"Sustainability isn't the burden on bottom lines that many executives believe it to be. In fact, becoming environment-friendly can lower your costs and increase your revenues. That's why sustainability should be a touchstone for all innovation.*
>
> *In the future, only companies that make sustainability a goal will achieve competitive advantage. That means rethinking business models as well as products, technologies, and processes."*
>
> – Nidumolu, Prahalad & Rangaswami, "Why Sustainability is Now the Key Driver of Innovation", 2009, p. 58

Ambitious companies should take a first step towards Green IS adoption by committing both financial and human resources through C-level leadership, as illustrated in Section 2.3 of this thesis. Corporate sustainability is a new challenge as well as an evolving opportunity for CIOs, who should promote the role of IS in a broader business and corporate sustainability context than is currently typical. Because of IS executives' cross-functional perspective, resulting from their core task being the delivery of technological solutions to a wide range of business units, CIOs are in a unique position to identify cross-functional synergies that can advance corporate sustainability initiatives.

However, the main inhibitor of investing in Green IS is the prevailing uncertainty with regard to the economic long-term benefits. Business and IS executives are unsure about the business value of environmental technologies and cross-functional Green IS initiatives. In this respect, this research has important implications for managers because the empirical results suggest that coherent Green IS investments generate business value and economic benefits. The adoption of Green IS not only contributes to environmental goals but also enhances the competitiveness of business firms: IT-related first-degree Green IS practices reduce costs whereas second- and third-degree Green IS practices enhance corporate reputation and Green product innovation capabilities (Section 11.5). By providing detailed insights into the relationship between adopting specific Green IS initiatives and achieving distinct competitive benefits, this research is expected to motivate both business and IT executives to advance their corporate sustainability efforts. However, it should be noticed that the competitive potential of Green IS is context-dependent, being influenced by customer preferences and stakeholder demands.

Second, IS researchers emphasize that practice-oriented management frameworks are urgently needed by IS executives to ensure the coherent implementation of Green IS initiatives. To address this requirement, a framework that allows for a holistic management of Green IS adoption was developed in this thesis (Figure 33).

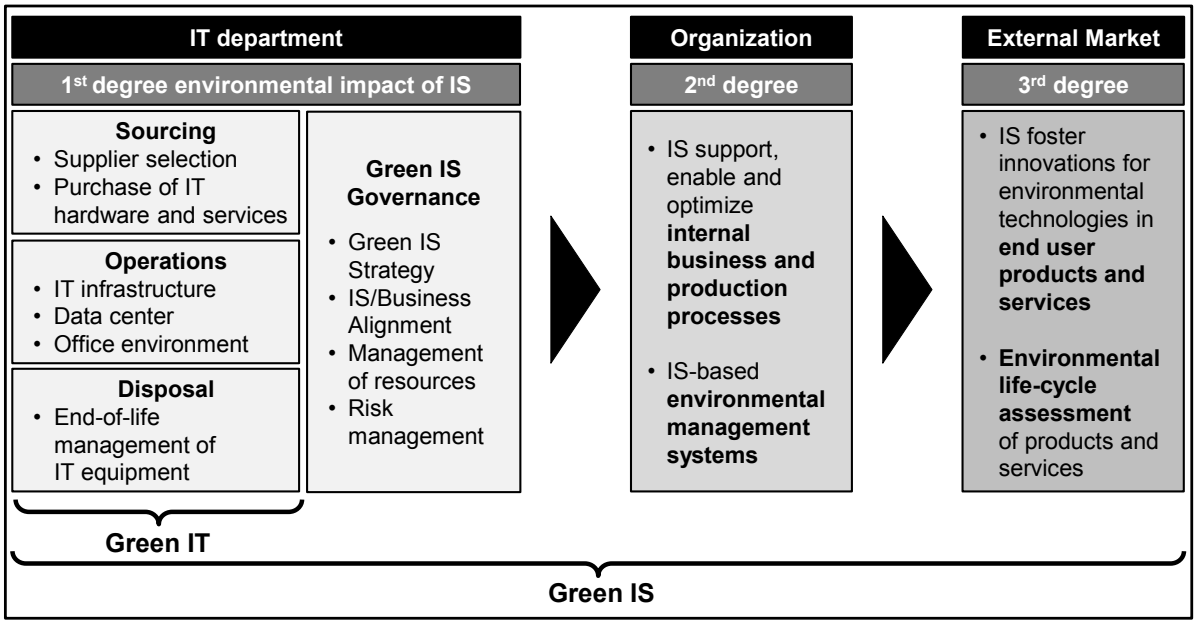


Figure 33: Framework for a holistic management of Green IS initiatives.

The model distinguishes between three degrees of IS environmental impacts and identifies specific management areas:

a) Green IT measures that can be implemented in IT departments and IT organizations.
b) Enterprise-wide Green IS initiatives that take internal business and production processes into consideration.
c) IS-enabled innovation capabilities for the design of environment-friendly end-user products and services according to customer demands in external markets.

The main benefits of this framework are the clarification of the different environmental impacts Green IS initiatives can have and the insight that current Green IT initiatives, which focus on a reduction of the power consumption of IT operations, are only the tip of the iceberg – the potential of Green IS is significantly larger than most executives might think.

To translate ideas and strategies into managerial actions, Appendix C provides a comprehensive catalogue of ninety-one exemplary Green IS practices that either address tasks performed by IT organizations, internal processes of business companies, or end-user products and services. In line with the Green IS management framework, the catalogue categorizes measures that reduce first-degree IT environmental impacts according to specific functional areas, such as IT sourcing, IT operations in data centers and office environments, and IT disposal. Process reengineering initiatives and environmental management systems facilitate positive second-degree impacts by decreasing the resource use, waste, and emissions that are associated with business operations. Finally, sustainable products and infrastructure solutions, which build on technology-enabled environmental innovations, feature positive third-degree impacts through a reduction of the ecological footprint concerning the entire product lifecycle. The firm-specific distribution of the three degrees of environmental impact differs substantially among companies and, in particular, across industries (as described in Section 1.2). Hence, a close collaboration between IS and business executives is recommended in order to identify the areas where Green IS practices offer the largest potential to contribute to the organization’s environmental goals.

However, since "you can't manage what you can't measure" (Peter Drucker, in: Park *et al.*, 2012, p. 129), the accurate monitoring and accounting of environmental and economic impacts of Green IS initiatives is mandatory to advance corporate sustainability. To evaluate the multifaceted contribution to long-term corporate goals, the predominant focus on financial aspects is insufficient. As a consequence, there is a need for performance measurement systems which allow for a detailed evaluation of different performance dimensions. Unfortunately, the creation of business value as well as the environmental impacts of IS are difficult to measure. IS-enabled resource efficiency gains of internal processes (e.g., through digitization

or reengineering) must be balanced against investment costs of sustainability initiatives, and against negative environmental impacts of IT operations.

To address this challenge, an IT-oriented Sustainability Balanced Scorecard (BSC) which provides information to different organizational actors, such as high-level executives, process owners, and IT operations managers, was developed (see Figure 24 in Section 9.3). The resource consumption of IT infrastructure can be quantified and analyzed in the *environmental perspective*. On the basis of the power consumption of specific hardware components, CO2 emissions can be derived. These emissions can be assigned to the deployment of IT capacities, which are measured and displayed in the *performance perspective*. The IT performance measures are directly linked to the provision of IT services that support the execution of business processes. In this way, the IT-induced CO2 emissions of specific business processes can be quantified. The corresponding process performance indicators are illustrated in the *business process perspective*. The measures that are assigned to one of these three perspectives are finally linked to the indicators of the output-oriented *financial perspective*. Here, economic impacts, such as cost savings that stem from the enhanced IT infrastructure energy efficiency, can be measured. As a result, IT operations managers can analyze the energy efficiency of their IT infrastructure, process owners can quantify process-specific, IT-induced CO2 emissions, and executives can base their investment decisions for sustainable IT infrastructure and process reengineering initiatives on reliable data. Although this Sustainability BSC was designed for the purposes of the *Green IT Cockpit* research project, it can serve as a blueprint for the development of similar scorecards which take the requirements of the particular context into account. The adaptation of BSCs to firm-specific affordances is a usual procedure in practice due to the fact that these scorecards feature high flexibility and customizability.

Third, the analysis of strategic aspects of Green IS adoption led to original research insights that make a valuable contribution to managerial practice. Until now, the discussion about the competitive potential of Green IS has been superficial while lacking both a theoretical background and empirical evidence. This thesis revealed that Green IS initiatives are currently implemented in an unorganized and unstructured manner. Due to the internally-oriented management perspective, IS-enabled environmental initiatives have been restricted to functional level Green IT measures which decrease operational costs. As a result, this research underlines that a holistic approach is necessary to leverage the strategic potential of Green IS. IS strategy formulation and IS/business alignment have been and remain to be major concerns on the CIO agenda. The consideration of sustainability aspects now adds a new dimension and thus further increases the complexity of this already complex challenge. Such being the case, this research offers guidance and practice-oriented

solutions that allow for Green IS strategy formulation, strategic alignment and better decision-making concerning Green IS investments that foster technological product and process innovations to advance corporate sustainability and to create new market opportunities.

The empirical results of this research (Section 11.4) suggest that Green IS strategies are a prerequisite for the coherent adoption of Green IS which finally increases firm competitiveness through cost reduction, improved corporate reputation, and environmental product and process innovation capabilities. Green IS strategy and Green IS practices are complementary, and they enhance firm competitiveness only in conjunction with each other. A strategy without a consequent implementation of environmental initiatives is as useless as an uncoordinated implementation of activities and practices without a strategic focus.

In terms of an environmentally sustainable IS management, the central outcome of this research is a typology of four distinct Green IS strategies (Table 37). To leverage the environmental and economic potential of Green IS, CIOs should embed Green IS strategies at specific management levels. The proposed Green IS strategy typology gives advice to executives on how Green IS strategies can be formulated as organizational perspectives (corporate level), as positions (competitive level), and as plans (functional level). In this context, it should be acknowledged that none of the strategies is superior to the others. Each of the strategies comes along with positioning choices and trade-off decisions. To benefit from Green IS, executives have to assess the potential of Green IS under consideration of their specific organizational context. The presented typology of Green IS strategies can be used as a tool to guide this analysis and to assist the process of strategy formulation.

Table 37: Typology of Green IS strategies.

	Green IS for Efficiency	**Green IS for Innovation**	**Green IS for Transformation**	**Green IS for Credibility**
Corporate level: Organizational perspective on Green IS	Green IS are used to reduce operational costs	Green IS are used to achieve environmental technology leadership	Green IS are used to achieve business leadership	Green IS are used to improve stakeholder satisfaction
Competitive level: Strategic goal of Green IS	Implement business strategy	Foster environmental product innovations	Reengineering of business processes	Achieve superior corporate reputation
Functional level: Sources of competitive advantage based on Green IS	IS support competitive strategies by decreasing costs of IS-based business processes	IS improve environmental characteristics throughout the entire product lifecycle	IS reduce organization-wide footprint and allow for superior resource efficiency of internal processes	IS allow for an exceptionally small footprint of the organization and of end-user products and services

The *Green IS for Efficiency* strategy allows for cost and emission reductions facilitated by an energy-efficient IT infrastructure, thus corresponding to a corporate sustainability strategy that seeks cost leadership. This strategy is particularly suitable for companies whose IS function is rather supportive and whose core business is not directly dependent on sophisticated and innovative IS solutions, e.g., companies from the manufacturing industry and mass-volume producers.

The *Green IS for Innovation* strategy is appropriate for companies that strive for an environmental technology leadership position based on eco-innovations that differentiate the firm's products from those of competitors. Green IS play a significant role in building capabilities for IS-enabled innovations that substantially improve the environmental characteristics of end-user products. This strategy is adequate for high-tech or industrial and mechanical engineering companies where environmental product innovations and technologies add value to customers and allow for price premiums.

> *"We need new strategic frameworks that are aimed at deliberately harnessing the unique capabilities of digital technology that are embedded into products to gain competitive advantages."*
>
> – Yoo, Hendfridsson & Lyytinen, "The New Organizing Logic of Digital Innovation: An Agenda for Information Systems Research", 2010, p. 730

The *Green IS for Transformation* strategy aims at occupying an industry leadership position based on highly efficient business processes and an organizational infrastructure that features superior resource productivity. In contrast to the aforementioned efficiency approach, this strategy requires a profound organizational transformation, which can be achieved through a fundamental reengineering of internal processes or through cross-functional Green IS initiatives that enable process innovations and leverage synergies between different business functions. This strategy is appropriate for organizations with IS-based core business processes who serve price-sensitive markets while striving for low environmental impacts, such as companies from the banking and financial services industry.

Finally, the *Green IS for Credibility* strategy suits companies who follow a holistic sustainability approach with the goal of becoming a "good corporate citizen". IS-based environmental management systems allow for detailed accounting of environmental data and facilitate transparency, which leads to a positive corporate reputation, thus attracting new customers and intensifying the relationships with existing ones. Executives anticipate that the extraordinary sustainability efforts result in a first-mover advantage and pay off in the long-term. Firms pursuing this strategy strive for IS-enabled product and process innovations and even invest in unprofitable Green IS initiatives aiming at the reduction of first-, second- and third-degree environmental impacts.

The examination of Green-IS related competitiveness aspects combined with empirical insights from qualitative and quantitative research demonstrates that environmental sustainability can enhance profitability through superior resource efficiency or competitive differentiation. Certainly, strategic alignment is a prerequisite for long-term success. However, the inclusion of environmental sustainability aspects increases the complexity of strategically aligning business goals and corporate sustainability targets with the IS function. The Strategic Green IS Alignment Framework (Figure 20) illustrates how strategic fit can be obtained between the internal and external management perspective. Furthermore, the alignment framework facilitates functional integration between the technological infrastructure and the organizational infrastructure and processes. Each of the four proposed alignment perspectives refers to a specific logic that differs with regard to competitive focus and advantage as well as in terms of characteristics, roles and objectives of the firm's Green IS management. With the help of the alignment framework, executives can ensure that the implemented Green IS initiatives support the environmental and competitive targets of the organization.

In this context, an analysis of the social dimension of Green IS alignment revealed that the sharing and transfer of knowledge between business, sustainability and IS executives is a necessity for an effective alignment process. The collaboration in strategic planning processes and, above all, the informal relationships between executives from the three domains, are decisive for successfully achieving strategic alignment. Only if tacit knowledge is shared and applied collaboratively, Green IS can improve long-term firm profitability and advance environmental sustainability of business practices. This thesis offers guidance to managers concerning the organizational roles that should be involved in strategic Green IS alignment and with regard to the responsibilities that have to be assigned to assure effective communication and sharing of knowledge (Section 8.4).

The key implication for management practice is that Green IS initiatives feature considerable potential for supporting environmental strategies and enhancing competitiveness if adopted holistically under consideration of the firm-specific strategic context. Apart from efficiency-increasing measures that target cost reductions of IT operations, the adoption of Green IS can enhance firm competitiveness and environmental sustainability through fundamental product and process innovations. However, this potential can only be leveraged if environmental aspects are addressed through corporate, competitive, and functional Green IS strategies. When Green IS practices are implemented according to a distinct strategic rationale, they can unfold their potential of decreasing environmental impacts of IT sourcing, IT operations, and IT disposal as well as reducing waste and emissions of firm-wide business and production processes or minimizing the

footprint of end-user products and services. Industry characteristics as well as the firm-specific organizational context determine whether first-, second-, or third-degree environmental impacts are of particular relevance to be addressed through Green IS. Aside from these considerations, executives have to decide whether to strive for cost leadership or for competitive differentiation based on environmental characteristics with the help of Green IS.

To provide an overview structuring the practical contributions of this cumulative thesis, the insights of the six research articles were matched with the four aspects of practice-relevant research (Table 38), as proposed by Benbasat & Zmud (1999).

Table 38: Matching the articles of this thesis with four aspects of practice-relevant research (Benbasat & Zmud, 1999).

Re-search article	Enduring or current organizational problem, challenge, or dilemma.	Implications can be put into prac-tice to resolve problems or exploit opportunities.	Synthesis of existing research: classification or categorization.	Stimulation of critical thinking: challenge assumptions or identify emerging trends.
B6	Implementation of Green IT/IS	Holistic Green IS management framework	Catalogue of Green IT/IS measures	
B7	Green IS/business alignment	Four alignment perspectives		
B8	Knowledge-sharing to advance corpo-rate sustainability			Identification of relevant roles and responsibilities
B9	Holistic perfor-mance manage-ment	Sustainability Balanced Scorecard for the Green IT Cockpit		
C10	Leveraging the strategic potential of Green IS	Green IS strategy typology with four strategies		Using Green IS to create competitive advantages
C11	Uncertainty concerning Green IS business value	Empirical evidence for economic benefits of Green IS	Relationship between Green IS and firm competitiveness	New business logic based on sustainability aspects

15. Limitations and Further Research

Although this research provides useful contributions to research and practice, it also exhibits several limitations.

First, the four theory-based research articles (Part B) are based on conceptual or argumentative deductive analyses, thus relying on theoretical concepts from literature while lacking empirical evidence. Established theories and concepts from strategic management and IS research were adapted to a new context, but their utility has not yet been validated in practice. In particular, the artifacts that were developed in the three design-oriented conceptual articles (B6, B7, B9) should be empirically validated, preferably utilizing implementation-oriented action research, e.g., in the scope of university-industry projects that build on a transdisciplinary perspective. In this context, academics from IS, sustainability and strategic management research as well as practitioners, such as IS executives, CSR managers, and members of strategy development committees or board members should be involved to assure practical relevance.

The framework for a holistic management of Green IS initiatives (Section 6) should be validated in the scope of expert discussions with IS executives. This target group is in the position to assess the usefulness of the management framework, which is meant to assist managers in identifying relevant areas of Green IS adoption under consideration of the firm's core processes, its environmental impacts as well as the significance of IS for its business model and products. The integration of feedback from executives could contribute to a continuous refinement of the framework. In addition, the catalogue of Green IS measures represents only a snapshot of current practices and must be extended with the emergence of new initiatives. In this context, further quantitative survey research, similar to the pre-study (Section 3), could evaluate the implementation complexity, the environmental effectiveness, and the economic benefits of every single measure. By doing so, the measures could be classified according to efforts required and benefits expected. As a result, the most promising and recommendable initiatives could be identified.

The Strategic Green IS Alignment Framework (Section 7) builds on Henderson & Venkatraman's (1993) Strategic Alignment Model, which has been applied in various contexts in research and management practice. Nonetheless, the applicability of the proposed model should be verified, e.g., in the scope of longitudinal case study research that analyzes the alignment process in detail. Such a research project could also examine and verify the actors involved, their responsibilities, and the related communication structures and processes which constitute the social dimension of

alignment (Section 8). To capture the richness of this research topic, a qualitative approach should be applied here.

Second, the two empirical studies (Part C) also feature certain limitations. With regard to the proposed typology of Green IS strategies (Section 10), it must be acknowledged that the four strategies represent ideal profiles. These choice-based strategies describe stylized appearances of Green IS adoption that should help researchers and practitioners to understand this complex issue through the simplification of certain aspects. The boundaries between the distinct strategies are blurred in reality and not all strategies that can be found in a real-life context can be mapped to one of the four generic strategies. Furthermore, this qualitative study, which relies on four extreme cases, has a limited generalizability. As a consequence, the strategy typology should be validated in the scope of an empirical quantitative analysis. It would be of interest to study the contingency factors that influence the formulation of Green IS strategies. A cross-industry analysis could deliver valuable insights concerning dominant Green IS strategy types in specific industries. Corresponding empirical insights would allow for detailed managerial recommendations under consideration of firm-specific contexts.

The quantitative empirical study (Section 11) also has a few limitations. The insights rely on a survey with a comparatively low response rate. In particular, a single informants approach was used and the data builds on the individual perception of the participating executives. A multiple-informant approach, which also involves business executives, could generate more objective results, especially concerning the economic effectiveness of Green IS initiatives. Furthermore, the sample consisted of large companies from five countries. Future studies with larger datasets could test the differences between different company sizes, industries, and regions. Finally, the study was restricted to the economic performance dimension and did not analyze the positive environmental impacts of adopting Green IS. The evaluation of the environmental effectiveness of Green IS adoption for the achievement of corporate sustainability goals is an important area for future research. In this context, longitudinal research that investigates the adoption maturity and the environmental and economic effects of Green IS adoption in the course of time could also provide valuable insights.

Apart from these limitations, which provide opportunities for additional studies, further areas that necessitate scholarly research can be identified. Harmon & Demirkan (2011, p. 24) state that Green IS research is "developing into a discipline that’s focused on the long-term importance of IS as a source of market-based innovative solutions to address societal problems. Increasingly, how companies impact society through their economic, environmental, and social actions defines their risks and opportunities, differentiates their products, and impacts their growth

potential. Sustainability is a megatrend that follows a logical progression that organizations can anticipate to develop market-based innovative sustainability solutions." Due to the significance of Green IS research and in spite of the contributions of this thesis, further academic research is urgently needed. As argued in the first sections of this thesis, theory development in Green IS research is still in its infancy while only few empirical studies have been conducted so far.

This thesis emphasized the increased strategic importance of IS and sustainability in the last years (Corbett, 2013; Teubner, 2013). Although this research delivers first insights into the relationship between the two, further research is needed to explore the strategic dimension of Green IS. In the last decades, IS have become a vital factor for the achievement of competitive advantages. As a consequence, Drnevich & Croson (2013) predict a convergence between strategic information systems (SIS) research and the field of strategic management. SIS research is currently shifting from "a focus on internal IT resource management to leveraging human, social, relational and intellectual capital dynamically and across boundaries" (Merali *et al.*, 2012, p. 130), but the discipline has been slow to adopt a transdisciplinary perspective that also takes environmental and social sustainability aspects into account. A major limitation of this thesis is the restriction to the economic and environmental dimension of sustainability. Further research should explore how IS-enabled capabilities can also enhance the social dimension of sustainability, both in an organizational and a societal context.

Furthermore, this research has only touched the surface with regard to environmental accounting and disclosure. Researchers should analyze how IS can facilitate appropriate technological systems that allow for a seamless tracking of resource flows, wastes and emissions – not only within the boundaries of a single organization, but along entire supply chains (Melville, 2010). The ICT industry, in particular, still has a long way to go to facilitate transparency throughout its own supply chain – from conflict minerals that are mined in Africa to working conditions in the assembling industry in China to the responsible disposal of e-waste around the world. In this context, IS research should advice companies and industry initiatives in developing environmental standards and certificates.

Further research is also needed concerning IS-enabled innovation capabilities for environmental technologies that facilitate cleaner production processes and products. Schaltegger (2013, p. 219) explains that "sustainability management has developed from a complementary topic – managed in parallel or addition to conventional core business activities – to an integrative or even transformative driver of market development and business models." This shift towards a more sustainable economy offers numerous business opportunities and IS play a major role in this game. However, concrete guidance on how to conduct IS-enabled

organizational sustainability transformations and Green business process reengineering or how to initiate IS-based business model innovations is still missing (Kiron *et al.*, 2013b). In this area, future Green IS research can make a valuable contribution.

16. Concluding Statements

ICT have shaped our modern knowledge and information society and have transformed the way we work and communicate. In today's economy, IS have become the backbone for advanced business and production processes. IS are major innovation drivers and thus influence firm competitiveness and economic growth in global markets. At the same time, sustainability has evolved as the next business megatrend which is expected to fundamentally change the rules of competition in the 21st century.

In this context, IS play a crucial, albeit contradictory, role: on the one hand, the ever-rising demand for computation, storage and network capacities, together with short ICT product lifecycles, comes along with three problematic issues: a) mining and processing of problematic raw materials, such as conflict minerals or toxic substances; b) continuously increasing energy consumption of IT operations, which induce enormous carbon dioxide emissions, similar to those of the airline industry; and c) huge amounts of e-waste that are, often illegally, dumped in landfills each year.

On the other hand, IS are perceived as a key technological enabler of the transition towards a more sustainable economy and society. Green IS provide opportunities to substantially decrease organizational resource consumption, waste and emissions with the aid of IS-enabled environmental management systems that allow for a sophisticated environmental management and accounting. IS-based reengineering of business and production processes can considerably enhance the internal resource efficiency of companies while technological innovations can make end products and services more sustainable or even substitute digital products for physical ones.

Due to the importance of IS for business and sustainability, Green IS offer attractive opportunities to enhance environmental sustainability and competitiveness of business firms. However, the potential of Green IS to decrease operational costs, to improve the corporate reputation, and to drive environmental product and process innovations can only be leveraged if the adoption of Green IS is managed holistically, allowing for a thorough consideration of the firm-specific competitive context.

Such being the case, this thesis was aimed at accomplishing four initially defined research goals to contribute to theory-building in the evolving Green IS research discipline and to advance Green IS adoption in practice:

1) **Terminology:** Essential terms and concepts, such as *Green IT*, *Green IS*, *Green IS strategy*, and *Green IS practices*, were clarified on the basis of transdisciplinary, theory-based conceptual research while their specific, practice-related characteristics were described and illustrated in detail. These well-grounded concepts served as a foundation for this research and are also expected to be valuable in facilitating a deeper understanding of key constructs and their respective fields of application, both in the IS research community and in managerial practice.

2) **Challenges arising:** The increasing demand for IT capacities comes along with negative environmental impacts while IS are perceived as key technological enablers of corporate sustainability. Although IS are major drivers of organizational change and fundamental business transformations, the actual implementation of cross-functional Green IS initiatives proves to be challenging in practice because a holistic management approach and consistent strategies are missing. Furthermore, the complexity and multi-dimensionality of Green IS initiatives demand for sophisticated accounting and measurement systems to balance IS-related negative and positive environmental effects. This research underlined that the economic uncertainty with regard to the business value of Green IS practices is one of the main inhibitors of Green IS adoption.

3) **Current responses:** Empirical qualitative and quantitative observations facilitated a deeper understanding of how companies address the evolving environmental challenges by adopting Green IS. The investigation of current technological developments and the analysis of their specific environmental impacts resulted in a catalogue of Green IS initiatives that demonstrates the wide range of possible implementation measures. The case research methodology proved to be helpful to identify distinct Green IS strategies in a real-life context, illustrating how firms follow different strategic rationales to achieve specific competitive targets. In addition, the quantitative study, based on a cross-sectional survey sample, empirically explored the relationship between executives' belief formation processes, environmental actions, and organizational outcomes. The empirical findings allowed for a detailed examination of the cause-and-effect relationships between environmental firm orientation, Green IS strategies, Green IS practices, and specific dimensions of firm competitiveness.

4) **Future actions:** The empirical insights of this research helped to decrease the prevailing uncertainty with regard to the business value of Green IS initiatives, thus adding to the body of knowledge in Green IS research and promoting the quick adoption of environmental measures in practice. Above all, this thesis offers meaningful, practice-oriented frameworks to guide the adoption of far-

reaching Green IS practices. First, the proposed typology of Green IS strategies demonstrates different strategic options IS executives can choose from in order to follow a coherent strategic investment rationale. The fine-grained Green IS strategy concept allows for the formulation of sophisticated strategies that address the corporate, competitive, and functional management level. Second, the Strategic Green IS Alignment Framework provides guidance for a consistent alignment process, ensuring that Green IS strategies support the firm's economic and environmental targets on the corporate, competitive, and functional management level. In this context, relevant organizational actors, roles and responsibilities are identified because the social dimension is a crucial aspect for achieving strategic alignment. Third, the framework for a holistic management of Green IS initiatives specifies relevant areas and distinguishes between three degrees of environmental impacts. This framework assists executives in turning environmental challenges into business opportunities. Finally, managers can build on the extensive catalogue of Green IS initiatives to select those implementation measures that are most appropriate for their organization.

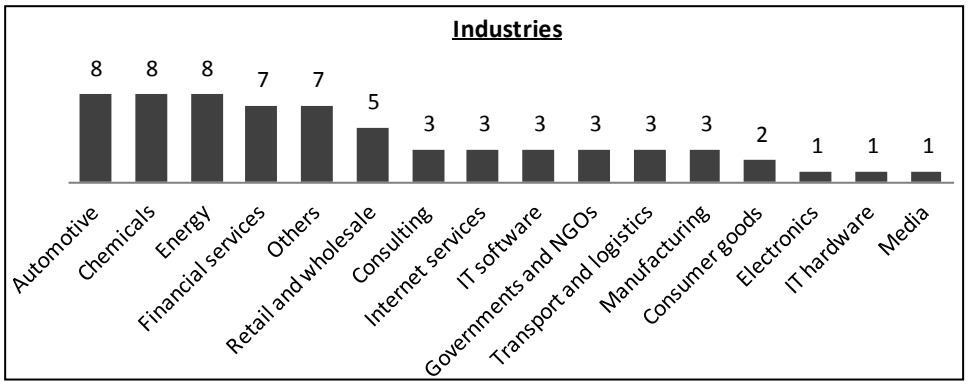
Summarizing, it can be concluded that this cumulative thesis carefully addressed the identified research gaps in the scope of both conceptual and empirical research, striving to achieve four overarching research goals. It is to be hoped that the theoretical and empirical insights as well as the proposed management frameworks make a small contribution to the important field of Green IS research, thus promoting responsible management practices and advancing corporate sustainability to meet the most pressing societal challenges of the 21st century.

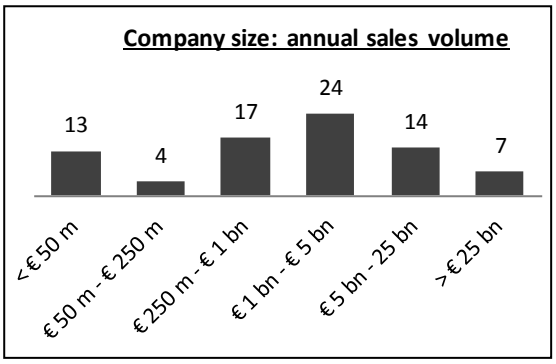
APPENDIX

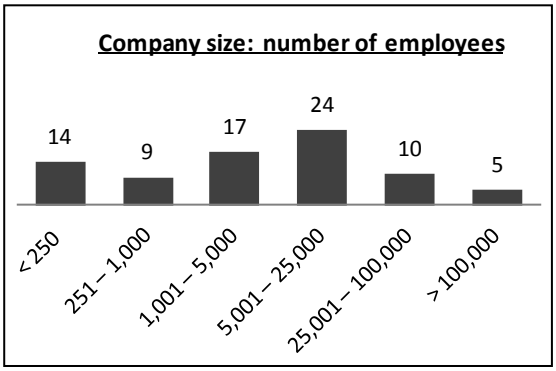
Appendix A: Pre-Study

Descriptive statistics of the pre-study: Company Characteristics (n=79)

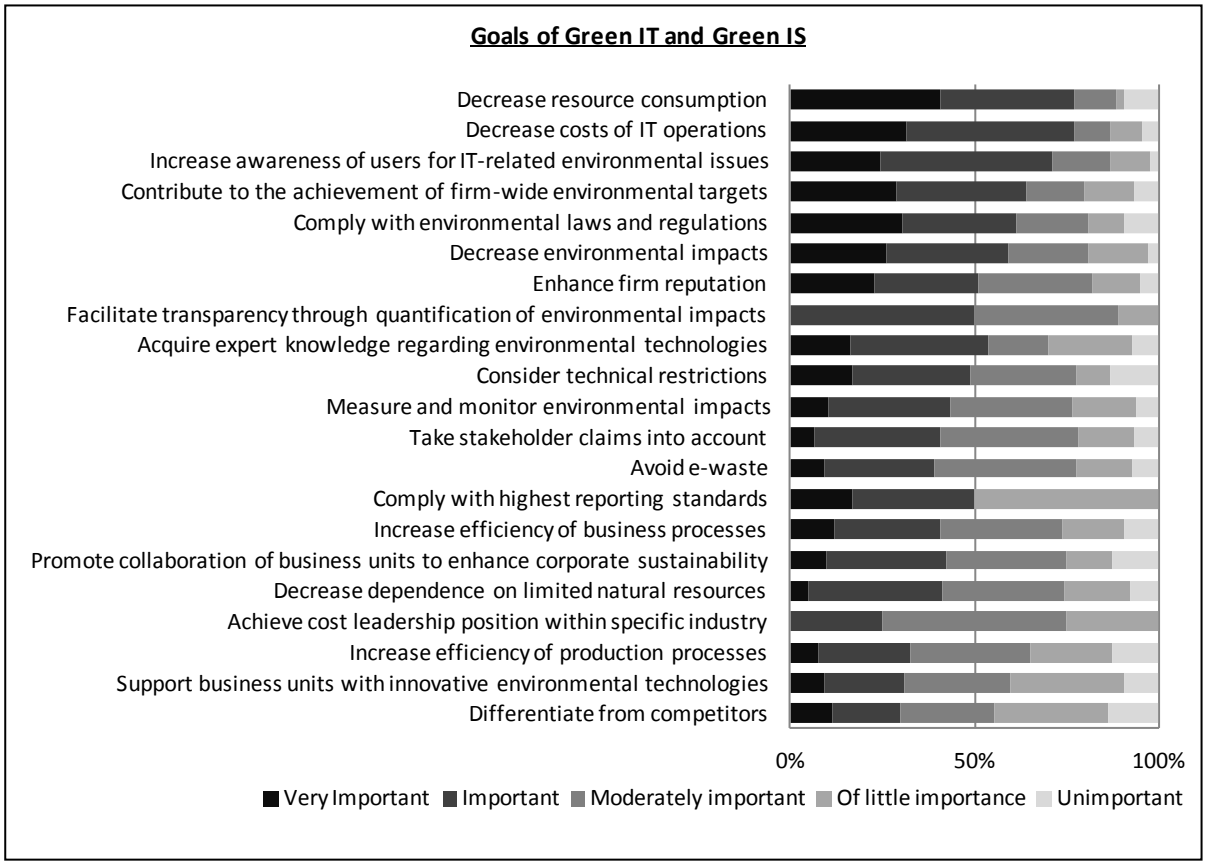
79 IT executives from a wide range of companies participated in the survey.



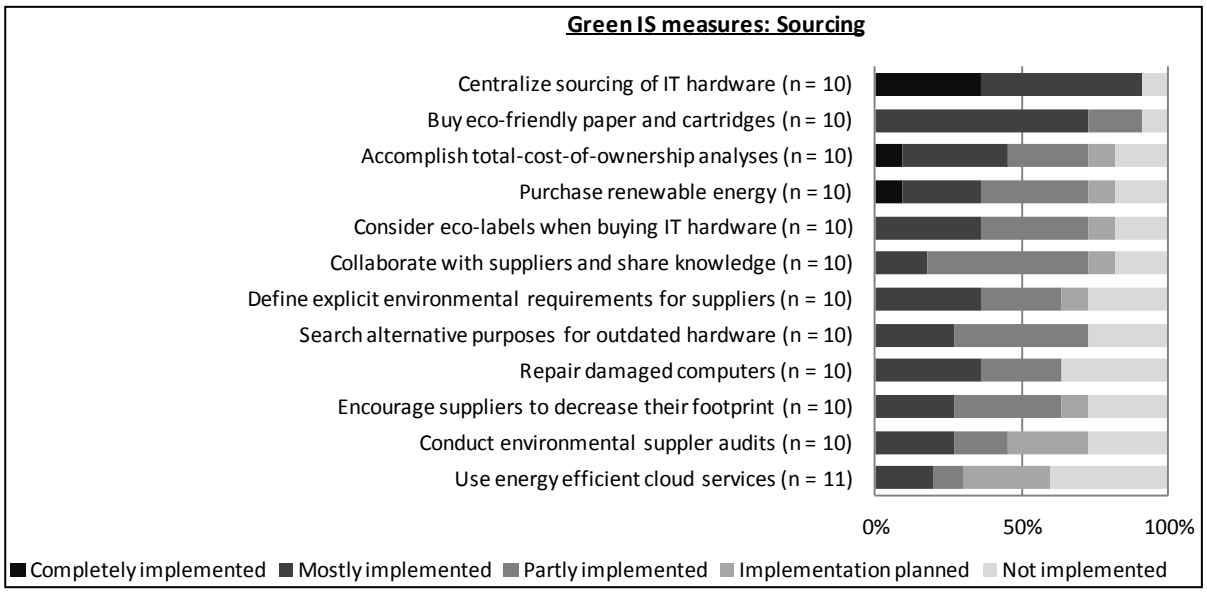




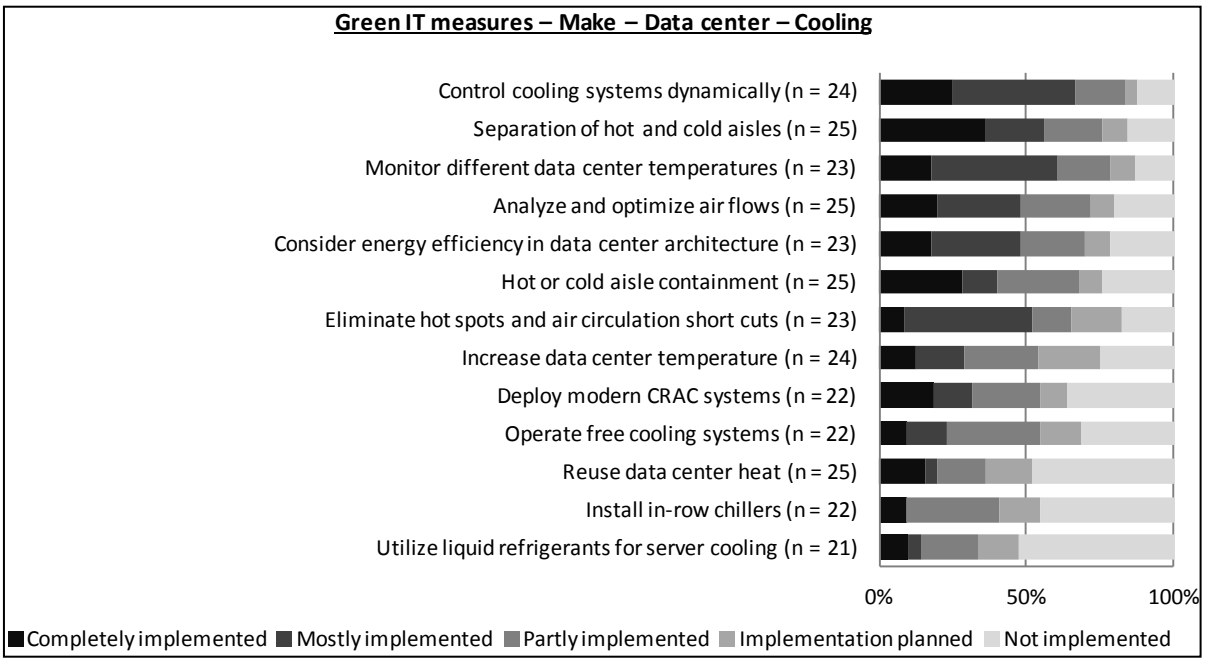
Motivational factors that drive the implementation of Green IT/IS

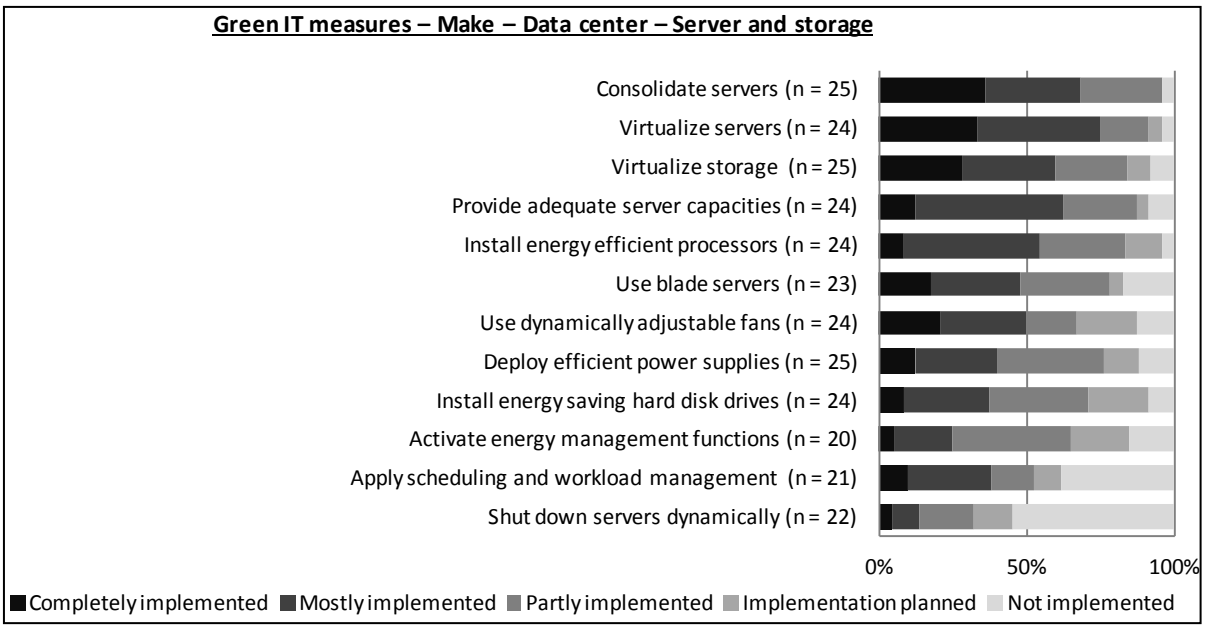


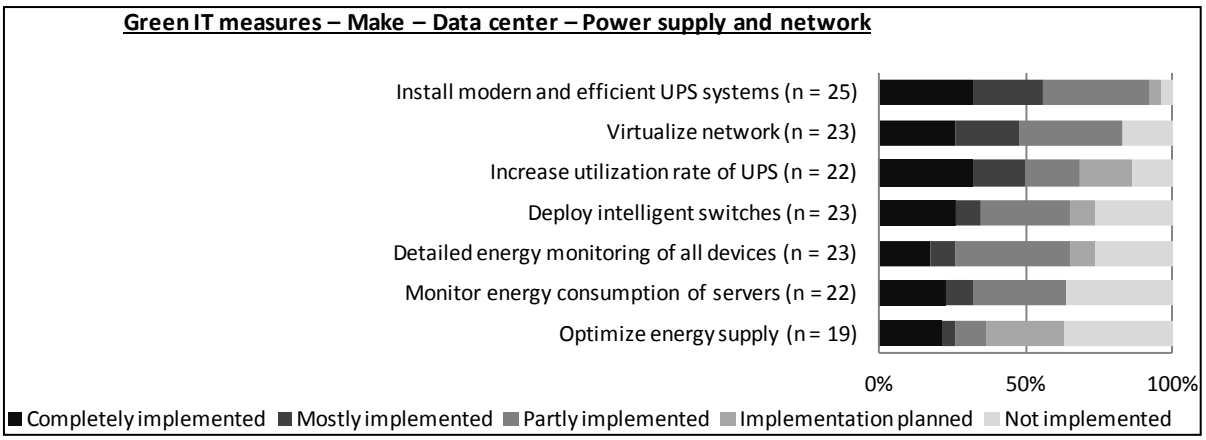
Green IT implementation maturity in the area of IT sourcing



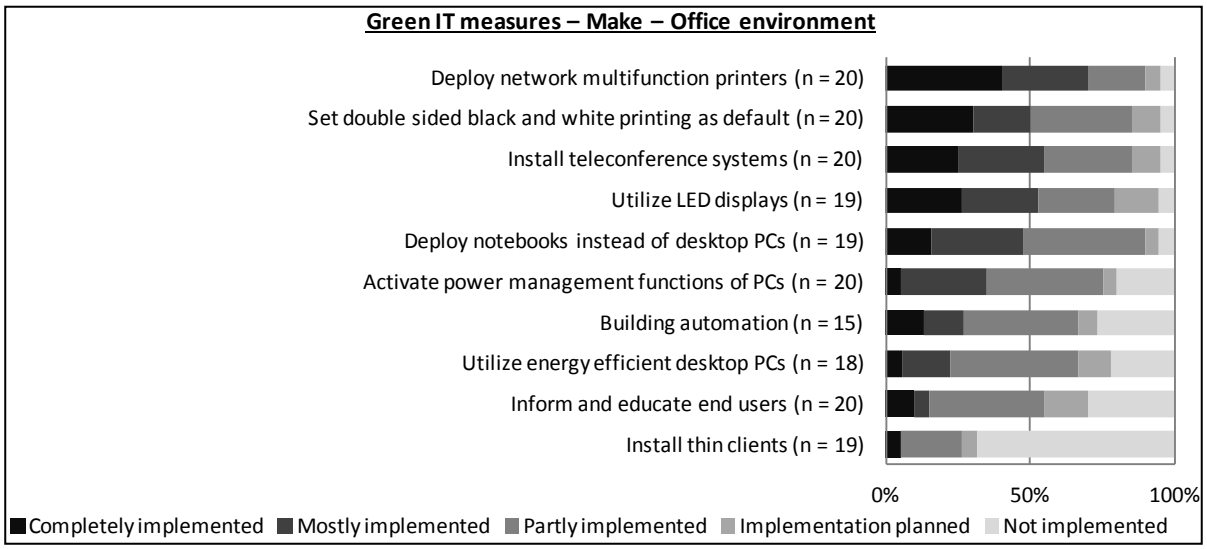
Green IT implementation maturity in the area of IT Service Production (Make) – Data center

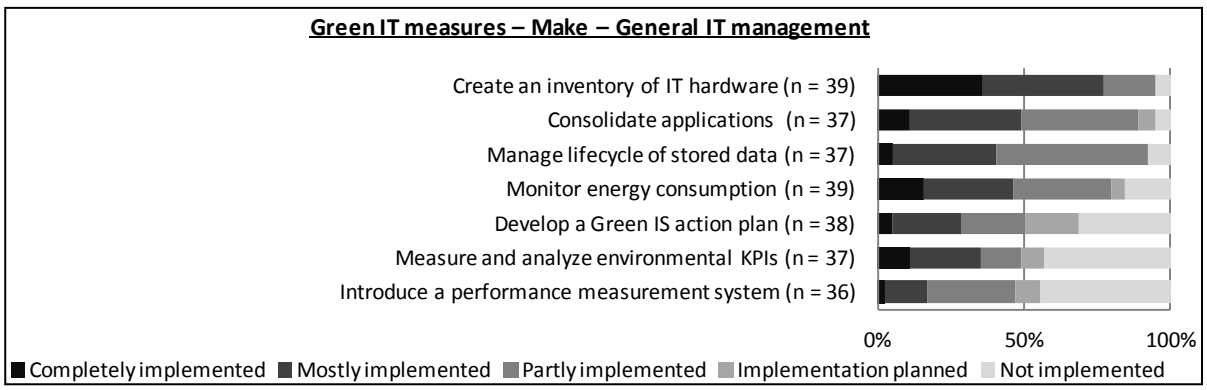






Green IT implementation maturity in the area of IT Service Production (Make) – office environment & general IT management





Appendix B: Definitions of Green IT and Green IS

Table 39: 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	Theo-retical propo-sitions	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	Theo-retical propo-sitions	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	Concep-tual 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).

Table 39 (continued): Definitions of Green IT, non-empirical research, AISeL.			
Author	**Source**	**Method**	**Definition Green IT**
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 40: 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, Comput-er-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 41: 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-chawan	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-chawan	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.

Table 41 (continued): Definitions of Green IT, empirical studies based on primary data, AISeL.

Author	Source	Method	Definition Green IT
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 & 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., 2009a). 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 42: Definitions of Green IS, non-empirical research, AISeL.			
Author	**Source**	**Method**	**Definition Green IT**
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 et 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 43: Definitions of Green IS, empirical studies, AISeL.			
Author	**Source**	**Method**	**Definition Green IT**
Butler	ECIS 2011	Transcribed conference presenta-tions	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 & Visser, 2007).
Hedman, Henning-sson, Selander	ICIS 2012	Longitudi-nal 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, Zarne-kow	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, Land-wehr	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.

Table 43 (continued): Definitions of Green IS, empirical studies, AISeL.			
Author	**Source**	**Method**	**Definition Green IT**
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.

Appendix C: Green IS Practices

Table 44: Exemplary first-degree Green IS practices, adopted from Loeser (2013).

Process	Scope	First-degree Green IS practices ("Green IT")	
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 operations	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

Table 44 (continued): Exemplary first-degree Green IS practices, adopted from Loeser (2013).

Process	Scope	First-degree Green IS practices ("Green IT")	
IT operations	Data center	• 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	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 45: Exemplary second-degree Green IS practices, adopted from Loeser (2013).	
Category	**Second-degree Green IS practices**
Process reengineering	• 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)
Environmental management systems	• Implement firm-wide environmental management systems • Track and analyze corporate waste and emissions • Use carbon management and trading systems • Measure resource consumption and report the firm's environmental footprint • Provide aggregated information regarding environmental sustainability aspects to consumers

Table 46: Exemplary third-degree Green IS practices, adopted from Loeser (2013).	
Category	**Third-degree Green IS practices**
Environmental technologies	• 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

Appendix D: Measurement Items

Table 47: Measurement items.

Code	Item	Adopted from...
Environmental Orientation (EO)		
EO1	Our company's executives and employee feel that the company has carved out a significant position with respect to environmental protection.	Chen (2011)
EO2	Our company's executives and employees feel that the company has a set of environmental goals worth striving for.	Chen (2011)
EO3	Our company's executives and employees feel that environmental preservation is a central value of the company.	Banerjee (2002)
EO5	Our company's executives and employees identify strongly with the company's actions with respect to environmental matters.	Chen (2011)
Green IS Strategy (S) at Corporate Level (1) / Competitive Level (2) / Functional Level (3)		
S11	Our company's top management recognizes the possibilities and strategic potential of Green IT/IS.	Kearns & Sabherwal (2007a)
S12	Our company's top management emphasizes the role of Green IT/IS to drive environmental sustainability within our company.	Paulraj (2011)
S13	Our company's top management demonstrates a high degree of involvement concerning Green IT/IS initiatives.	Henriques & Sadorsky (1999)
S15	Our company's top management considers Green IT/IS to be an essential enabler of our corporate sustainability strategy.	Paulraj (2011)
S16	Our company's top management responds rapidly to early signals concerning areas of opportunity for Green IT/IS.	Chen *et al.* (2010a)
S21	In our IT organization/department, we have explicitly formulated a Green IT/IS strategy.	Chen *et al.* (2010a)
S22	In our IT organization/department, we search for ways to exploit new business opportunities using Green IT/IS.	Basselier & Benbasat (2004)
S23	In our IT organization/department, we analyze business problems in order to identify Green IT/IS-enabled solutions.	Basselier & Benbasat (2004)
S26	In our IT organization/department, we understand how Green IT/IS can support our competitive strategies.	New
S28	In our IT organization/department, we always consider environmental issues when new IT/IS products or services are developed.	Banerjee (2002)
S31	In our IT/IS planning processes, we have integrated environmental aspects.	Banerjee (2002)
S33	In our IT/IS planning processes, we always give preference to IT projects and infrastructure investments that are favorable from an environmental point of view.	New

Table 47 (continued): Measurement items.		
Code	**Item**	**Adopted from…**
S34	In our IT/IS planning processes, we have established performance indicators for assessing the impact of Green IT/IS initiatives.	Molla *et al.* (2011)
S35	In our IT/IS planning processes, we have earmarked financial and other resources for Green IT/IS initiatives.	Molla *et al.* (2011)
S36	In our IT/IS planning processes, we define concrete environmental targets for each Green IT/IS initiative.	Molla *et al.* (2011)
Implementation of Green IS Practices (I) – First Degree (F) – IT Sourcing (S) / Data Center Operations (D) / Office Environment IT Operations (O) / IT Disposal (E)		
IFS1	We monitor the environmental performance of our IT hardware and service suppliers.	Molla *et al.* (2011)
IFS2	We always give preference to IT hardware and service suppliers which have a green track record.	Molla *et al.* (2009a)
IFS5	We exclusively purchase energy-efficient IT hardware.	Chen *et al.* (2010a)
IFD1	In our data center, we have consolidated and virtualized our servers.	New
IFD3	In our data center, we have optimized the energy efficiency of our storage systems.	New
IFD4	In our data center, we have optimized airflows and the entire cooling system.	New
IFD6	In our data center, we thoroughly monitor IT energy consumption.	New
IFO2	In our company's offices, we inform and educate users regarding the energy consumption of IT.	New
IFO3	In our company's offices, we have installed power management software.	New
IFO4	In our company's offices, we exclusively deploy energy efficient computers, such as laptops and thin clients.	New
IFE1	To reduce e-waste, we dispose IT equipment in an environmentally friendly manner.	Chen *et al.* (2010a)
IFE2	To reduce e-waste, we repair IT systems whenever possible.	New
IFE3	To reduce e-waste, we always search for alternative uses of outdated IT systems.	New
Implementation of Green IS Practices (I) – Second Degree (S) – Process Reengineering (R)		
ISR1	Our company makes use of Green IT/IS to improve the efficiency of its production facilities.	Karacaoglu & Özkanli (2011)
ISR2	Our company makes use of Green IT/IS to streamline existing business processes.	Tallon (2011)

Table 47 (continued): Measurement items; (*) = item excluded from the analysis due to a low factor loading [λ<0.7].		
Code	**Item**	**Adopted from…**
Implementation of Green IS Practices (I) – Second Degree (S) – Process Reengineering (R) / Environmental Mgmt. Systems (E)		
ISR3	Our company makes use of Green IT/IS to develop new processes that are more environmentally-friendly.	Christmann (2000)
ISR4	Our company makes use of Green IT/IS to transform the entire business towards long-term sustainability.	Tallon & Pinsonneault (2011)
ISR5*	Our company makes use of Green IT/IS to reduce individual employee travel through teleconferences.	New
ISR6	Our company makes use of Green IT/IS to optimize its supply chain processes.	Wagner (2003)
ISE1	Our company makes use of information systems that provide important environmental information for decision-making.	Venkatraman & Grant (1986)
ISE2	Our company makes use of information systems to track resource and energy flows.	New
ISE3	Our company makes use of information systems to control the effectiveness of environmental programs.	Sharma (2000)
ISE4	Our company makes use of information systems to quantify company-wide carbon dioxide emissions.	Molla *et al.* (2009a)
Implementation of Green IS Practices (I) – Third Degree (T) – Environmental Technologies (S)		
ITS1*	Our company improves existing products with the help of information systems (e.g., tracking and analyzing the footprint of product lifecycles).	Christmann (2000)
ITS2	Our company offers IT-enabled services with decreased environmental impact (e.g., dematerialization: e-commerce, online banking, digital music).	New
ITS3	Our company enhances the environmental characteristics of its products or services by embedding IT/IS in them (e.g., smart logistics, smart buildings, smart engines).	Tallon (2011)
ITS4	Our company views IT/IS as enabler for developing new products and services that reduce environmental impacts (e.g., traffic management systems, smart grids)	Banerjee (2002)
Firm Competitiveness (C) – Cost Reductions (C) / Corporate Reputation (R) / Green Innovations (I)		
CC1	Our company has incurred lower costs for complying with environmental regulations than our competitors.	Christmann (2000)
CC2	Our company requires relatively less material and resources than our competitors.	Christmann (2000)
CC4	Our company has lower operational costs than our competitors.	Kearns & Lederer (2000)
CR1	Our company has a better corporate image than our competitors.	Chang (2011)
CR3	Our company is perceived as being environmentally responsible by our customers.	Tallon & Pinsonneault (2011)
CR5*	Our company is favored by shareholders due to our good reputation.	New

Table 47 (continued): Measurement items.		
Code	**Item**	**Adopted from…**
CI2	Our company is more capable of environmental R&D than our major competitors.	Chen (2011)
CI3	Our company is more capable of environmental management than our major competitors.	Chen (2011)
CI4	Our company is more capable of green innovations than our major competitors.	Chen (2011)

Appendix E: Sample Characteristics

Table 48: Comparison of expected and observed responses according to company size distributions.					
Company size: Number of employees	**Distribution in original population (US Census[3])**	**Distribution of contact records in database (random sample)**	**Expected observations (according to database)**	**Observations (distribution of empirical results)**	**Chi-Squared test of homogeneity**
251–1,000	49%	45.6%	53.8	47	0.86
1,001–5,000	38%	31%	36.6	29	1.57
5,001–25,000	9%	18%	21.2	32	5.45
25,001–100,000	2%	3.5%	4.1	6	0.85
> 100,000	0.3%	1.9%	2.2	4	1.38
χ^2 (critical value for f = 5: 11.07 for α = 0.05)					10.11

Table 49: Nonresponse reasons (n = 100).		
Reason for not participating in the survey	**#**	**Percentage**
I was too busy.	27	27%
Our company does not participate in any surveys.	19	19%
Our company security policies prevent us from sharing this kind of information.	10	10%
I did not receive your invitation.	9	9%
I never participate in surveys.	7	7%
Other reasons.	7	7%
I have a new position in the organization and thus cannot answer your questions.	6	6%
My time is too valuable to participate in research projects.	5	5%
I did not trust the confidentiality protection of your institution.	4	4%
Personally, I am not interested in the topic.*	2*	2%*
Our company does not address these issues.*	2*	2%*
I could not access your survey.	1	1%
I do not participate in un-solicited surveys from outside my country.	1	1%
(*) = topic-specific reasons		

[3] https://www.census.gov/econ/esp/

Appendix F: Results from Data Analysis

Table 50: Confirmatory factor analysis with item-to-construct- and cross-loadings.

Third-order construct					Green IS Practices									
Second-order construct		Green IS Strategy			First-Degree Practices				Second-Degree Practices		Third-Degree Practices	Firm Competitiveness		
First-order construct	Environmental Orientation	Corporate Level	Competitive Level	Functional Level	IT Sourcing	IT Operations Data Center	IT Operations Office Environment	IT Disposal	Reengineering of Internal Processes	Environmental Mgmt. Systems	Environmental Technologies	Cost Reductions	Corporate Reputation	Green Innovations
EO1	**0.93**	0.61	0.44	0.48	0.47	0.42	0.40	0.32	0.48	0.58	0.43	0.37	0.58	0.57
EO2	**0.95**	0.62	0.53	0.57	0.54	0.46	0.41	0.31	0.56	0.59	0.43	0.35	0.56	0.59
EO3	**0.92**	0.55	0.38	0.44	0.49	0.47	0.39	0.22	0.46	0.50	0.36	0.35	0.48	0.53
EO5	**0.95**	0.64	0.49	0.51	0.54	0.52	0.41	0.32	0.56	0.61	0.49	0.39	0.56	0.60
S11	0.62	**0.89**	0.62	0.61	0.51	0.44	0.50	0.18	0.52	0.52	0.56	0.37	0.45	0.35
S15	0.60	**0.92**	0.61	0.64	0.54	0.55	0.54	0.21	0.64	0.58	0.59	0.32	0.46	0.38
S16	0.53	**0.90**	0.62	0.66	0.53	0.44	0.48	0.15	0.59	0.54	0.52	0.36	0.38	0.35
S21	0.34	0.50	**0.78**	0.70	0.49	0.23	0.43	0.25	0.37	0.46	0.37	0.17	0.28	0.27
S22	0.40	0.61	**0.87**	0.70	0.54	0.40	0.50	0.31	0.53	0.58	0.51	0.34	0.36	0.33
S23	0.46	0.63	**0.93**	0.77	0.65	0.34	0.51	0.32	0.56	0.54	0.50	0.26	0.37	0.45
S26	0.43	0.65	**0.87**	0.68	0.53	0.27	0.47	0.26	0.50	0.48	0.51	0.27	0.35	0.42
S28	0.45	0.48	**0.79**	0.62	0.60	0.42	0.43	0.34	0.56	0.52	0.39	0.33	0.42	0.43
S31	0.48	0.53	0.71	**0.81**	0.57	0.35	0.52	0.34	0.48	0.51	0.46	0.39	0.35	0.41
S33	0.53	0.56	0.70	**0.81**	0.63	0.38	0.53	0.28	0.54	0.52	0.45	0.41	0.34	0.54
S34	0.47	0.61	0.69	**0.89**	0.68	0.37	0.57	0.29	0.52	0.53	0.46	0.21	0.22	0.42
S35	0.35	0.63	0.69	**0.85**	0.53	0.35	0.52	0.19	0.50	0.49	0.46	0.24	0.27	0.32
S36	0.43	0.60	0.67	**0.86**	0.61	0.34	0.54	0.16	0.52	0.55	0.42	0.20	0.34	0.33
IFS1	0.44	0.57	0.56	0.64	**0.82**	0.54	0.61	0.24	0.49	0.48	0.41	0.26	0.28	0.30
IFS2	0.48	0.52	0.67	0.68	**0.90**	0.51	0.55	0.34	0.62	0.52	0.38	0.35	0.34	0.41
IFS5	0.43	0.32	0.36	0.41	**0.72**	0.49	0.49	0.35	0.46	0.34	0.21	0.35	0.25	0.30
IFD1	0.28	0.24	0.21	0.22	0.31	**0.71**	0.29	0.37	0.22	0.29	0.27	0.22	0.29	0.04
IFD3	0.41	0.43	0.31	0.39	0.50	**0.87**	0.48	0.30	0.47	0.45	0.36	0.35	0.42	0.12
IFD4	0.38	0.30	0.24	0.19	0.43	**0.76**	0.28	0.41	0.26	0.24	0.30	0.28	0.21	0.27
IFD6	0.46	0.57	0.42	0.46	0.64	**0.80**	0.61	0.28	0.58	0.44	0.45	0.37	0.31	0.28
IFO2	0.30	0.36	0.35	0.42	0.59	0.43	**0.76**	0.32	0.46	0.27	0.31	0.38	0.24	0.16
IFO3	0.40	0.50	0.57	0.64	0.58	0.42	**0.86**	0.17	0.50	0.53	0.43	0.26	0.30	0.25
IFO4	0.33	0.49	0.39	0.46	0.46	0.52	**0.82**	0.20	0.38	0.43	0.37	0.25	0.27	0.13
IFE1	0.30	0.19	0.32	0.25	0.31	0.42	0.26	**0.79**	0.26	0.25	0.24	0.32	0.35	0.14
IFE2	0.27	0.13	0.22	0.21	0.31	0.30	0.21	**0.83**	0.25	0.23	0.17	0.20	0.28	0.23
IFE3	0.15	0.13	0.30	0.26	0.27	0.23	0.19	**0.77**	0.27	0.25	0.22	0.17	0.17	0.14
ISR1	0.38	0.50	0.50	0.48	0.58	0.53	0.51	0.25	**0.83**	0.54	0.42	0.35	0.44	0.31
ISR2	0.40	0.52	0.47	0.48	0.57	0.48	0.50	0.29	**0.90**	0.52	0.46	0.29	0.44	0.27
ISR3	0.51	0.57	0.56	0.60	0.54	0.45	0.49	0.30	**0.88**	0.58	0.45	0.31	0.45	0.35

Table 50 (continued): Confirmatory factor analysis with item-to-construct- and cross-loadings.

Third-order construct		Green IS Practices												
Second-order construct		Green IS Strategy			First-Degree Practices				Second-Degree Practices		Third-Degree Practices	Firm Competitiveness		
Fir-t-order construct	Environmental Orientation	Corporate Level	Competitive Level	Functional Level	IT Sourcing	IT Operations Data Center	IT Operations Office Environment	IT Disposal	Reengineering of Internal Processes	Environmental Mgmt. Systems	Environmental Technologies	Cost Reductions	Corporate Reputation	Green Innovations
ISE1	0.45	0.50	0.53	0.55	0.46	0.31	0.42	0.23	0.52	**0.83**	0.39	0.15	0.36	0.31
ISE2	0.50	0.51	0.50	0.51	0.51	0.48	0.48	0.31	0.59	**0.90**	0.43	0.17	0.45	0.39
ISE3	0.57	0.57	0.56	0.58	0.50	0.44	0.49	0.31	0.65	**0.94**	0.56	0.29	0.55	0.46
ISE4	0.62	0.55	0.57	0.56	0.47	0.43	0.45	0.22	0.58	**0.87**	0.44	0.21	0.50	0.43
ITS2	0.32	0.40	0.39	0.41	0.25	0.32	0.19	0.21	0.34	0.37	**0.83**	0.19	0.28	0.31
ITS3	0.41	0.60	0.52	0.49	0.37	0.45	0.46	0.26	0.44	0.47	**0.92**	0.37	0.45	0.34
ITS4	0.47	0.60	0.50	0.50	0.44	0.41	0.51	0.22	0.55	0.51	**0.90**	0.34	0.45	0.38
CC1	0.38	0.34	0.27	0.30	0.35	0.40	0.34	0.37	0.36	0.29	0.28	**0.84**	0.45	0.28
CC2	0.34	0.35	0.32	0.29	0.37	0.33	0.32	0.24	0.30	0.16	0.33	**0.92**	0.37	0.34
CC5	0.30	0.29	0.28	0.32	0.30	0.32	0.30	0.18	0.28	0.17	0.33	**0.88**	0.34	0.25
CR1	0.45	0.39	0.34	0.29	0.27	0.32	0.26	0.33	0.46	0.44	0.43	0.46	**0.91**	0.27
CR3	0.61	0.49	0.43	0.37	0.38	0.41	0.35	0.31	0.50	0.53	0.41	0.35	**0.92**	0.43
CI2	0.59	0.36	0.43	0.45	0.40	0.24	0.21	0.19	0.40	0.42	0.36	0.29	0.36	**0.95**
CI3	0.58	0.36	0.42	0.46	0.39	0.21	0.22	0.21	0.40	0.45	0.40	0.32	0.35	**0.97**
CI4	0.61	0.37	0.44	0.47	0.39	0.22	0.23	0.21	0.37	0.43	0.36	0.34	0.40	**0.95**

Table 51: Inter-construct correlations (bold values = AVE of latent constructs; off-diagonal elements = squared correlations among constructs).

	Environmental Technologies	Green IS Strategy at Competitive Level	Green IS Strategy at Corporate Level	Cost Reductions	Green Innovations	IT Disposal	Environmental Management Systems	Green IS Strategy at Functional Level	IT Operations Data Center	IT Operations Office Environment	Environmental Orientation	Process Reengineering	Corporate Reputation	IT Sourcing	Composite reliability
Environmental Technologies	**0.78**	0	0	0	0	0	0	0	0	0	0	0	0	0	0.91
Green IS Strategy at Competitive Level	0.29	**0.72**	0	0	0	0	0	0	0	0	0	0	0	0	0.93
Green IS Strategy at Corporate Level	0.38	0.46	**0.85**	0	0	0	0	0	0	0	0	0	0	0	0.97
Cost Reductions	0.12	0.11	0.14	**0.78**	0	0	0	0	0	0	0	0	0	0	0.91
Green Innovations	0.15	0.20	0.15	0.11	**0.91**	0	0	0	0	0	0	0	0	0	0.97
IT Disposal	0.07	0.13	0.04	0.09	0.04	**0.64**	0	0	0	0	0	0	0	0	0.84
Environmental Mgmt. Systems	0.27	0.37	0.36	0.06	0.21	0.09	**0.78**	0	0	0	0	0	0	0	0.93
Green IS Strategy at Functional Level	0.29	0.67	0.48	0.12	0.23	0.09	0.38	**0.71**	0	0	0	0	0	0	0.93
IT Operations Data Center	0.21	0.15	0.27	0.16	0.06	0.17	0.22	0.18	**0.62**	0	0	0	0	0	0.87
IT Operations Office Environment	0.21	0.30	0.32	0.13	0.05	0.08	0.27	0.40	0.31	**0.66**	0	0	0	0	0.85
Environmental Orientation	0.21	0.24	0.42	0.15	0.38	0.10	0.37	0.29	0.25	0.19	**0.88**	0	0	0	0.97
Process Reengineering	0.27	0.36	0.40	0.13	0.17	0.11	0.44	0.37	0.28	0.30	0.31	**0.75**	0	0	0.94
Corporate Reputation	0.21	0.18	0.23	0.20	0.15	0.12	0.28	0.13	0.16	0.11	0.34	0.28	**0.84**	0	0.91
IT Sourcing	0.17	0.44	0.34	0.15	0.17	0.14	0.30	0.52	0.39	0.45	0.30	0.42	0.36	**0.67**	0.86

Table 52: Evaluation of higher-order constructs (*** = path between constructs significant at p<0.001).				
Construct	**Sub-construct**	**# items**	**VIF**	**Weights**
Green IS Strategy	Green IS Strategy at Corporate Level	5	2.07	0.406***
	Green IS Strategy at Competitive Level	5	3.28	0.349***
	Green IS Strategy at Functional Level	5	3.39	0.350***
Green IS Practices	First-Degree Practices	13	1.97	0.457***
	Second-Degree Practices	9	2.15	0.522***
	Third-Degree Practices	3	1.53	0.202***
First-Degree Practices	IT Sourcing	3	2.24	0.343***
	IT Operations Data Center	4	1.82	0.389***
	IT Operations Office Environment	3	1.95	0.303***
	IT Disposal	3	1.25	0.212***
Second-Degree Practices	Process Reengineering	5	1.76	0.610***
	Environmental Management Systems	4	1.76	0.486***
Third-Degree Practices	Environmental Technologies	3	1.00	1.000***
Firm Competitiveness	Cost Reductions	3	1.24	0.441***
	Corporate Reputation	2	1.63	0.294***
	Green Innovations	3	1.39	0.560***

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LIST OF PUBLICATIONS

List of Publications.			
Author(s)	**Title**	**Year**	**Published in**
Loeser, F., vom Brocke, J., Molla, A. Zarnekow, R. & Erek, K.	Enhancing Firm Competitiveness with Green IS: An Empirical Analysis of the Antecedents and Consequences of Adopting Green IS	2014*	Information Systems Journal's (ISJ's) Special Issue on Information Systems addressing the Challenges of Environmental Sustainability (original submission 15th August 2013; revision submitted on 31st March 2014; under review)
Zarnekow, R. & **Loeser, F.**	Nachhaltiges IT-Management: Informationssysteme als Schlüsseltechnologie für eine zukunftsorientierte Unternehmenstransformation	2014*	dpunkt Verlag, to be published in October 2014
Loeser, F.	Green IT and Green IS: Definition of Constructs and Overview of Current Practices *Best Paper Award*	2013	Proceedings of the 19th Americas Conference on Information Systems (AMCIS 2013), Chicago, USA
Moeller, B., Erek, K., **Loeser, F**. & Zarnekow, R.	How Sustainable is COBIT 5? Insights from Theoretical Analysis and Empirical Survey Data	2013	Proceedings of the 19th Americas Conference on Information Systems (AMCIS 2013), Chicago, USA
Loeser, F., Erek, K., Limbach, F. & Zarnekow, R.	Shared Domain Knowledge in Strategic Green IS Alignment: An Analysis from the Knowledge-Based View	2013	Proceedings of the 46th Hawaii International Conference on Systems Sciences (HICSS 2013), Maui, USA
Erek, K., **Loeser, F.** & Zarnekow, R.	Nachhaltigkeit in der Wirtschaftsinformatik: Ein Forschungsrahmen für das Nachhaltige Informationsmanagement	2013	Proceedings of the 11th International Conference on Wirtschaftsinformatik (WI 2013)
Loeser, F., Erek, K. & Zarnekow, R.	Towards a Typology of Green IS Strategies: Insights from Case Study Research	2012	Proceedings of the 33rd International Conference on Information Systems (ICIS 2012), Orlando, USA

List of Publications (continued).			
Loeser, F., Grimm, D., Erek, K. & Zarnekow, R.	Information and Communication Technologies for Sustainable Manufacturing: Evaluating the Capabilities of ICT with a Sustainability Balanced Scorecard	2012	Proceedings of the 10th Global Conference on Sustainable Manufacturing (GCSM 2012), Istanbul, Turkey
Erek, K., **Loeser, F.** & Zarnekow, R.	Reference Model for Sustainable Information Systems Management: Establishing a Holistic Research Agenda	2012	Sprouts: Working Papers on Information Systems
Grimm, D., **Loeser, F.**, Erek, K. & Zarnekow, R.	Evaluation von Performance-Measurement-Systemen für IKT-Energieeffizienz	2012	Tagungsband der 42. Jahrestagung der Gesellschaft für Informatik (Informatik 2012), Braunschweig, Germany
Loeser, F., Erek, K. & Zarnekow, R.	Green IT Strategies: A Conceptual Framework for the Alignment of Information Technology and Corporate Sustainability Strategy	2012	In: Ordóñez de Pablos, P. (editor), "Green Technologies and Business Practices: An IT Approach", Information Science Reference, IGI Global, pp. 58–95.
Loeser, F., Erek., K., Schmidt, N.-H., Zarnekow, R. & Kolbe, L. M.	Aligning Green IS with Environmental Strategies: Development of a Conceptual Framework that Leverages Sustainability and Firm Competitiveness	2011	Proceedings of the 17th Americas Conference on Information Systems (AMCIS 2011), Detroit, USA
Loeser, F., Erek, K. & Zarnekow, R.	Generische Green-IT-Strategien: Entwicklung eines konzeptionellen Rahmenwerks für strategisches Alignment	2011	Tagungsband der 41. Jahrestagung der Gesellschaft für Informatik (Informatik 2011), Berlin, Germany
Erek, K., **Loeser, F.** & Zarnekow, R.	Green IT Strategies: A Case Study-Based Framework for Aligning Green IT with Competitive Environmental Strategies	2011	Proceedings of the 15th Pacific Asia Conference on Information Systems (PACIS), Brisbane, Australia
Loeser, F.	Empirical Study of Industry Complexity: The Retail Industry	2010	In: Schwandt, A. & Franklin, J. R. (editors), "Logistics: The Backbone for Managing Complex Organizations", Haupt Verlag, Bern, pp. 205–240
Loeser, F. & Mosavi, M.	Vom Benchmarking zum kontinuierlichen Performance-Management	2006	IT-Management, 12 (2006), pp. 28–32

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Strategic Information Systems Management for Environmental Sustainability

Manufacturing, operation, and disposal of Information Technology (IT) cause serious environmental impacts whereas Green Information Systems (IS) shape the path towards a sustainable economy: Environmental Management Systems and the Reengineering of Business Processes can substantially reduce resource consumption and emissions of business organizations. In addition, technological innovations provide opportunities to decrease the ecological footprint of end-user products and services.

Although Green IS practices feature a considerable potential to increase corporate environmentalism and to create promising business opportunities, the adoption of enterprise-wide, cross-functional initiatives has been slow. Economic uncertainties and the lack of appropriate management frameworks are the main inhibitors of Green IS adoption.

This thesis establishes key concepts for the evolving Green IS research discipline, develops practice-oriented management frameworks, and emphasizes the importance of a strategic approach to leverage the competitive potential of Green IS. This dissertation offers both empirical insights and conceptual models to advance the adoption of Green IS initiatives, thus meeting the challenges of climate change and turning corporate sustainability into a business opportunity.

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