Environmental Sustainability in Design Science Research: Direct and Indirect Effects of Design Artifacts

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Abstract. There is an increasing consensus that information systems (IS) design needs to consider effects related to environmental sustainability. While information technology (IT) can help solving environmental problems, it also causes environmental problems through emissions, wastage, and the consumption of renewable and nonrenewable resources throughout its lifecycle. Against this background, the notions of Green IT and Green IS have evolved. While the former primarily relates to the energy efficiency and equipment utilization of IT, the latter pertains to the design and implementation of information systems that contribute to sustainable business processes. In this paper, we explore how environmental sustainability can be considered in design science research. While traditionally design science research has focused on the utility of artifacts, we propose to also consider a design artifact's environmental impact. We discuss how the design goal of sustainability relates to artifact utility and suggest a framework that describes two dimensions of design artifact environmental impact, namely direct and indirect environmental impacts. While the first pertains to effects of the physical existence of an IT artifact through its production, use, and disposal, the latter relates to the potential of the artifact to contribute to sustainable business processes.

Keywords: Design Science Research, Green IS, Green IT, Sustainability.

1 Introduction

It has been argued that information systems (IS) can play a meaningful role in creating sustainable work practices and products. It has also been highlighted that the IS discipline can contribute to this development through providing information systems that enable sustainable business processes. Prominent examples include the fields of energy informatics to increase energy efficiency [24], remote work to reduce carbon emissions through travel [3], or monitoring emissions and waste to decrease the environmental impact of specific processes. While it has been asserted that information technology (IT) can help solving environmental problems, it also contributes to the deterioration of the natural environment through emissions, wastage, and the consumption of renewable and nonrenewable resources throughout the lifecycle [7, 25]. Efforts related to a more environmentally sustainable use of IT have been discussed under the labels of Green IT and Green IS. While the former primarily relates to the

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energy efficiency and equipment utilization of IT, the latter pertains to the design and implementation of information systems that contribute to the implementation of sustainable business processes [25].

Sustainability has been defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [27]. More specifically, Goodland [9] describes environmental sustainability as the "maintenance of natural capital," and identifies two primary environmental services: the source and the sink functions. Environmental sustainability "is a set of constraints on the four major activities regulating the scale of the human economic subsystem: the use of renewable and nonrenewable resources on the source side, and pollution and waste assimilation on the sink side" [p. 10].

Against this background, Information Systems as a solution-oriented discipline can contribute to both the worsening and the enhancement of the natural environment. The effects of information systems can be related to the above definition of environmental sustainability:

(1) On the sink side, IS produce outputs in the form of waste and emissions throughout their lifecycle.
(2) On the source side, IS require inputs in the form of both renewables and non-renewables throughout their lifecycle.
(3) IS have the potential to allow for more sustainable business processes, that is, processes that use less renewable and non-renewable resources on the source side, and that assimilate less pollution and waste on the sink side.

As the effects of information systems are intimately connected to their design, we suggest considering the environmental impact of design artifacts in design science research (DSR). This is because, in current thinking, utility is seen as the primary goal of DSR, without linking the discussion to environmental aspects [8, 13]. Design science research aims at creating innovative and purposeful IT artifacts [12, 13]. With this, it can be distinguished from the behavioral science paradigm, which typically aims at studying IT artifacts that are implemented in organizational settings [13].While the main goal of behavioral science research is to provide explanations [20], the primary goal of design science research is the utility of the resultant artifacts [12].

In this paper, we explore the role of environmental sustainability in design science research. In doing so, we aim to make three primary contributions: First, we conceptualize environmental sustainability as an explicit goal of design science research by means of a design artifact's environmental impact. Second, we discuss how the goal of environmental sustainability can be considered in design science research methodology. Specifically, we discuss the goal of environmental sustainability with regard to the general principles of design research [13, 16, 20], practice rules [13], and procedures [20], as these have been identified as mandatory components of a design science research methodology [20]. Besides, we relate the goal of environmental sustainability to the concept of design theories as a means to capture knowledge about IT artifact design. Third, our discussion of the environmental sustainability of IT artifacts allows us to propose a unified perspective on Green IT and Green IS.

We proceed as follows. In the next section, we provide a brief overview of IS research on environmental sustainability. In the subsequent section, we explore the goals of design science research as they have been discussed in recent publications. We then examine how environmental sustainability can be considered as an additional goal in design science research and propose a framework for environmentally sustainable design artifacts in IS research. Finally, we discuss our findings, and provide a conclusion where we also identify some important limitations of this research.

2 Environmental Sustainability in IS Research

Organizations are a main contributor to the deterioration of the natural environment [17], and information systems have been the most prominent contributor to economic growth over the last decades [25]. Consequently, the impact of information systems on the natural environment warrants further investigation. Recently, the concepts of Green IT and Green IS have gained increasing popularity and have been subject to research from diverse areas, most notably computer science [e.g., 14] and information systems [5]. While Green IT primarily relates to the energy efficiency and utilization of IT equipment, Green IS pertains to the design and implementation of information systems that support environmental sustainability [25]. Green IS thus targets a much bigger problem and, therefore, is said to have a much bigger potential than Green IT [25]. Watson et al. [24], for example, discuss the potentials of energy informatics to increase energy efficiency and reduce energy consumption, and propose a framework for energy informatics. Melville [17] argues that information systems research can contribute to "the creation and evaluation of systems that break new ground in environmental responsibility" [p. 1] and identifies a number of research questions that are relevant in the domain of IS innovation for environmental sustainability. Among others, he identifies different questions that are related to IS design issues: "What design approaches are effective for developing information systems that influence human beliefs about the natural environment" [p. 11]? or "What design approaches are effective for developing information systems that influence human actions about the natural environment" [p. 12]? Elliot [7] provides a "holistic, trans-disciplinary, integrative framework for IT-enabled business transformation" [p. 197]. He proposes a set of hypotheses, among others: "Technology (including IT) has a negative impact on the environment at various stages in the technology life cycle" [p. 228], thus lending an argument to the above Green IT discussion, and "Technology (including IT) has a moderating effect on the negative impact of the environment on human beings" [p. 228], thus relating to the above Green IS discussion.

This duality of IT as being both a contributor and a potential solution has also been discussed in the field of environmental informatics in terms of first, second, and third order effects of information and communication technology [14]: First order effects relate to the direct environmental impact that is due to the physical existence of the technology, second order effects are those indirect impacts due to the IT-enabled change in business processes, and third order effects result from the medium- or

long-term adaption of behaviors and structure resulting from the availability of IT and IT services [14].

In summation, Green IT and Green IS offer two complementary perspectives on the role of IT in environmental sustainability. Consequently, in this study, we will explore the role of environmental sustainability in design research by considering this duality.

3 Design Science Research

In this section, we first discuss the goals of design research in order to provide a conceptual basis for integrating the concept of environmental sustainability. Second, we provide a brief overview of the DSR methodology in order to prepare the ground for a more detailed discussion on how environmental sustainability can be considered in DSR in the subsequent sections.

3.1 The Goals of Design Science Research

Design science research has emerged as a popular field in IS research, due to a widely acknowledged view that information systems is much characterized by applied research, often drawing from other disciplines, and having the purpose of providing solutions to organizations [20]. The development of design knowledge is hence of high relevance to both IS research and practice [22, 26]. Design science research is concerned with the systematic creation of knowledge about organizational problems and potential solutions through building and evaluating novel artifacts [12]. Design-science research "creates and evaluates IT artifacts intended to solve identified organizational problems" [13, p. 77]. In this context, design is both a process (i.e., a set of activities) and a product (i.e., an artifact) [13]. In current design thinking, the preeminent goal is that of utility [8, 13]. Consequently, the evaluation of the design artifact is crucial. Hevner et al. [13], for example, building upon the work of March and Smith [16], write with regard to the results of design science research: "Purposeful artifacts are built to address heretofore unsolved problems. They are evaluated with respect to the utility provided in solving those problems" [p. 78]. Similarly, Peffers et al. [20] say that in "DS research, design and the proof of its usefulness is the central component" [p. 72]. In the context of the development of design theories, Gregor and Jones [11] further state that the requirements of a system are to be understood in relation to the environment in which the system will operate. What these authors agree upon is the consideration of goals that are preeminently related to solving organizational problems. However, it is not clear how these organizational problems are related to the concept of environmental sustainability. While some solutions are intended to contribute to solving specific organizational problems, they may produce negative environmental effects at the same time. Other solutions may be developed with the explicit intention to contribute to the design and implementation of sustainable business processes.

3.2 Design Science Research Methodology

Peffers et al. [20] state that a comprehensive design science research methodology comprises of three elements: (1) conceptual principles that define design science research, (2) practice rules for design science research, and (3) procedures that describe how to carry out design science research. Table 1 provides an overview.

Table 1. Components of a design science methodology [drawing from 20]

Component of design science research methodology	Description	References
Principles	Defining what is meant by DS research	[11, 13, 16, 20]
Practice Rules	Rules that have to be considered when carrying out design research	[13]
Procedures	How to conduct and present design science research	[20]

General principles. Different authors [e.g. 11, 13, 16, 20] have coined the meaning of design science research. There is now some agreement upon its goals, typically related to utility in the context of solving organizational problems.

Practice rules. Hevner et al. [13] have notably contributed to our understanding of what principles researchers should adhere to when conducting design science research, and their work has been widely cited in IS design science studies.

Procedures. Peffers et al. [20] propose a process model for the conduct of design science research.

While a design science research methodology comprising of these three components focuses on "design research as a knowledge building activity rather than the structural nature of the knowledge or theory that results" [10, p. 317], other researchers have coined the notion of *design theory* [11], or theory for design and action [10, 11, 23].

For our study, we chose Hevner et al. [13] as the most prominent example for practice rules, Peffers et al. [20] for the procedures in design science research, and Gregor and Jones' [11] components of an information systems design theory as a recent proposal of how design knowledge can be captured in the form of theory.

4 A Framework for Environmentally Sustainable Design Artifacts

There are at least two perspectives that need to be considered when conceptualizing the sustainability of design artifacts as an additional goal in design science research: First, the environmental impact of the artifact throughout its lifecycle due to its physical existence (independent from its specific purpose) through wastage and resource consumption [e.g. 14] and, second, the impact of the use of the artifact on business processes and human behavior in more general terms [5]. Consequently, grounded in the

distinction between Green IT and Green IS, the distinction between first, second, and third order effects of IT, as well as the source and sink functions as fundamental environmental services, we propose two dimensions of design artifact environmental impact: direct environmental impact and indirect environmental impact of the design artifact. The first represents the first order effects that an artifact has, viz., the environmental consequences of the use of the artifact independent from the organizational problem it tackles, due to its physical existence. The second represents second and third order effects, viz., intended and unintended environmental consequences of the use of the artifact through its impact on business processes. As the latter is closely related to organizational problems—and as an organizational problem can indeed be related to becoming more sustainable—it can be viewed as a sub-concept of utility. Table 2 provides an overview of the two sustainability dimensions of design artifacts.

Table 2. Direct and indirect environmental impact of design artifacts

Concept	Description	Example	References / prior literature
Direct environmental impact of the design artifact	The effects of the production, use, and disposal of an IT artifact, that is, the use of renewable and nonrenewable resources on the source side, and the assimilation of pollution and waste on the sink side, due to the physical existence of the artifact.	The use of a software system that runs on a computer causes waste and emissions (sink side) and consumes energy and natural resources throughout its lifecycle (source side).	First order effects [14], Green IT [18], source and sink functions [9]
Indirect environmental impact of the design artifact	The effects of an IT artifact on the sustainability of business processes and human behavior in more general terms, that is, the use of renewable and nonrenewable resources on the source side, and the assimilation of pollution and waste on the sink side, in business process that are designed and implemented using the artifact. Can be viewed as a sub-dimension of utility.	The use of software for virtual collaboration allows for reduced travel, thus limiting emissions (sink side) and consumption of non-renewable energy (source side), thus contributing to the sustainability of, for example, a sales process.	Second order effects, third order effects [14], Green IS [5, 24], source and sink functions [9]

We will explore how the environmental impact of design artifacts can be considered in (a) practice rules of design research, (b) procedures for design research, and (c) design theory, in turn.

4.1 Environmental Sustainability and Practice Rules for Design Research

Practice rules describe "good" design science research and build a foundation for evaluating such research [20]. Hevner et al. [13], in their seminal MISQ article, propose seven guidelines for conducting design science research. These are design as an artifact, problem relevance, design evaluation, research contributions, research rigor, design as a search process, and communication of research. We argue that the environmental sustainability of the design artifact (its environmental costs and benefits) can be considered in each of these guidelines. Table 3 provides an overview.

Table 3. Environmental sustainability and practice rules for design research

Guideline [13]	Description [13, p. 83]	Consideration of sustainability
Guideline 1: Design as an artifact	"Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation."	In order to contribute to environmental sustainability, design-science research must produce viable artifacts that have low direct environmental impact throughout their lifecycle and/or that contribute to the design and implementation of sustainable business processes, thus being associated with positive indirect effects on the natural environment.
Guideline 2: Problem relevance	"The objective of design-science research is to develop technology-based solutions to important and relevant business problems."	In order to contribute to environmental sustainability, the objective of design science research is to develop technology-based solutions that contribute to the design and implementation of sustainable business processes while, at the same time, having low direct impact on the natural environment
Guideline 3: Design evaluation	"The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods."	In order to ensure that a design artifact contributes to environmental sustainability, any evaluation must consider the direct and indirect environmental effects of the design artifact.
Guideline 4: Research contributions	"Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies."	In order to contribute to environmental sustainability, design-science research must provide clear and verifiable contributions that are associated with low direct environmental effects and/or that bear the potential of contributing to the design and implementation of sustainable business processes, thus realizing positive indirect effects on the environment.
Guideline 5: Research rigor	"Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact."	In order to contribute to environmental sustainability, this principle applies likewise.

Table 3. (*continued*)

Guideline 6: Design as a search process	The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment."	In order to contribute to environmental sustainability, design-science research must employ a search process utilizing available means that allow designs with low direct environmental impact and/or the potential to contribute to the design and implementation of sustainable business processes.
Guideline 7: Communication of research	"Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences."	The effective communication of the environmental sustainability of design artifacts can contribute to decision-making at the individual, organizational, and societal level related to the use of technology.

It thus becomes noticeable that, in order to contribute to environmental sustainability, researchers must relate the proposed practice rules to the environmental sustainability of the design artifact. Alternatively, one could propose an additional guideline labeled design artifact sustainability to capture the explicit goal of considering environmental sustainability in design science research. Table 4 provides an overview.

Table 4. Guideline of design artifact sustainability

Design artifact sustainability	In order to contribute to environmental sustainability, design science research must provide artifacts that have low direct environmental impact due to their physical existence and/or that bear the potential to contribute to the design and implementation of sustainable business processes. That is, design science research must consider the use of renewable and non-renewable resources as well as the assimilation of waste and emissions, both with regard to the physical existence of design artifacts and their indirect impact on business processes.

4.2 Environmental Sustainability and Procedures for Design Research

As indicated by Peffers et al. [20], a complete design science research methodology requires not only principles and practice rules, but also a process model. Pfeffers et al. [20] analyze prior literature on design science from various disciplines, including that of IS, and propose a method that is intended to "serve as a commonly accepted framework for carrying out research based on DS research principles" [p. 52]. The method was built upon a consensus-building approach and thus incorporates the views of different researchers [1, 4, 6, 13, 19, 21, 23]. Specifically, six activities are suggested: identify problem and motivate, define objectives and solution, design and development, demonstration, evaluation, and communication. We argue that the

environmental sustainability of the design artifact can be considered in each of these activities. Table 5 provides an overview.

Table 5. Environmental sustainability and procedures for design research

Activity [20]	Description [20]	Consideration of sustainability
Identify problem & motivate	"Define the specific research problem and justify the value of a solution. Because the problem definition will be used to develop an artifact that can effectively provide a solution, it may be useful to atomize the problem conceptually so that the solution can capture its complexity. Justifying the value of a solution accomplishes two things: it motivates the researcher and the audience of the research to pursue the solution and to accept the results and it helps to understand the reasoning associated with the researcher's understanding of the problem. Resources required for this activity include knowledge of the state of the problem and the importance of its solution" [p. 52-55].	In order to contribute to environmental sustainability, define a specific research problem that is related to/considers environmental sustainability. The problem definition builds the foundation to develop an artifact that effectively provides a solution by (a) suggesting designs with low direct environmental impact, and/or (b) with the potential to contribute to the design and implementation of sustainable business processes.
Define objectives of a solution	"Infer the objectives of a solution from the problem definition and knowledge of what is possible and feasible. The objectives can be quantitative, such as terms in which a desirable solution would be better than current ones, or qualitative, such as a description of how a new artifact is expected to support solutions to problems not hitherto addressed. The objectives should be inferred rationally from the problem specification. Resources required for this include knowledge of the state of problems and current solutions, if any, and their efficacy" [p. 55].	In order to contribute to environmental sustainability, researchers must define objectives related to the direct and indirect environmental impact of the design artifact. The objectives should be rationally inferred from the specific environmental problem to be targeted (e.g., wastage, carbon emissions, energy consumption).
Design & development	"Create the artifact. […] Conceptually, a design research artifact can be any designed object in which a research contribution is embedded in the design. This activity includes determining the artifact's desired functionality and its architecture and then creating the actual artifact. Resources required for moving from objectives to design and development include knowledge of theory that can be brought to bear in a solution" [p. 55].	In order to contribute to environmental sustainability, the research contribution in form of low direct environmental impact and/or positive indirect environmental impact of the design artifact must be embedded in the design. It needs to be argued in how far the functionality and the architecture of the artifact are actually intended to positively influence direct or indirect effects.

Table 5. (*continued*)

Demonstration	"Demonstrate the use of the artifact to solve one or more instances of the problem. This could involve its use in experimentation, simulation, case study, proof, or other appropriate activity. Resources required for the demonstration include effective knowledge of how to use the artifact to solve the problem" [p. 55].	Demonstrate the use of the artifact in a way its direct and indirect environmental impacts can be observed.
Evaluation	"Observe and measure how well the artifact supports a solution to the problem. This activity involves comparing the objectives of a solution to actual observed results from use of the artifact in the demonstration. It requires knowledge of relevant metrics and analysis techniques" [p. 56].	Observe and measure how well the artifact supports the direct or indirect environmental effects it is aimed at.
Communication	"Communicate the problem and its importance, the artifact, its utility and novelty, the rigor of its design and its effectiveness to researchers and other relevant audiences such as practicing professionals, when appropriate" [p. 56].	In addition to utility, novelty, design rigor, and effectiveness, also communicate the design artifact sustainability.

4.3 Environmental Sustainability and Design Theory

Design theories have been discussed as an important means to communicate, justify, and develop design knowledge in IS [11, 23]. At this, it must be noted that design research as an activity as described above and design theory are closely interrelated. There is some agreement that design research should rely on existent theory [2, 15, 23] and, also, that the result of design research can be a contribution to theory [15]. Peffers et al. [20] also establish a link between design research as an activity and design theory by noting that meta requirements as specified in design theories describe the objectives of a (class of) design solutions. Design theories (or theories for design and action) say how something should be done [10] by providing explicit prescriptions for constructing an artifact [10]. Gregor and Jones [11], building upon the works of others [e.g. 23], propose eight components of an information systems design theory. We argue that the environmental sustainability of the design artifact (its environmental costs and benefits) can be considered in each of these components. Table 6 provides an overview.

Table 6. Environmental sustainability and design theory

Component [11]	Description [10, p. 322]	Consideration of sustainability
Purpose and scope	"'What the system is for,' the set of meta-requirements or goals that specifies the type of artifact to which the theory applies and in conjunction also defines the scope, or boundaries, of the theory."	In order to contribute to environmental sustainability, purpose and scope should pertain to direct and/or indirect environmental impacts of a design artifact. That is, an artifact can be designed to meet a given purpose with less resource utilization or emission. In addition, artifacts can be specifically designed to contribute to sustainable business processes.
Constructs	"Representations of the entities of interest in the theory."	In order to contribute to environmental sustainability, the design theory should comprise constructs that allow to minimize the direct environmental impact and/or contribute to the artifact's potential to contribute to the design and implementation of sustainable business processes.
Principles of form and function	"The abstract 'blueprint' or architecture that describes an IS artifact, either product or method/intervention."	In order to contribute to environmental sustainability, principles of form and function can relate to both direct and indirect environmental impacts of the design artifact, that is, they describe how an artifact is designed that has low direct environmental impact and/or the potential to contribute to the design and implementation of sustainable business processes.
Artifact mutability	"The changes in state of the artifact anticipated in the theory, that is, what degree of artifact change is encompassed by the theory."	In order to contribute to environmental sustainability, the design theory describes how the artifact needs to change in order to allow for control of direct and indirect environmental impacts over time.
Testable propositions	"Truth statements about the design theory."	Truth statements about the environmental sustainability (direct and indirect environmental impacts) of a design artifact.

Table 6. (*continued*)

Justificatory knowledge	"The underlying knowledge or theory from the natural or social or design sciences that gives a basis and explanation for the design (kernel theories)."	In order to contribute to environmental sustainability, researchers can draw from a broad variety of theories both from natural and social sciences that can inform the design of artifacts with low direct environmental impact and/or the potential to contribute to the design and implementation of sustainable processes.
Principles of implementation	"A description of processes for implementing the theory (either product or method) in specific contexts."	In order to contribute to environmental sustainability, principles of implementation need to consider both direct and indirect impacts of specific systems to be implemented in a specific context.
Expository instantiation	"A physical implementation of the artifact that can assist in representing the theory both as an expository device and for purposes of testing."	The physical instantiation can be used to test the theory with regard to the environmental impacts of artifacts belonging to the class of artifacts described by that theory.

5 Discussion

We set out to examine how environmental sustainability can be considered in design science research. Drawing on prior literature, we were able to relate environmental sustainability to the general principles (and goals) of design science research, to practice rules for design science research, to procedures of design science research, as well as to design theory. We thus argue that, in order to contribute to environmental sustainability, researchers must consider the environmental impact of their artifacts in all stages of the design process. That environmental sustainability should indeed be considered in the design of IT artifacts, both in terms of direct and indirect effects on the natural environment, is consistent with prior literature from the areas of Green IT and, more recently, Green IS. For instance, Elliot [7] states that while technology per se has a negative impact on the natural environment throughout its lifecycle, it can also have a moderating impact on the negative effects of human behavior on the natural environment.

While environmental informatics has focused on hardware and software, IT artifacts can be of various natures. Specifically, there is some agreement that methods, constructs, models, and instantiations are the output of design science research [13, 20]. While for IT hard- and software (i.e., concrete instantiations) the environmental impact is rather obvious, for models, constructs, and methods this is not the case. We thus need to discuss how environmental sustainability can be related to the different types of IT artifacts. Table 7 provides some concrete examples. We contend that the direct environmental impact of constructs, models, and methods (e.g., through the construction of the artifact and its storage) is rather limited and can be neglected. However, as constructs, models and methods contribute to the design of information

systems, those systems will be associated with direct and indirect environmental impacts, in turn. It thus becomes apparent that the indirect environmental consequences of a design artifact can impact on both the direct and indirect environmental sustainability of a concrete instantiation.

Table 7. Environmental impact of different types of IT artifacts

	Constructs example: building blocks of a systems design	Models example: System design	Methods example: process modeling grammar	Instantiations example: software
Direct environmental impact	The direct environmental impacts of constructs can be neglected.	The direct environmental impact of a system design can be neglected.	The direct environmental impact of a modeling grammar due to its sheer existence can be neglected.	Emissions, resource, and energy consumption of the system on which the software runs. A software tool can, for example, require more or less computational power and disk space.
Indirect environmental impact	As constructs are the building blocks of models, methods, and instantiations, they can influence both the direct and indirect environmental impact of design artifacts. In particular, they help building a sustainability-related terminology.	A systems design describes a system, or class of systems. Therefore, the system design impacts on both the direct and indirect environmental impact of the systems that are described. Principles of form and function contributing to sustainability can be incorporated in instantiations based on a specific model.	A modeling grammar may, for instance, contribute specific constructs that allow for the design of processes in the light of environmental considerations.	The environmental impact of the processes that are supported by the software. A software tool that allows virtual collaboration, for example, may reduce travel and, therefore, energy consumption and carbon emissions.

Consequently, environmental sustainability needs to be considered with regard to the different types of IT artifacts. As the different types are interrelated, the consideration of environmental impacts at one level may impact on the environmental sustainability at other levels.

In summation, from a broad level, we suggest the following primary conjecture: In order to contribute to environmental sustainability, design-science research must consider the sustainability of a design artifact, that is its direct and indirect effects on the

natural environment, (a) in the general principles of design science, (b) in the rigorous application of practice rules, and (c) all stages of the design research process.

6 Conclusion

In this paper we set out to discuss the role of environmental sustainability in design science research. We contend that IS research, through its contributions to the development of novel and purposeful IT artifacts, bears a responsibility when it comes to both the worsening and the enhancement of the natural environment. Our intent was to make three primary contributions: First, to conceptualize environmental sustainability as an explicit goal of design science research by means of a design artifact's environmental impact; second, to discuss how the goal of environmental sustainability can be considered in design science research methodology; third, to propose a unified perspective on Green IT and Green IS based on our conceptualization of the environmental impact centered around a discussion of the IT artifact.

This work has some limitations. First, in this conceptual article, we focused on environmental sustainability. We acknowledge that environmental sustainability cannot be separated from economic and social sustainability, and that other foci may lead to different conceptualizations. Second, one crucial aspect that we did not explore in much depth is that of the evaluation of IT artifacts with regard to the indirect and direct impact on the natural environment. Future research must thus consider how artifacts can be evaluated with regard to their environmental sustainability, both in terms of source and sink functions.

It will be interesting to see in how far we as a discipline take responsibility for environmental deterioration by contributing to the design of purposeful and novel IT artifacts that not only have low environmental impact throughout their lifecycle, but also contribute to the design and implementation of sustainable business processes.

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