Göttinger Wirtschaftsinformatik

Herausgeber: J. Biethahn† • L. M. Kolbe • M. Schumann

Benjamin Brauer

Persuasive User-Centric Green IS

Exploring the Role and Paving the Way of Information Systems to Induce Pro-Environmental Behavior Change

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Prof. Dr. J. Biethahn† Prof. Dr. L. M. Kolbe Prof. Dr. M. Schumann

Georg-August-Universität
Wirtschaftsinformatik
Platz der Göttinger Sieben 5
37073 Göttingen

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Persuasive User-Centric Green IS – Exploring the Role and Paving the Way of Information Systems to Induce Pro-Environmental Behavior Change

Dissertation

zur Erlangung des wirtschaftswissenschaftlichen Doktorgrades

der Wirtschaftswissenschaftlichen Fakultät der Georg-August-Universität Göttingen

vorgelegt von

Benjamin Brauer, M. Sc.

aus Göttingen

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Erstbetreuer:	Prof. Dr. Lutz M. Kolbe
Zweitbetreuer:	Prof. Dr. Margarete Boos
Drittbetreuer:	Prof. Dr. Matthias Schumann

Preface

This cumulative thesis emerged during my time as a research associate at the Chair of Information Management at the University of Göttingen. The thesis results from my personal interest for the ecology and the advancing digitalization with all its opportunities and threats. The completion of this work would have not been possible without the support of countless great people around me who stood by me and helped me to persevere.

First and foremost, I would like to thank my supervisor Prof. Dr. Lutz M. Kolbe. Lutz Kolbe and I have a decade-long history of collaboration at the chair throughout my entire academic career. Without his trust, support, and the provision of a comfortable and professional work environment, this dissertation would not exist. Moreover, my thanks go to the former heads of the Sustainable Mobility Research Group (SMRG) Dr. Andre Hanelt and Dr. Sebastian Busse for giving me the opportunity to be part of this group. Also great thanks to Prof. Dr. Margarete Boos and Prof. Dr. Matthias Schumann for completing my thesis committee. Furthermore, I wish to express my deepest gratitude to all my great colleagues and friends I had the pleasure working with. This concerns the entire SMRG: Everlin, Sromona, Henning, Björn, Ilja, Bene, Johannes, Matthias, Gerrit, and Patryk; as well as the boys from “up-stairs”: Daniel, Schahin, Fabian, and David. And also, the “Tower Guys”: Vujdan, Markus, Sebastian, Simon, Thierry, and Patrick. Thanks for the countless hours of fun during recreational FIFA sessions and the unforgettable conference trips! From all these great people I want to accentuate Carolin Ebermann. Thank you for your great support with my research and projects. You have become more than a friend throughout our joint time at the chair! Additional thanks go to Dr. Mauricio Marrone for his support with my thesis in several interesting talks, and to Frank Polster who has been the greatest student assistant I could have wished for. Last but not least, a big thanks to our great secretariat staff Maria und Nicole for your support with all the bureaucracy.

The greatest thanks, however, go to my parents Roswitha and Ralph who always supported me in my life. There have been many obstacles during my school career which caused quite some problems, but your trust and support never ceased. Thank you so much! This also includes my awesome sister Mira, and of course my niece Lana –, and Sven. Likewise, I want to express my gratitude to Yvonne Schulz who has been a never forgettable companion throughout a long period of my life, thank you so much!

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Göttingen, December 2017 *Benjamin Brauer*

Table of Contents

List of Figures

List of Tables

Acronyms

ANCOVA	Analysis of covariance
AVE	Average Variance Extracted
CO_2	Carbon Dioxide
CR	Composite construct reliability
CV	Convergent validity
DSS	Decision Support System
DV	Discriminant validity
ESB	Environmental Sustainable Behavior
FBM	Fogg's Behavior Model
GIS	Geographic Information System
HCI	Human Computer Interaction
IoT	Internet of Things
IS	Information System
IT	Information Technology
MREB	Model of Responsible Environmental Behavior
PESS	Persuasive Environmental Sustainable System
PFA	Perceived Functional Affordances
SD	Standard deviation
SDT	Self-Determination Theory
SEM	Structured Equation Modelling
TAM	Technology Acceptance Model
TPB	Theory of Planned Behavior
TRA	Theory of Reasoned Action
UTAUT	Unified Theory of Acceptance and Use of Technology
UX	User Experience
VIF	Variance Inflation Factor

A. Foundations

This cumulative thesis is structured into three parts. The first part serves as an introduction to the corpus of this thesis located in Part B. The foundation encompasses an introduction and a chapter outlining the theoretical background of this thesis. The introduction chapter (A.I) is further subdivided into five sections. The first section (A.I.1) outlines the motivation and relevance of this thesis. Section A.I.2 presents the core research questions examined in this dissertation, followed by a structural overview (A.I.3) of the thesis based on the presented research questions. Section A.I.4 describes the research context and design as the foundation of the studies conducted in Part B. The foundation chapter closes with the presentation of the anticipated contributions of this cumulative dissertation.

I. Introduction

The first section of this chapter gives a short introduction to the topic and highlights the motivation behind this cumulative thesis. Afterwards, the central research questions are presented and followed by a presentation of the structure of the thesis. The next section outlines the greater research context and the fundamental research design to establish a comprehensive overview of the studies conducted and their respective connection and synergy. The chapter closes with a summary of the anticipated contributions pursued by this cumulative thesis in terms of theoretical and practical findings.

I.1 Motivation

Environmental sustainability has become a topically and important subject more than ever before. Nearly no week goes by without news with political statements about the importance of the protection of the environment – reinforced by reports on natural disasters and their aftermath caused by climate change. Manmade CO_2 emissions lead to an increase of the worldwide temperature (Filcak et al. 2013; IEA 2007) caused by, e.g., transportation, energy use, purchase behavior, etc. The same applies to extensive resource consumption, not only in the industry – but also in the private sector. Moreover, unnecessary high consumption of water, fossil fuel, or food caused by people's behavior contribute to environmental degradation (Simpson 2012). These negative impacts on the natural environment are of concern for the entire society and it is the responsibility of every single person to prevent the harmful consequences on the environment (IPCC 2007; Vlek and Steg 2007).

In order to mitigate environmental pollution, governments and research develop and introduce initiatives and policies to raise awareness about environmental topics, and sanction the negative effects of environmental harmful actions in the organizational and private sector (Chen et al. 2009; Gifford 2011). In the organizational context these regulations show promising results because companies are forced to improve their CO_2 footprint or they will be fined for non-compliance of the specified regulations (Chen et al. 2009). However, in the private context such regulations and penalties are difficult to enforce (Gifford 2011). Although a person can get directly fined for, e.g., littering, or indirect in case of paying increased taxes for gas, or driving an old environmental harmful car in general. However, this sort of punishment and its impact is not comparable with organizational policies and their consequences. Personal penalties might serve as an educational tool and will possibly prevent a person from littering in the future, and could also possibly provoke the consideration of buying a new – more sustainable – car. However, these penalties and tax regulations do not convey and exhibit the negative impacts on the environment of these behaviors and attitudes, and also do not raise awareness and educate about other environmental harmful behavior in other areas, e.g., energy and water consumption or the purchase of CO_2 neutral food and goods.

Behavioral change and the preceding intention of an individual to engage in a behavior change process is a complex circumstance (O'Conner et al. 1999). This pertains nearly every area where behavioral change is of pivotal interest, i.e., education, health, and also pro-environmental behavior (Tscheligi and Reitberger 2007). However, when highlighting the aforementioned three areas it is apparent – for the majority of people – that the negligence of educational and health-influencing actions directly affect a person's literacy and well-being. While there is also an effect of the degradation of the environment on the same individual – these impacts are predominantly long term and not likewise perceived as a threat with the same intensity (Gifford 2011). Moreover, compared to educational and sanitary concerns, environmental causations and repercussions are more likely to be attributed to the fault of others than to one-self (Gifford 2011). People might have the mindset that other people elsewhere have a bigger share in environmental degradation, leading to a lack of motivation to give additional effort and to accept restrictions on the private lifestyle, whereas others do not take their part in saving the world (Gifford 2011). This shows that many factors come into play when pro-environmental behavior change is pursued although a general awareness persists.

"If so many people are concerned about climate change, the environment, and sustainability, why are more of us not doing what is necessary to ameliorate the problems?"

—Robert Gifford, "The Dragons of Inaction", 2011

This multitude of reasons that prevent people from engaging in pro-environmental behavior – despite the general perception of prevailing issues – can be both: a curse and a chance. A curse in that way, that there are so many barriers hindering a person to seek for change – but also so many starting points to address the issues, in multiple ways.

Another important fact that distinguishes the seek for pro-environmental behavior from other domains where behavioral change is desired, is that there is predominantly no clear positioning of individuals regarding the topic. People cannot be strictly assigned to groups that strongly believe in climate change and will do anything in their power to act as pro-environmental as possible. On the other hand, there is no confined group that knocks down every effort towards environmental improvement (O'Conner et al. 1999). The answer lies somewhere in-between, giving the opportunity to convince people, by any chance. However, regardless of individual attitudes, raising awareness about the causes of climate change is an effective way to convey the aftermath of environmental degradation, and to spark behavioral intentions (O'Conner et al. 1999).

Based on this, it is the challenge to discover options to raise awareness and to guide people through the change process. In this context, information systems (IS) have proven to be a promising tool to support people in behavior change tasks.

"Information systems are an important but inadequately understood weapon [...] for environmental sustainability by enabling new practices and processes in support of belief formation, action formation, and outcome assessment."

—Nigel P. Melville, "Information Systems Innovation for Environmental Sustainability", 2010

In health care people use mobile apps to stop smoking, monitor and track exercise performance, or optimize their diet (Lehto and Oinas-Kukkonen 2015; Toscos et al. 2006; Yoganathan and Kajanan 2013). In education, pervasive micro-learning apps are available for nearly every imaginable subject. However, the use of information technology and systems to improve the natural environment is still underexplored (Corbett and Mellouli 2017; Loeser 2013; Pernici et al. 2011). Green Information Systems (Green IS), are a first approach in IS research to investigate the potential of computer technology to ameliorate environmental problems (vom Brocke et al. 2013b; Chen et al. 2008; Melville 2010). Though, emerging from the organizational context, Green IS historically focuses on optimizing enterprise processes towards sustainable practices (Flüchter and Wortmann 2014; El Idrissi and Corbett 2016; Loeser 2013; Loock et al. 2013). A user-oriented approach with the goal to directly address people's behavior is an uncommon procedure in Green IS research (Corbett and Mellouli 2017), despite single advances (Flüchter and Wortmann 2014; Froehlich et al. 2009; Hilpert et al. 2013; Loock et al. 2013).

Hence, the focus on individuals utilizing IS to trigger pro-environmental behavior is a rare phenomenon in IS research. Therefore, it is necessary to explore and expose the field of user-centric Green IS, and to derive possible advancements to utilize IS for pro-environmental behavior change. Thereby, IS will help to unleash the great potential for positive environmental change by activating a comprehensive resource in form of people all around the world.

Thus, the goal of this cumulative thesis is to gain insights in the use of information systems to improve environmental sustainability in a user-centric manner, to analyze and evaluate existing approaches and solutions, and to identify shortcomings and gaps from existing research. In this vein, the concept of user-centric Green IS is examined in deep detail in order to pinpoint appropriate measures to foster pro-environmental behavior and to determine the suitability and perception of pro-environmental solutions and their acceptance by potential users.

I.2 Research Questions

The exploration of user-centric Green IS in this cumulative thesis is divided into three building blocks in order to provide a clear structure. The three building blocks constitute the corpus of this dissertation and are located in Part B. The first building block gives insight in the status quo of user-oriented Green IS solutions (B.I Status Quo), followed by the examination of appropriate theories and mechanisms applicable for successful user-centric Green IS design (B.II Theories and Mechanisms). The last building block (B.III User Acceptance) covers design recommendations of user-centric Green IS with emphasis on user acceptance.

As briefly mentioned in the preceding motivation, Green IS constitutes a well-established research domain in the IS community. Originating in the organizational context, Green IS research is primarily concerned with the pro-environmental redesign of business processes, supply chains, etc. in order to improve the organizational CO_2 footprint (Loeser et al. 2012).

However, besides the industry, cities and their citizens have a great share on global carbon emissions and resource consumptions (Neirotti et al. 2014). Hence, the huge potential of addressing individuals to induce behavioral change towards pro-environmental behavior poses a promising approach. This thesis answers the call from multiple Green IS researchers from the IS community to perform more research on this topic and to diversify the perspective within this research field (vom Brocke et al. 2013b; Melville 2010; Watson et al. 2013).

The aim of the first research question is to give an overview of the current state of Green IS research outside the organizational context in the IS community and thematically adjacent domains, e.g., urban planning and energy management. Momentarily, Green IS research is predominantly bound to the organizational context (Chen et al. 2009; Loeser 2013), and thus poses a strong restriction for the potential of Green IS (vom Brocke et al. 2013b).

The analysis of the status quo in Green IS research within this building block constitutes the starting point for detailed research approaches throughout the remainder of this thesis and helps to set the focus on the revealed research gaps. Moreover, the practical perspective on user-centric Green IS with the goal to support pro-environmental behavior is of interest. Thereby, both perspectives: theory and practice are covered within this first part of this thesis.

This first research question not only addresses the status quo of user-centric Green IS solutions but also reveals further research gaps in this area (vom Brocke et al. 2013b). These gaps identified add to the research stream of Green IS and help other researchers to structure future studies (vom Brocke et al. 2013b).

RQ1. How do information systems contribute to environmental sustainability and what solutions exist to address user-centric approaches of Green IS?

After drawing a comprehensive picture of Green IS research and practical approaches in course of the first research question, the second part of this cumulative thesis illuminates the perspective on pro-environmental behavior change processes. The process of pro-environmental behavior change poses a very complex topic (Gifford 2011; Kurz 2002) and is widely under-represented in the Green IS research domain despite its huge credited potentials (Boudreau et al. 2008; vom Brocke et al. 2013b; Butler 2011; Dedrick 2010; El Idrissi and Corbett 2016; Pernici et al. 2011).

The central research question of this second building block draws upon the determination of behavioral theories and concepts particularly suited for pro-environmental behavior change, and sheds light on the technical implementation of suitable behavioral theories towards ecological behavior. In this part of the thesis the focus is set on the individual person and how s/he can be convinced for engagement in pro-environmental behavior with the aid of IS.

Existing research outlines the importance of information feedback to the individual in order to successfully pursue pro-environmental behavior (Gifford 2011; Kollmuss and Agyeman 2002; Kurz 2002). Thus, information technology and systems are predestined as information provider for the support of this information provision process (Shevchuk and Oinas-Kukkonen 2016). However, research on the interaction between system and user is still low regarding the effective and efficient design and use of persuasive feedback systems for pro-environmental behavior change (Dedrick 2010; Lehto et al. 2012; Shevchuk and Oinas-Kukkonen 2016).

Moreover, motivational processes take a key role in the engagement process of people for behavioral change (Kollmuss and Agyeman 2002; Shevchuk and Oinas-Kukkonen 2016). Hence, it is of great importance to match motivational theories and mechanisms with information systems as an instrument to motivate people for the use of Green IS to improve their pro-environmental behavior (Froehlich et al. 2010; Shevchuk and Oinas-Kukkonen 2016). Because of the lack of research with focus on user oriented Green IS design and evaluation (Dedrick 2010; Melville 2010) there is little to no concrete literature serving as a foundation for user-centric Green IS research (vom Brocke et al. 2013b; Dedrick 2010).

In conclusion, the goal of this second research question is to structure existing knowledge on behavioral change in general and in the ecological context, and make suggestions for the implementation of IS-based solutions helping to induce IS-driven pro-environmental behavior change of people. The findings from this part of the thesis contribute to the deduction of concepts for the design of user-centric Green IS and build the foundation for future research endeavors in the field of user-centric Green IS.

RQ2. Which theories and mechanisms need to be considered to support people towards IS-aided sustainable behavior change?

Finally, the third research question takes the analysis and findings from the preceding two research questions one step further towards the conceptual design of user-centric Green IS with particular focus on system acceptance. In contrast to the second research question with focus on the design of interaction and motivation processes to improve the persuasiveness of user-centric Green IS – the third building block is concerned with the acceptance and adoption process of these systems. Here, the prime goal is to increase the acceptance rate of these systems for frequent use in people's everyday life.

The effective and efficient design and technical implementation of the concrete processes to support system interaction and motivation alone (RQ2) does not guarantee the use of user-centric Green IS. An information system is only successful if the user is willing to use it voluntarily and enjoys doing so (Shevchuk and Oinas-Kukkonen 2016).

Acceptance research constitutes an elaborated research field in the IS community with a consistent growing number of studies (Bagozzi 2007; Barki 2007; Sun and Zhang 2006; Venkatesh et al. 2000, 2003, 2012). This growing number and the results of these studies indicate the relevance of analyzing user acceptance of information systems in order to build effective and efficient IS with high likelihood for long-term system adoption by the user. Particularly in a relatively young research area with little knowledge and evidence about the overall successful design of user oriented information system it is fundamental to gain and create insights for future research endeavors and practical projects.

Hence, the third and last research question of this cumulative thesis answers the question:

RQ3. How should user-centric Green IS be designed to achieve user acceptance?

The gradual approach from the presentation of the state of research in this domain and the identification of research gaps, over the examination of behavioral theories and models, to the derivation of design patterns with the proposition of user acceptance draws a holistic picture of this research topic. Only the combination of these three research areas lead to a profound overall picture providing broad Insights to the comprehensiveness and potential of the user-centric Green IS research area.

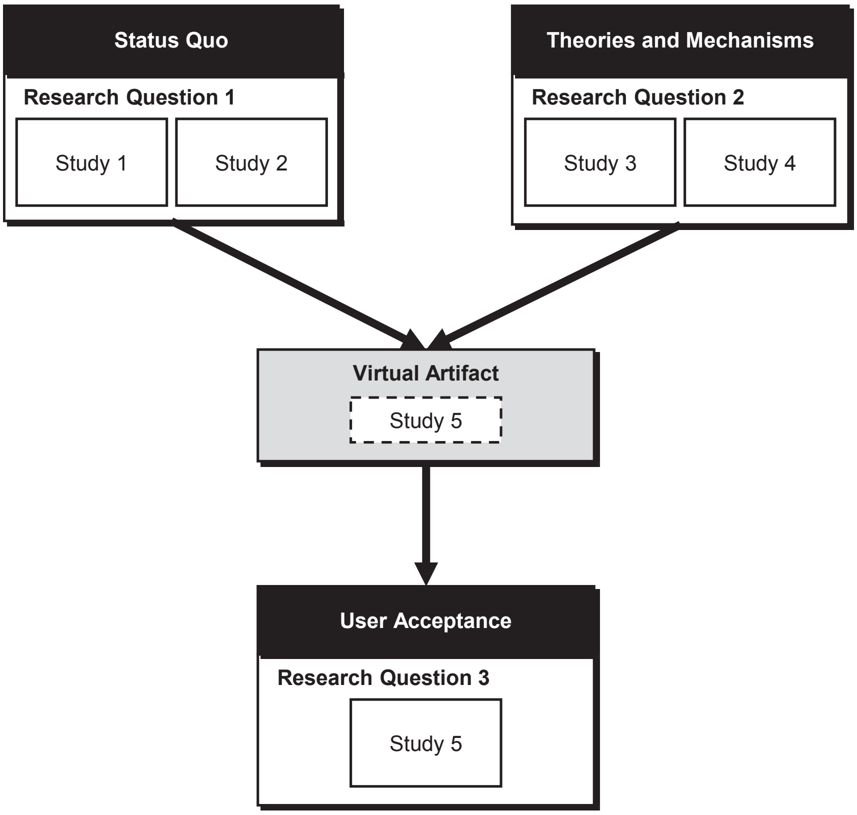
I.3 Structure of the Thesis

The thesis is structured in three main parts (Part A, Part B, and Part C) as illustrated in Figure A-2. Each of these parts is further subdivided. Part A consists of two chapters (A.I and A.II) and both Part B and Part C are further sub-divided into three chapters (B.I-III and C.I-III).

Part A covers the foundation of this thesis. It starts with an introduction (A.I) to this work. Within the introduction, the motivation behind this research endeavor is presented (A.I.1), followed by a short presentation of the central research questions (A.I.2) and a structural overview (A.I.3). Afterwards, the research context and research design is outlined by positioning this thesis in terms of the underlying IS research stream and epistemology (A.I.4). Chapter A.I closes with a peek into the anticipated contributions of this thesis.

The second chapter of Part A delivers insight into the theoretical background (A.II) required to understand the general idea of this thesis. The overarching goal of user-centric Green IS is to change people's behavior. Therefore, it is helpful to first understand what constitutes behavior change, and how behavior change can be provoked. Thus, this chapter starts with the presentation of fundamental behavior change theories and models (A.II.1) in order to convey the complexity of this domain and gives insight into the socio-psychological realm of behavioral change. Subsequently, the concept of the use of information systems to foster environmental sustainability by inducing pro-environmental behavior is introduced. The IS research domain Green IS is briefly defined, as well as the concept of persuasive systems as a prospective approach for IS-driven behavior change initiatives (A.II.2). Finally, the chapter gives insight into the theory behind user acceptance research in context of information system adoption (A.II.3).

Figure A-1: Overview of the thesis' building blocks and the comprised studies



The actual studies on user-centric environmental sustainable information systems are composed in Part B and embody the core component of this thesis. The studies composed in this thesis help to answer the three research questions specified above (Section A.I.2). The assignment of the studies conducted to their respective building block is illustrated in Figure A-1. The structure of Part B aims to convey the constructive idea of this thesis. The findings of the two studies conducted in building block B.I (Status Quo) as well as the two studies of the second building block B.II (Theories and Mechanisms) are incorporated into the third building block B.III (User Acceptance) in course of the design of an virtual artifact that is analyzed regarding the acceptance decision of potential users. The building blocks and their studies are further outlined in the following.

The first two studies give an overview about the current state of research and practice on the topic of user-centric Green IS. In the first study (1) two literature analysis are performed based on articles from different research areas. Within the first review, the leading IS journals and conference articles are screened for Green IS solutions. The second review analyzes articles without restrictions regarding the research field. Thus, the results of this analysis give a holistic view on the state of research on the use of Green IS outside organizational boundaries. The second study (2) of this building block (B.I Status Quo) covers the practical perspective. The study explores the Google Play Store for mobile applications that help people to improve their personal pro-environmental behavior. Furthermore, the apps discovered are analyzed regarding their purpose and properties to draw a picture of existing real-world implementations of user-centric Green IS, aside from the sole academic research point of view.

The following two studies are attributed to the building block (B.II Theories and Mechanisms) of this thesis. Both studies take on the socio-psychological prospect of this topic by focusing on behavioral theories and mechanisms applicable in the context of pro-environmental behavior change. The first study (3) of this building block provides a framework for the establishment of sustainable communities based on the potential synergy of socio-psychological theories for behavior change and the capability of information systems to address and ultimately change people’s behavior. The other study (4) in this building block analyzes an existing solution to foster pro-environmental behavior in communities by utilizing IS to motivate bicycle use regarding its effect.

Finally, the third building block of this cumulative thesis outlines the user acceptance (B.III) of user-centric Green IS. The study in this part of the thesis explores the suitability of persuasive design principles for user-centric Green IS solutions. This study examines the influence of different functional implementations of these established persuasive design principles (see A.II.2) on the acceptance of system use from the user’s perspective. Table A-1 illustrates the five containing studies and summarizes their main contribution.

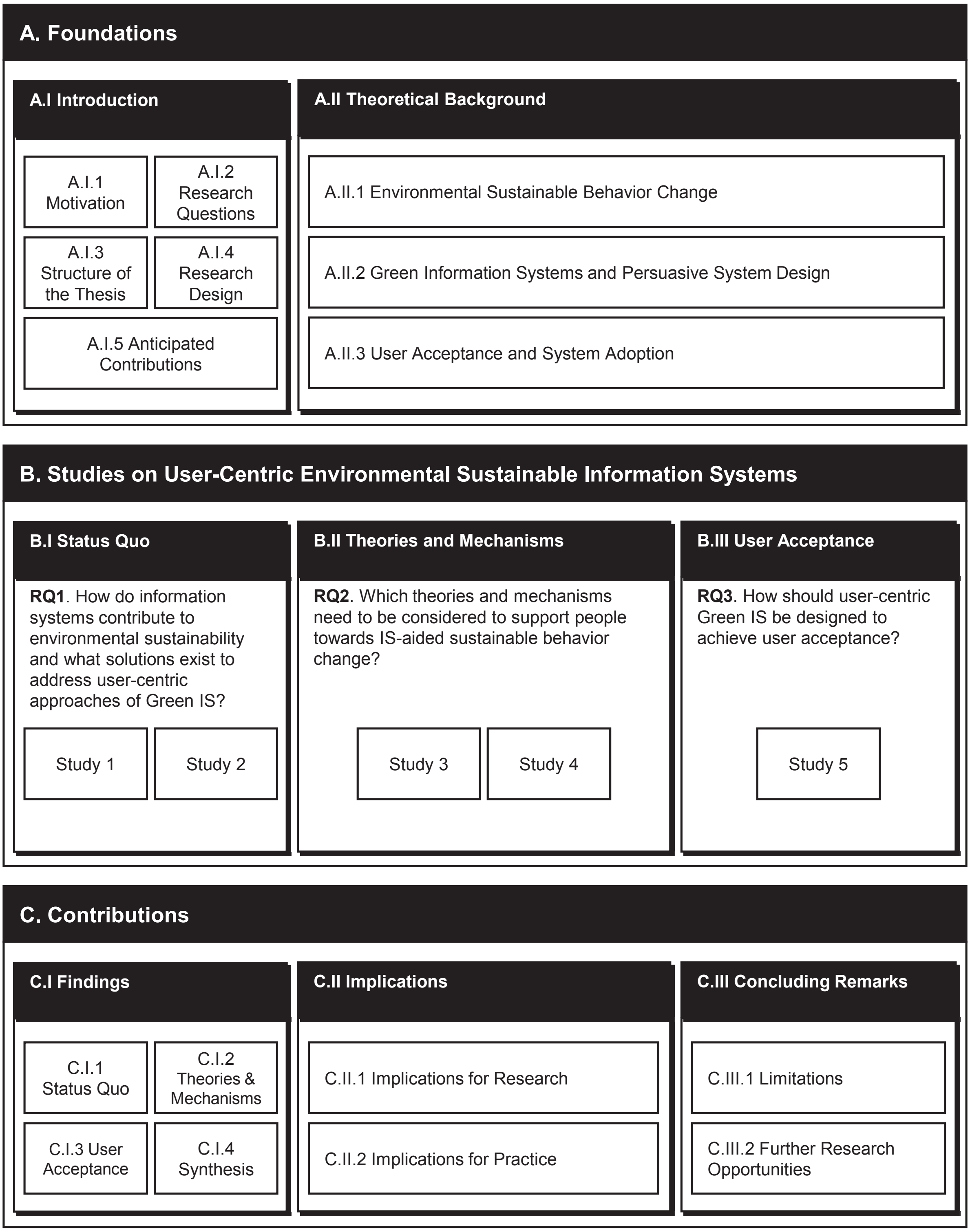
Table A-1. Overview of studies in this thesis

No.	Outlet	Ranking[1]	Section	RQ	Main contribution
1	Pacific Asia Conference on Information Systems (PACIS)	C	B.I	1	Structured overview of the implementation of Green IS practices and solutions in the smart city domain, and the deduction of a research framework to identify and address existing research gaps in this research field.
2	Pacific Asia Conference on Information Systems (PACIS)	C	B.I	1	Insights about the status quo of existing user oriented solutions on the market with the goal to foster and/or change environmental sustainable behavior on an individual level, and the analysis of these existing solutions.
3	Americas Conference on Information Systems (AMCIS)	D	B.II	2	Identification of prevailing problems and psychological barriers, possible counter measures, and the potential of information systems to support environmental sustainable behavior change with the development of a conceptual framework.
4	European Conference on Information Systems (ECIS)	B	B.II	2	Function oriented analysis of motivational processes and user experience in the use of persuasive information systems to support environmental sustainable behavior.
5	International Conference on Information Systems (ICIS)	A	B.III	3	Acceptance analysis of persuasive design principles for the development of user oriented environmental sustainable information systems and the effect on system adoption.

At last, Part C summarizes and reflects the key findings of the presented studies regarding the research question's building blocks (Section C.I.1-C.I.3) and provides a holistic view on user-centric environmental sustainable information systems based on the combined results of the collated studies (C.I.4). These results are further elucidated regarding their implications for research (C.II.1) and practice (C.II.2). As concluding remarks of this cumulative thesis the limitations (C.III.1) of the studies are discussed and future research opportunities (C.III.2) of this research topic are outlined at the end of this work.

[1] The ranking is based on the VHB Journal 3 ranking (*http://vhbonline.org/service/jourqual/vhb-jourqual-3/; 2015*)

Figure A-2. Structure of the Thesis



I.4 Research Context and Design

This cumulative thesis follows a progressive approach with step-by-step studies as it is indicated in course of the preceding two chapters (A.I.2 & A.I.3). The studies in this thesis build-up on each other in order to draw a clear picture of the pursuit for the overarching research goal. This thesis aims to pave the way for user-centric Green IS research within the IS community and establish it as a discrete and extensive research area within the Green IS research domain.

Information systems research represents a diversified and continuously growing research field with a great range of areas with specific foci (Bernroider et al. 2013; vom Brocke et al. 2013b). Historically, IS research constitutes a discipline with strong reference to adjacent research fields, and borrows from – as well as contributes to – these fields (Benbasat and Weber 1996). Over the years interdisciplinary research of IS with the research fields organizational science, management science, computer science/engineering, economics, management, and social/psychological sciences emerged as major IS research streams (Banker and Kauffman 2004; Benbasat and Weber 1996; Bernroider et al. 2013). Traditionally, Green IS research originates from the organizational science as an evolution of Green IT (Loeser 2013). In the early stages, Green IT was primarily concerned with the ecological design of organizational processes and infrastructures by alleviating the negative impacts of the organizations IT infrastructure (Dedrick 2010; Loeser 2013). Gradually, IS was considered as a helpful tool to improve environmental sustainability by utilizing information technology inside the business environment, e.g., to monitor and control energy consumption (Loock et al. 2013; Melville 2010). Thus, the research stream Green IS was born with the goal to improve environmental sustainability with the aid of information systems (vom Brocke et al. 2013a; Dedrick 2010; Loeser 2013; Melville 2010; Pernici et al. 2011).

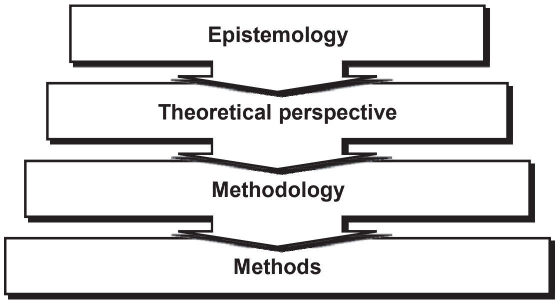
Generally, the IS research domain is dominated by two predominant research paradigms serving as an orientation for the corpus of IS literature to generate and diffuse knowledge about the management and use of information technology (Hevner et al. 2004). On the one hand there is *behavioral science*, concerned with human behavior in the natural world (Hevner et al. 2004). Behavioral science aims to understand and predict human behaviors, develop and verify theories on human behaviors, and examine the interaction of people with information technology (Hevner et al. 2004; Wilde and Hess 2006). On the other hand, *design science* describes an artifact-driven paradigm (Hevner et al. 2004). Design science emphases the development of concrete IS artifacts (Hevner et al. 2004). The strict adherence to the paradigm incorporates the rigor and rigorously analysis of the environment where the artifact is determined to be deployed as well as the overall design and development process (Hevner et al. 2004). This encompasses the exploration of the research environment and processes in terms of users, systems, theories, and mechanisms regarding interaction, use, and outcome. (Hevner et al. 2004). Implicitly, this comprises theories, models, and mechanisms to examine system specific attributes of the to-be designed artifact (Hevner et al. 2004). Although both paradigms are distinct, they also complement each other in various areas (Hevner et al. 2004).

Scientific articles on Green IS are mainly of conceptual and analytical nature attributed to the organizational realm (Gholami et al. 2016). The majority of these studies follow the behavioristic approach to identify and explain the role of Green IS in the organizational context. Only few studies are concerned with the design and evaluation of concrete Green IS, and reside in the design science sphere (Gholami et al. 2016).

However, apart from the restricted scope of Green IS on the organizational context, another limitation of existing Green IS research lies in the manner of analysis. Studies mainly focus on the outcome of system usage of single specific IS. These studies do not examine and analyze why and how these systems succeed or fail their purpose (Lehto et al. 2012; Shevchuk and Oinas-Kukkonen 2016). This thesis takes on these two major research gaps by taking Green IS research outside the organizational context (vom Brocke et al. 2013b) and by focusing on the question how such systems should be designed. Thus, this thesis has the characteristics of the design science paradigm with emphasis on the behavioral perspective.

The research approach of this thesis follows the framework by Crotty (1998) for the planning and design of research projects. According to this framework (see Figure A-3), the researcher should consider four basic elements prior to the engagement in any research activities (Crotty 1998).

Figure A-3: The four elements of research decision (adapted by Crotty 1998)



Typically, IS research takes one of the three research streams: positivist, interpretivist, and critical as epistemological approach to position one's work (Cecez-Kecmanovic et al. 2008). Positivist research is free from the researcher's personal beliefs or perspectives, and with strict distance to the participants of the study conducted. The goal is to make generalizations based on underlying theory free from time and context by utilizing suitable methodologies to test well-derived hypotheses (Orlikowski and Baroudi 1991). Interpretivists, on the other hand, approach their research from a more personal and explorative angle. The researcher takes the stance that the existing knowledge and understanding of a phenomenon is not sufficient enough to be conclusive, and seeks to understand the context of the phenomenon rather than aim to prove or disprove certain assumptions. Moreover, the researcher directly interacts with the participants of the study and shapes the analysis with their interactions (Orlikowski and Baroudi 1991). At last, the critical research approach attempts to expose fundamental structural problems with existing research constituting the status quo of a certain phenomenon. Critical studies primarily evaluate and explain the examined circumstance, underlying theory, and their inherent connection with a researcher's skeptical viewpoint (Orlikowski and Baroudi 1991).

Table A-2: Overview of research design

No.	RQ	Research design	Data collection	Data analysis
1	1	Literature analysis	Secondary data	Content analysis
2	1	Mobile app analysis	Primary data	Taxonomy building
3	2	Literature analysis	Secondary data	Content analysis
4	2	Statistical analysis	Primary data	Analysis of covariance
5	3	Statistical analysis	Primary data	Structural equation modelling

This thesis adopts the positivistic research approach as the studies investigate the current state of user-centric Green IS in theory and practice with a neutral and observer-like position (Orlikowski and Baroudi 1991). The first two studies of this cumulative thesis are dedicated to the exposure of the status quo of user-centric Green IS, whereas the following three studies investigate the field based on existing theory (Orlikowski and Baroudi 1991).

Alongside the above introduced framework (Crotty 1998) as a foundation of this thesis and the comprised single studies, the theoretical perspective of this cumulative thesis is based on the coherent theory of environmentally significant behavior (Stern 2000). The theory outlines the complexity of the research field of pro-environmental behavior change, and introduces major types of environmental significant behaviors (e.g., environmental activism, purchase behavior, lifestyle, etc.) and general variables influencing these behaviors (e.g., attitudes, capabilities, contextual factors, and habit) (Stern 2000). The theory builds a foundation for the derivation of practical programs for pro-environmental behavior by guiding the research through the process of creating pro-environmental behavior change initiatives (Stern 2000).

According to the structure of Part B the first research question addresses the exploration of the (1) status quo of Green IS in theory and practice. Thus, structured analysis methods are used to gain insight in the current state of user-centric Green IS research and to structure these findings. The second research question addresses the (2) theoretical and methodological scope of this research by taking a deeper look into appropriate approaches to successfully implement IS based pro-environmental behavior change initiatives. This analysis is performed in two ways: a structured analysis and the design of a framework for the design of user-centric Green IS, and the practical examination of a real-world implementation regarding its effect. Finally, the third research question builds upon these findings and constitutes the basis for the theoretical design of a user-centric persuasive Green IS. The corresponding study aims to analyze the appropriate design of such artifacts to increase the likelihood of (3) user acceptance based on empirical data and statistical analysis methods. An overview about the single studies and the corresponding applied data collection and analysis approaches is given in Table A-2.

I.5 Anticipated Contributions

The overarching goal of this cumulative thesis is to answer the call for more and deeper research on Green IS and the dissemination of the potentials of information systems to facilitate pro-environmental behavior (vom Brocke et al. 2013b; Melville 2010). This thesis is structured into three building blocks (see Section A.I.3) aiming to thoroughly cover this greater research goal by the execution of five discrete studies associated to their respective building block. The anticipated contributions of this thesis are outlined in the following and summarized in Table A-3.

According to the consecutive structure of this thesis the first anticipated result addresses the exploration and exposure of the status quo of Green IS research. Given the fact that the Green IS research field constitutes a relatively novel research stream within the IS community (vom Brocke et al. 2013b) it is of great importance for future studies to gain detailed insight into existing studies on this topic in order to identify relevant and timely research gaps. Ever since the establishment of Green IS research within the IS community this research field faces the great challenge of acquiring multiple perspectives from different research domains as well as the limited contribution of knowledge and methods outside business centric-boundaries (Hovorka and Corbett 2012). A great opportunity to overcome this narrow focus is offered by viewing cities as a major component towards the striving to ameliorate the ecology (Corbett and Mellouli 2017; Neirotti et al. 2014). Considering the amount of people living in cities and using its infrastructure and resources (Lövehagen and Bondesson 2013) cities constitute a great example taking the focus of Green IS research to different domains (vom Brocke et al. 2013b). Thus, providing a structured analysis of existing literature not only restricted to the IS research domain but also including adjacent research fields provides insight on novel Green IS application areas and builds ground for future research opportunities.

Secondly, this thesis aims to contribute to the understanding of the prevailing challenges of pro-environmental behavior change and how these challenges can be addresses with the aid of information systems. Behavior change constitutes a complex field and a multitude of factors influence the successful outcome of behavior changing interventions (Gifford 2011; Michie et al. 2013). Several research fields, e.g., sociology, psychology, environmental sciences, and lately even the IS research community seek for theories, models, frameworks, and mechanisms in order to increase the success rate of such interventions. However, this knowledge is primarily strictly located within the respective research domain. Synergies between these fields are rarely utilized because of a lack of cohesion. Furthermore, information takes a key role in behavior change interventions (He et al. 2010; Lehto et al. 2012). In terms of the use of information systems as an agent to distribute these vital information, however, it is firstly essential to identify how these information is conveyed most successfully (Watson et al. 2011). Therefore, it is crucial for future studies in the research field of Green IS to structure existing knowledge and build a foundation for novel theoretical and practical approaches for user-centric Green IS solutions.

The third anticipated contribution takes on the availability and effectiveness of user-centric Green IS solutions. The findings of this thesis make a first attempt on disclosing the accessibility of Green IS solutions for personal use and illustrate their operational purpose. Thus, answering the call for studies beyond pure theory, and seek to gain valuable insights for the design of future solutions based on observations (vom Brocke et al. 2013b). Moreover, this thesis contributes to the understanding of the effectiveness of solutions to stimulate pro-environmental behavior in terms of their functional design. These findings help to deduce design patterns for Green IS artifacts based on the user's decision whether to use such systems to make an attempt for personal behavior change or not (Flüchter and Wortmann 2014). Furthermore, this approach answers the call of Green IS research to apply existing theories in practice in order to create valuable insights about these theories in an applied context (vom Brocke et al. 2013b; Gholami et al. 2016).

Finally, this thesis sheds light on the user acceptance perspective of user-centric Green IS solutions. While there are already few studies, their focus lie exclusively on the outcome of the systems analyzed (Flüchter and Wortmann 2014; Froehlich et al. 2009; Hilpert et al. 2013; Loock et al. 2013). Meaning, that these studies solely examine the difference in behavioral outcome in terms of, e.g., reduced energy consumption (Loock et al. 2013) or caused CO_2 emissions (Froehlich et al. 2009; Hilpert et al. 2013). Although these studies show that information systems can have a positive effect on behaviors, and therefore contribute to a better ecology, however, these results tell nothing about whether the end-user would intend to keep using those systems. Neither do the results indicate how such an IS should be designed ideally in order to foster the acceptance of such solutions, and thereby add to an increase of the probability for long term use.

From the practical perspective this thesis generally helps application designers and organizations dedicated to ecological improvement to plan and create IS based interventions in order to save the environment.

First, this is achieved by giving an overview about promising application areas where user-centric Green IS can have high positive impact on the environment. Moreover, it is shown *how* IS based solutions can positively contribute to the environment in the respective application area. These findings help decision makers associated to the domain of environmental sustainability to organize beneficial IS driven campaigns to improve the ecology.

Secondly, this thesis contributes to the understanding of the potential of user-centric Green IS in the real world. It is demonstrated that the use of information systems to improve the ecology is not only of theoretical nature, but also shows positive effect in practice. This shall help to communicate and promote such solutions in everyday life environments, and can also open the market for commercial solutions in form of concrete applications or services. Hence, the industry can learn from the potentials of user-centric Green IS in terms of promising application areas and functionalities. Furthermore, the design principles examined can support the industry with a framework for the successful design and implementation of these commercial applications and services.

Table A-3: Summary of anticipated contributions

Audience	Anticipated contributions
Theory	(1) Insights on Green IS research outside the organizational context and the identification of associated research gaps. (2) Understanding the challenges of pro-environmental behavior change processes and the deduction of suitable concepts as foundation for practical implementations and the extension of the theoretical basis for pro-environmental behavior change. (3) Insights on the availability, and understanding of the effectiveness of user-centric Green IS solutions. (4) Insights on the acceptance decision of users regarding the use of Green IS solutions for behavioral change.
Practice	(1) Insights about potential application areas for Green IS solutions outside the organizational context, e.g., for smart cities. (2) Understanding of the potential of user-centric Green IS solutions and the deduction of appropriate design concepts.

II. Theoretical Background

This chapter provides extended insights in the underlying theoretical background examined and discussed in the articles in Part B. The aim of this chapter is a deep dive into the matter of the articles included in this dissertation while keeping redundancies with the theoretical background sections of the single articles contained as low as possible. Core concepts and theories are briefly outlined in the articles' foundation sections due to page limitations of the respective outlets. Therefore, this chapter provides an extended look into the subject-matter of this work. The ultimate goal of environmental sustainable persuasive systems is to trigger and maintain pro-environmental behavior change of individuals. Thus, it is crucial to understand how behavior change is triggered and sustained. Section A.II.1 outlines this topic in two parts. First, a general introduction to common behavior change theories and models is given in Section A.II.1.1. Second, the specific characteristics in the context of environmental sustainability are discussed in Section A.II.1.2. In Section A.II.2 the scope is set on the supportive capabilities of information technologies (IT) and systems (IS) for environmental sustainability. The first Section (A.II.2.1) gives a short definition of the research field of Green IS and their potential to positively contribute to the environment. The second part of Section A.II.2 describes the design of persuasive systems as a promising and emerging realization of behavior changing technology (Lehto and Oinas-Kukkonen 2015). The third section of the theoretical background (Section A.II.3) focuses on theories and models to measure and predict user acceptance of information systems.

II.1 Environmental Sustainable Behavior Change

The following two sections outline the topic of behavior change research. The first section covers general theories and models from different research areas (i.e., social and psychological science) and the fundamental stages of the change process of individuals. The second section emphasizes the application of behavioral theories and models, as well as intervention strategies in the area of pro-environmental behavior change.

1 Behavior Change Theories and Models

Behavior change poses a complex (Michie et al. 2013) and widespread phenomenon (Marcus et al. 1992; Marshall and Biddle 2001; Prochaska and Diclemente 1983) among various application areas, e.g., education, health, or ecology (Lehto et al. 2012). Different scenarios require varying approaches in the process of triggering the desired change and outcome (Marshall and Biddle 2001). Research about behavior change is very popular in the medical domain, specifically concerning physical activity and exercise in order to increase individual's health, or in clinical psychology regarding addictive behavior (Marshall and Biddle 2001).

A plethora of studies in psychotherapy could successfully show the positive effect of professional treatments on behavioral change for addictive behavior (Prochaska et al. 1992). However, these studies focused on the sole outcome of the applied treatments and interventions executed by the therapists (Rice and Greenberg 1984). For a long time little has been known about the inherent process of change within the individual resulting in actual behavioral adaptions for change (Prochaska et al. 1992).

The transtheoretical model of behavior change (Prochaska et al. 1992) structures the different stages of change (see Table A-4) traversed by an individual. The model postulates that a linear progression by an individual throughout the single stages, or phases, of the transtheoretical model is a rare and unusual circumstance (Prochaska et al. 1992). Thus, the transtheoretical model is described as an upward spiral where the different stages are subsequently traversed by the individual until the successful termination of the process (Prochaska et al. 1992).

Table A-4: Stages of change of the transtheoretical model of change (adapted from Prochaska et al. 1992, pp. 1103-1104)

Stage of Change	Description
Precontemplation	In the first stage of precontemplation a person has not yet admitted (to others and himself) that a problem even exists. The intention to take actions is not manifested, although a person might already have the wish for change.
Contemplation	A person is aware of the problem and has the will to change. However, the person may remain in this stage for a longer time due to a lack of commitment to perform the required actions.
Preparation	People in the preparation stage are willing and ready for immediate engagement in the change process. Some people might already have taken actions before and fell back to the preparation stage for different reasons, e.g., insufficient commitment or inadequate interventions.
Action	The action stage covers the actual realization of the individually tailored behavior change processes. This phase constitutes a long-term activity and requires strong commitment of the individual.
Maintenance	Maintenance describes the successful abidance of the intervention from the action stage. The primary goal of this stage is the stipulation of a strong determination in the change process and the prevention of relapse. Likewise the action stage it is a long-term phase which can sometimes be a lifelong task.
Termination	The termination stage is reached upon successful behavior change.

However, relapse generally occurs between adjacent stages of the model during the complete change process (Abraham and Michie 2008; He et al. 2010; Prochaska et al. 1992). This can apply in non-critical situations such as the adherence to a New Year's resolution to visits the gym more regularly, but especially in scenarios related to addiction, e.g., smoking or alcoholism (Marcus et al. 1992; Prochaska et al. 1992). People struggle to change their behavior causing an interruption of the change process at a certain stage (Prochaska et al. 1992). Relapse causes the individual to fall back to earlier stages of the model and to start a new attempt to change their behavior (Prochaska et al. 1992). This is often accompanied by additional negative effects such as shame or guilt leading to a loss of motivation to engage in earlier stages and to restart the treatment or intervention (Prochaska et al. 1992).

The transtheoretical model suggest an extensive set of processes recommended for application during the single stages (Abraham and Michie 2008; He et al. 2010; Marshall and Biddle 2001; Prochaska et al. 1992). For the initial step of the transition from the precontemplation stage to contemplation, interventions aiming to raise self-consciousness and the awareness about environmental effects of the problematic behavior, e.g., on close peers, are of paramount importance (Prochaska et al. 1992). The initiation of the preparation stage is based on self-reevaluation techniques to encourage self-conscious thinking related to the prevailing problem and the impact on oneself in terms of emotional or health related issues causes by the problematic behavior (Prochaska et al. 1992). Studies show that the success rates of self- and controlled-therapies are significantly higher if the patient comes to terms with oneself. This self-confession constitutes a cornerstone of the change process and marks the start of the action stage by strengthening the belief that change is possible (Prochaska et al. 1992). At this point the individual engages in commitment techniques such as resolutions or logotherapy to scheme the change process (Prochaska et al. 1992). The goal of the action stage is to reach a point where the individual maintains the progress of the entire change process (Prochaska et al. 1992). Thus, the individual is in terms with the problem, its outcome and effect on one-self and the environment, and is willing to engage with interventions to tackle the issues (Prochaska et al. 1992). While in the action stage several mechanisms are employed in order to maintain motivation and progress of the ongoing intervention program (He et al. 2010; Prochaska et al. 1992). Starting by adjusting the environment by avoiding the risk of fallbacks, e.g., keeping alcohol or cigarettes out of reach (Webb and Sheeran 2006). This can be further supported by social factors, e.g., the immediate support and help of friends and family, or self-help groups in critical phases. Moreover, giving out rewards for adequate behavior can also show strong positive effects on maintaining the change process (Kurz 2002; Prochaska et al. 1992; Webb and Sheeran 2006). Ultimately, the process terminates with a successful change.

The transtheoretical model emphasizes a strong assessment of a client's readiness for transition between adjacent stages. Moreover, the success of the applied intervention methods during a stage is heavily bound to an ideal tailoring of interventions to the needs, feasibilities, and satisfaction of a person (Prochaska et al. 1992). While these kinds of adjustments – in terms of matching stages, possibilities, and client's needs – are usually common practice in supervised and controlled therapies –, it rarely takes place for self-changers in an uncontrolled environment (Prochaska et al. 1992). According to Prochaska et al. (1992) especially for self-changers it is important to initiate the ideal processes for an individual at the right time (stage) for maximum success.

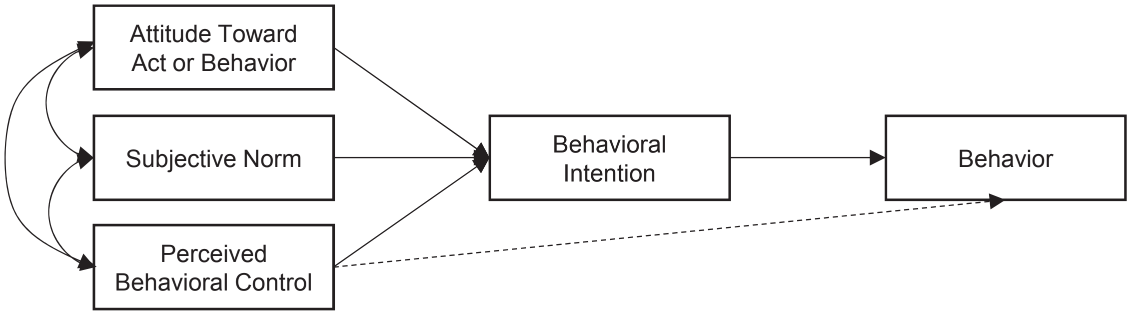
While the transtheoretical model offers a useful framework to plan and conduct behavior change processes – a second prevalent theory is also often used to understand and predict behavior change (Bandura 1977; Marcus et al. 1992). Self-efficacy is generally seen as an important starting point of individual behavior change practices (Bandura 1977). Bandura (1977) breaks the concept of self-efficacy down into two parts. On the one hand, *efficacy expectations* describe the belief of a person that one is able to execute certain actions in the course of a change process, e.g., exercising, stop drinking alcohol, etc. to reach the outcome. *Outcome expectations*, on the other hand, states that the person is confident that a particular behavior can result in the desired outcome (Bandura 1977). However, these two states of belief are differentiated because of a person's potential uncertainty. The belief that there is an actual behavior that can result in the desired outcome becomes irrelevant if the person has serious doubts in the own ability to conduct this behavior (Bandura 1977).

The individual's perceived efficacy expectation is based upon various sources of information allowing a person to assess their level of mastery for a certain behavior; more precisely, the ability of a successful adherence to a treatment or intervention (Bandura 1977). Bandura (1977) defines four key sources of efficacy information which impact an individual's evaluation of capability to comply with a proposed behavior. Own experiences of past actions constitute a strong parameter for future attempts for behavior change (Bandura 1977; Marcus et al. 1992). These experienced *(1) performance accomplishments* of a person have severe influence on the willingness of engaging in a proposed behavior and the estimation of success. Meaning, if a person has negative experiences with a similar task compared to the impending one, these negative experiences can lead to lower motivation to engage in this task (Bandura 1977). Analogously, observed *(2) vicarious experiences* come into account. Seeing other people coping with behavior change interventions, and witnessing positive outcomes for them can raise the readiness of an individual to try engaging in this behavior as well (Bandura 1977; Gifford 2011; He et al. 2010). Direct external influence in form of *(3) verbal persuasion* is considered as a weaker source of efficacy information due to the lack of concrete comprehensible evidence, because of missing self-experience of the given suggestions or shared experiences by others (Bandura 1977). Finally, *(4) emotional arousal* is considered as a determinant for self-efficacy. The fear of failure and the general anxiety about everything related to the behavior change process leads to a negative emotional state (Bandura 1977). It is important to identify ways to reduce the uncertainty regarding the process, and to strengthen coping skills by helping to handle stressful and threatening situations (Bandura 1977).

Alongside self-efficacy, additional factors have been proven as good predictors for behavioral change (De Vries et al. 1998). Despite the personal belief in the own ability to induce change, and the trust in the outcome and the effectiveness of the underlying processes, – attitude and social norm are also identified as key factors to predict behavior change (Ajzen and Fishbein 1977; De Vries et al. 1998). Compared to the concept of self-efficacy, attitude is defined as the general stance on an object or situation, more than the self-evaluation of having the ability to perform certain tasks to change ones behavior as specified for self-efficacy (De Vries et al. 1998). For example, a person struggling with the use of computers or technology in general might have a negative attitude towards the use of such technologies (Busch 1995). However, the same person can still belief in positive outcome expectations, as suggested by the concept of self-efficacy; meaning that the usefulness of this technology, e.g., to improve a certain process or behavior, is recognized by that same person (De Vries et al. 1998). Thus, the concepts self-efficacy and attitude share the nature of the cognitive perception of a concrete situation based on one's personal mind. In contrast to these two influencing factors to explain behavior change, social norm is concerned with the expectations of others, e.g., close social peers such as friends and family, or other helping or judgmental people, pertaining to an individual's behavior (De Vries et al. 1998). Social norm shows strong influence on a person's decision to engage in a behavior change process (Cialdini et al. 1991) besides the aforementioned predominantly personal perceptions of a situation or one's own abilities. The key factors of social norm are characterized as the opinions of others about the prevailing and the upcoming behavior, e.g., the intervention, and their respective outcomes (Schwartz 1977).

These three concepts of predicting behavior change: *self-efficacy*, *attitude*, and *social norm* have been manifested in general models to explain and predict behavior change. The theory of reasoned action (TRA) asserts that (*actual) behavior* is preceded by the intention to perform a concrete behavior (Ajzen and Fishbein 1977; Fishbein and Ajzen 1975). According to the theory, this *behavioral intention* is further determined by the concepts attitude and social norm. Hence, behavior is not directly influenced by personal cognitive information and social influence, but rather by the individual's intention of engagement in a particular behavior which is based on the given information and opinions of one-self (attitude) and the environment (social norm) (Ajzen and Fishbein 1977; Fishbein and Ajzen 1975). In an extension of the TRA the concept of *perceived behavioral control* was added to the model (Ajzen 1985). The concept of perceived behavioral control is adapted from Bandura's (1977) theory of self-efficacy. Based on this extension the theory of planned behavior (TPB) emerged (Ajzen 1985, 1991), becoming a cornerstone and the foundation for the measurement and prediction of behavior in various research fields and areas (Penttinen et al. 2014). The TPB comprises the three previously discussed concepts and their effect on the behavioral intention to perform a certain behavior, and ultimately the actual behavior (Ajzen 1991) as illustrated in Figure A-4.

Figure A-4: Theory of Reasoned Action Research Model (adapted from Ajzen 1991)



According to the TPB behavioral intention has immediate and strong influence on behavioral performance which is respectively determined by the aforementioned constructs of attitude, subjective norm, and behavioral control (Ajzen 1991). The measurements of the model's constructs and their relationships are based on determinants allowing an individual to express their agreement to a construct on a weighted scale (Montaño and Kasprzyk 2008). A person's evaluation of these determinants is influenced by their belief and motivation that a certain statement attributed to one of the constructs is applicable in the given context (Ajzen 1991; Montaño and Kasprzyk 2008).

Furthermore, motivation plays a key role in the attempt to explain and predict the readiness for behavior change. E.g., transferred on the TPB, motivation affects a person's attitude of acting towards a behavior (Gnoth 1997; Hsu et al. 2010; Montaño and Kasprzyk 2008). The motivation to adhere to the outcome expectations and forming the attitude of an objective situation is based on the individual's values and perceptions connected to this situation (Gnoth 1997). Meaning, that the assessment of effort, abilities, and expected outcome defines the determination for performance by a person – the motivation to act towards a certain behavior (attitude) (Gnoth 1997). This applies also to the positivity or negativity of the subjective norm. While subjective norm is determined by the perceived beliefs of others on the one hand, it is also influenced by the individual's motivation to comply with those beliefs on the other hand (Montaño and Kasprzyk 2008; De Vries et al. 1998). Hence, the willingness to adhere given normative beliefs has strong effect on a positive or negative weighted subjective norm (Montaño and Kasprzyk 2008).

Apart from the concrete case of the TPB motivation, in general, takes an important part throughout the entire behavior change process (Atkinson 1964; Boggiano and Barrett 1985; Deci and Ryan 1985a; Harackiewicz et al. 1987). As stated above, failing on a certain stage within the transtheoretical model of change and the corresponding fallback to a prior stage is associated with a lack of motivation to continue the behavior change process (Prochaska et al. 1992). Thus, it is desirable to overcome the emerging lack of motivation by employing adequate motivational techniques and mechanisms in order to stimulate re-engagement in the active stage of behavior change (Prochaska et al. 1992; Ryan and Deci 2000a).

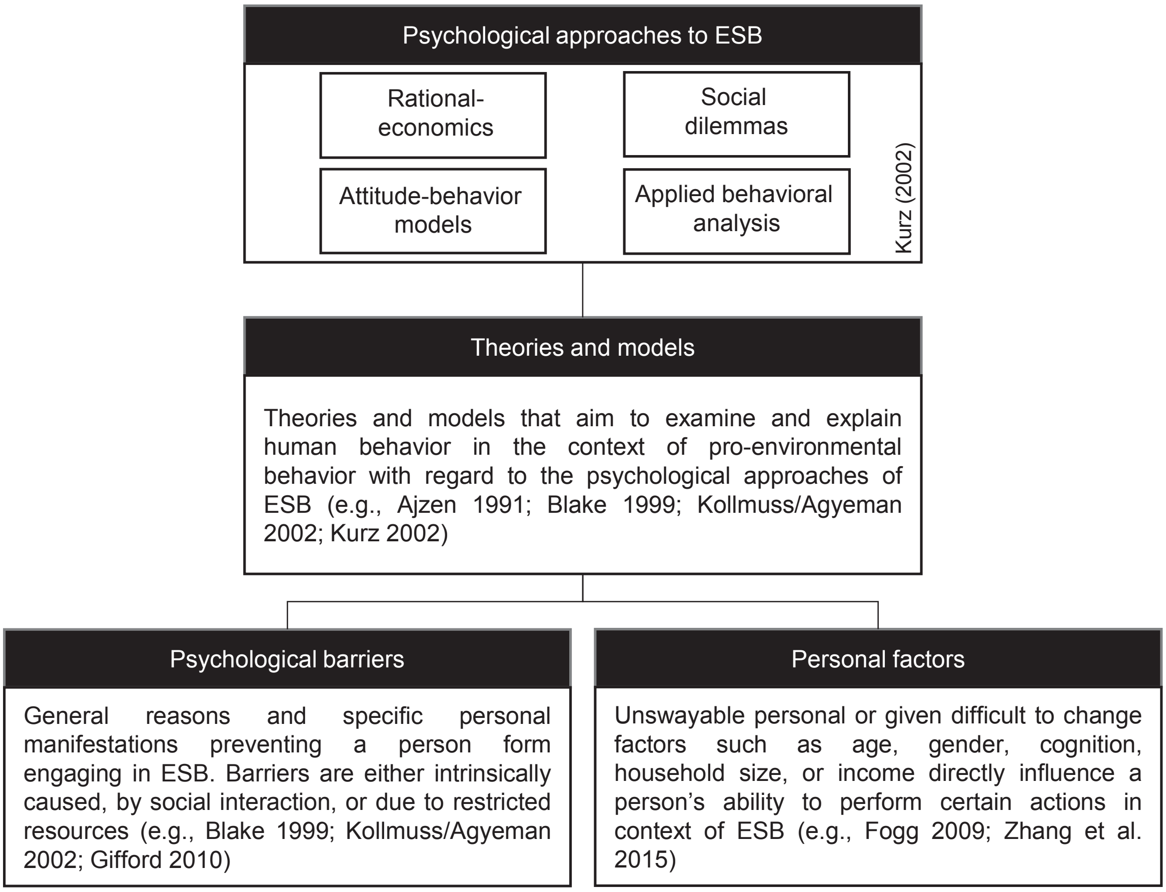
According to Ryan and Deci (2000a) there are not only different levels of motivation, i.e., the amount of motivation an individual has, e.g., to perform a certain task, but also different orientations of motivation. In this case, the orientation of motivation relies on a person's attitudes and goals to engage in a certain action (Ryan and Deci 2000b), and basically covers the question what drives a person to perform a certain action. This issue of the motivation behind people's choices is specifically addressed by the self-determination theory (SDT) (Ryan and Deci 2000a, 2000b). The SDT distinguishes between intrinsic and extrinsic motivation (Ryan and Deci 2000a). Intrinsic motivation describes a person's inherent will to perform a certain action, e.g., out of personal interest or because they value the underlying process of the action (Ryan and Deci 2000a, 2000b) as for doing sports to get in shape. Thus, an individual has a strong self-interest in the outcome of an action or the respective action associated with the desired outcome. On the contrary, extrinsic motivation is generated by external influences (Ryan and Deci 2000a, 2000b). In such cases the individual has little to no self-interest in engaging the impending task or the potential outcome (Ryan and Deci 2000a, 2000b).

Probably the most prominent implementation of extrinsic motivation is the use of monetary rewards where an individual is financially compensated for good performances. However, there are different types of external events to regulate behavior (Ryan and Deci 1987). Typical events are: rewards, threads and deadlines, evaluation and surveillance, choice, and feedback (Ryan and Deci 1987). Although, extrinsic motivation constitutes a promising approach to engage people in undesirable behaviors it also shows negative effects on prevailing intrinsic motivation (Gagné and Deci 2005). As for the aforementioned external events a multitude of studies show negative effects of the application of extrinsic motivation under existing intrinsic motivation (Barr 2007; Calder and Staw 1975; Ryan and Deci 2000b; Thom et al. 2012). Thus, the utilization of extrinsic motivation should be well-considered dependent on the underlying situation and the prevailing intrinsic motivation of the addressed individual.

2 Behavior Change in the Context of Environmental Sustainability

Initiatives with the goal to decrease environmental issues with the aid of people-oriented interventions recently gained increasing attention due to the continuous climate change (Kurz 2002). Such approaches constitute a promising enterprise to counter man-made causation of environmental degradation, exploit, and deterioration (Kurz 2002). However, as mentioned above, diverse application areas of behavior change initiatives require discriminative information and processes (Marshall and Biddle 2001). The classic and rigorously examined areas of behavior change in the medical or educational domain entail different approaches compared to pro-environmental behavior. In this context, many theoretical frameworks, models, and theories have been established in an attempt to explain the gap between existing environmental knowledge and awareness, and the actual pro-environmental behavior of people (Gifford 2011; Klöckner 2015; Kollmuss and Agyeman 2002; Lindenberg and Steg 2013; Steg and Vlek 2009). However, the versatility of the existing frameworks, models, and barriers aiming to explain pro-environmental behavior illustrates the complexity of the area of environmental sustainable behavior change (Kollmuss and Agyeman 2002). The following Figure A-5 gives an overview about the state of the art of Environmental Sustainable Behavior (ESB) approaches and is further described in the remainder of this section.

Figure A-5: Overview of Relevant Factors for Behavior Change



Generally, pro-environmental behavior describes people's actions to reduce their personal impact on the environment (Kollmuss and Agyeman 2002) and is influenced by many different factors (Barr 2007; Rees 2010). As mentioned before, the research field of ESB presents a complex topic which is addressed by various research domains, i.e., psychology, social sciences, environmental sciences, and IS (Barr 2007; vom Brocke et al. 2013b; Flynn et al. 2009; Gifford 2011; Kollmuss and Agyeman 2002). However, from the psychological perspective ESB can generally be broken down into four core approaches helping to outline, analyze, and explain the notion of ESB: *rational-economic*, *social dilemmas*, *attitude-behavior models*, and *applied behavioral analysis* (Kurz 2002).

Rational-economics states that people only engage in ESB when the action to be performed meets their financial interests (Kurz 2002). For example, the reduction of energy consumption in the private household, or the decrease of CO_2 emissions caused by private car-use could be achieved by using energy-efficient household appliances, or the substitution of the private car by a more efficient one or public transportation (Bamberg et al. 2007; Fischer 2008). Thus, a suitable counter-measure to tackle this issue would be to make sustainable alternatives more affordable (Kurz 2002). However, this might be a difficult task in practice. Another problem in this context is that people are often not aware of suitable substitutes, e.g., the existence of alternative sustainable products, and how these products could positively contribute to their ESB (Gonzales et al. 1988). An option to address this information asymmetry is the use of persuasive communication as a way to keep people informed about the market development (Gonzales et al. 1988; Mustaquim and Nyström 2014; Stern 2000).

Analogous to rational-economics *social-dilemma models* are also concerned with scarce resources. However, in this context the resource describes an environmental resource such as energy, water, etc. and their accessibility within a community rather than private financial resources as it is the case in rational economics (Kurz 2002). The dilemma describes the discrepancy of a person's interest in comparison to the collective interests within a community (Liebrand et al. 1992). Meaning, that the decision about the consumption of a certain resource within a social system is based on a person's assessment of the situation. Specific individual circumstances such as mistrust in the group can lead to detrimental outcomes for the group (Gifford 2011; Kurz 2002). Thus, a person might tend to maximize the own interests with malicious consumption behavior for the sake of the group and thereby create unsustainable behavior (Kurz 2002).

Complementary, *behavioral models* are utilized to examine the impacts of measures to trigger ESB as well as the immediate consequences of an individual's behavior induced by such measures. Behavioral models differ from rational-economics and social dilemma models in terms of scope and ascendency. While rational-economic focus solely on resources, e.g., money; behavioral models do not exclude any possible factors of influence on ESB such as any form of feedback, instructions, or others. Also the scope is exclusively on the single individual, independent of other persons or social groups, and their interaction (Kurz 2002). Exemplarily, in context of ESB the goal-framing theory[2] is frequently applied to identify an ideal set of interventions for an individual or a homogeneous group of people with similar interests (Lindenberg and Steg 2013). The theory claims that every person follows at least one intrinsic goal when engaging in an associated pro-environmental actions (Lindenberg and Steg 2013). According to the theory there are generally three overarching goals an individual aims to achieve during an ESB process: the normative, gain, and hedonic goal (Lindenberg and Steg 2013). The normative goal frame covers mechanisms to inform a person about the environmental impact of behavior, e.g., feedback about CO_2 emissions or resource consumption. The gain goal, on the other hand, focuses on information about personal resources, e.g., saved money or burned calories, for example, due to the use of the bike instead of the car (Lindenberg and Steg 2013). Hedonic goals support the playful aspect of a person (Lindenberg and Steg 2013). Common approaches to cover these interests are the implementation of interactive mechanisms allowing to track actions taken and to compare the outcomes and achievements with others, e.g., in form of a competition (Flüchter and Wortmann 2014; Loock et al. 2011). However, the utmost intent of the goal-framing theory is that a person's activated goal-frame is supported best possible by adequate measures (e.g., feedback, instructions, information, etc.) to increase the effectiveness of the intervention (Lindenberg and Steg 2013).

In comparison to behavioral models, *attitude-behavior models* examine not actual behavior performed by a person, their consequences, and the effects of antecedences, but aim to

[2] A detailed view on the Goal-Framing Theory is given in Study 4 of Part B.

understand, predict, and explain people's ESB on an abstract level (Kurz 2002). These models emphasize the importance of the relationship between a person's attitude towards ESB and the intention to execute the respective actions to change behavior (Kurz 2002). Well-established models in this context are the Theory of Reasoned Action (TRA; Fishbein and Ajzen 1975), the Self-Determination Theory (SDT; Ryan and Deci 2000b), and the Theory of Planned Behavior (TPB; Ajzen 1991) – introduced in Section A.II.1.1 – both forming the foundation for specialized derivations of attitude-behavior models in various contexts such as ESB. According to the TPB, attitude-behavior models in the context of ESB change focus on the identification of people's attitude influencing their view on ESB, and the deduction of ways to change people's attitudes towards ESB (Kurz 2002). There are several models exclusively dedicated to the examination of the gap between the attitude of ESB and the actual change of behavior (Kollmuss and Agyeman 2002).

The simplest model explaining the transition of people to engage in pro-environmental behavior describes a linear process triggered by environmental knowledge (Kollmuss and Agyeman 2002). The provision of situational and appropriate information about environmental issues was expected to create an environmental attitude that would lead a person to perform pro-environmental behavior (Burgess et al. 1998). However, studies showed that this assumption could not hold for practice, yet this basic approach to encourage people for pro-environmental behavior is still often practiced. Campaigns try to raise people's awareness about environmental issues by calling attention on an issue but lack follow-up actions to initiate people's engagement (Gifford 2011; Kollmuss and Agyeman 2002).

Analogous to the problem of the intention-behavior gap of the TPB several studies in the context of pro-environmental behavior show a discrepancy of people's attitudes and their actual behavior (Kollmuss and Agyeman 2002). Typical reasons for the deviation of people's attitudes and their behavior lies in experiences, normative influences, and temporal discrepancies (Rajecki 1982). Meaning, that individuals develop different attitudes towards pro-environmental behavior based on how they perceive their environment, and the way their surroundings behave. For example, a person directly undergoing the negative aftermath of environmental harm is more likely to be influenced towards engagement of pro-environmental behavior than somebody who learns about environmental issues in school or from television (Rajecki 1982). Likewise, if a person grows up in a community with unsustainable orientation, the person is less likely to become sensitized for environmental issues (Rajecki 1982). Temporal discrepancy describes the offset of information retrieval of a certain environmental problem, and the point in time of potential action. Meaning that a person's attitude about the initial problem can change over the time until the person is able to perform the required counter-action (Kollmuss and Agyeman 2002), e.g., the purchase of a more sustainable car or household appliances.

Based on the TPB the Model of Responsible Environmental Behavior (MREB; Hines et al. 1987) emerged. The MREB was one of the first models adjusting the TPB in the context of environmental sustainable behavior and aimed to tailor the behavioral model for the application in the ESB context. The model includes personal factors (attitude, locus of control, personal responsibility), knowledge of issues and action strategies, and action skills as determinants for the intention to act (Hines et al. 1987). However, the model still showed deficient performance explaining pro-environmental behavior (Hines et al. 1987; Kollmuss and Agyeman 2002). In this course Hines et al. (1986) identified additional factors that might influence pro-environmental behavior, e.g., economic constraints, social pressure, and opportunities to choose different actions composed as situational factors (Hines et al. 1987; Kollmuss and Agyeman 2002). Additional indicators for individual's pro-environmental behavior are models of altruism and empathy (Kollmuss and Agyeman 2002). Borden and Francis (1978) claim that the likelihood of a person to act pro-environmental is low when the person is particularly selfish or of competitive nature. On the other side, people with satisfied personal needs are more likely to perform pro-environmental behavior because they have the required resources (time, money, energy) available to engage in the corresponding actions.

Besides the aforementioned theoretical models, several psychological barriers have been identified hindering an individual engaging in ESB change processes (Gifford 2011; Kollmuss and Agyeman 2002). Psychological barriers describe factors leading a person to deny the performance of actions towards pro-environmental behavior. These barriers are highly individual, however, their sources are caused by both intrinsic and external by social contexts' (Blake 1999; Gifford 2011; Kollmuss and Agyeman 2002). Psychological barriers make another approach to examine and explain the gap between a person's intention, respectively the value of that action, and the eventual behavior (Blake 1999; Gifford 2011). The identification and composition of active barriers preventing people to practice pro-environmental behavior poses a complex topic which is being addressed by sociologists and psychologists for many years (Kollmuss and Agyeman 2002) and cannot be considered as complete.

Psychological barriers can basically be assigned into one of the three categories: *individuality*, *responsibility*, or *practicality* (Blake 1999). *Individual barriers* describe obstacles for ESB that either result out of a person's attitude or cognitive structure (Blake 1999; Kollmuss and Agyeman 2002). A typical cognitive related reason for refusing an action is the lack of knowledge (Gifford 2011; Kollmuss and Agyeman 2002). If a person is unaware of negative ecological influences because s/he is not directly affected, it is less likely that this person will engage in counter-actions. This Limited knowledge about environmental threads creates uncertainty about potential ESB within an individual (Gifford 2011). On the other hand, some people might also just be lazy (Kollmuss and Agyeman 2002) which can be more dangerous than expected, because a person might consider her/his-self sustainable because of some actions performed. These actions, however, might not have a big positive ecological impact. They may be easy to do and leave the person in a positive belief although there is only a minor positive effect compared to more exhausting and effective actions. This can lead to tokenism and limited behavior because the truth is not realized by the person. Moreover, a rebound effect might occur when follow-up actions take the opposite direction based on a shift in sustainable behavior; e.g. buying a fuel-efficient car might lead to more frequent or inefficient driving behavior because the car is thought to be more eco-friendly

(Gifford 2011). Besides this, habit takes a crucial role when it comes to behavior change aspirations. Long-term past behavior is hard to overcome and requires mental exertion and adequate treatments to trigger a change (Carrus et al. 2008; Kollmuss and Agyeman 2002).

In contrast, *responsibility* related barriers are caused by social factors (Blake 1999; Gifford 2011; Kollmuss and Agyeman 2002; Stern 2000). For example, a person might recognize that others or especially their peers probably do not act sustainable. This can cause the belief that either sustainable behavior is not important or undesirable (Corral-Verdugo et al. 2014). The later can cause the fear that if one engages in a sustainable life style, friends or colleagues will denounce them. Moreover, if others do not act sustainable it may arise the question why one should bring the effort engaging in a more sustainable lifestyle to make the world a better place (Blake 1999; Corral-Verdugo et al. 2014; Gifford 2011). In some cases people do not even believe in climate change and do not trust government and science about its causation and impact. Hence, those people are less likely to participate in actions to tackle the prevailing issues, if they do not share the ecological concerns and the magnitude of contribution counter-measures can have. Moreover, some people do not see the urge for personal efforts because of their ideological views of nature, humanity, and technological progress. They believe that nature does not need human intervention and expect that technological solutions will solve the prevailing ecological problems (Gifford 2011).

Besides intrinsic and social influences on people's intention and attitude to perform pro-environmental behavior (Ajzen 1991; Blake 1999; Kollmuss and Agyeman 2002; Kurz 2002) the lack of proper resources negatively influence the *practicality* of ESB, additionally (Blake 1999). People might not have the financial resources available to make costly investments, e.g., for new more sustainable household appliances, mobility, or energy sources (Blake 1999; Gifford 2011; Kollmuss and Agyeman 2002). Some do not have the time available to go the extra mile to perform ESB due to their jobs or recreational activities (Gifford 2011), are physically unable (Blake 1999), or lack the information what they could or should do in certain cases or the proper feedback on their prevailing behavior (Kollmuss and Agyeman 2002). From the motivational perspective the lack of proper incentives to perform ESB constitutes an additional barrier (Barr 2007; Fogg 2009a; Gifford 2011; Kollmuss and Agyeman 2002; Lindenberg and Steg 2013). Materialistic or virtual rewards in form of money or awards can positivley influence a person's attitude for ESB (Davis et al. 1992; Easley 2013; Graml et al. 2011; Stern 2000). However, as discussed in Section A.I.1.1, extrinsic motivation can also provoke the opposite effect (Barr 2007; Calder and Staw 1975; Ryan and Deci 2000b; Thom et al. 2012).

II.2 Green Information Systems and Persuasive System Design

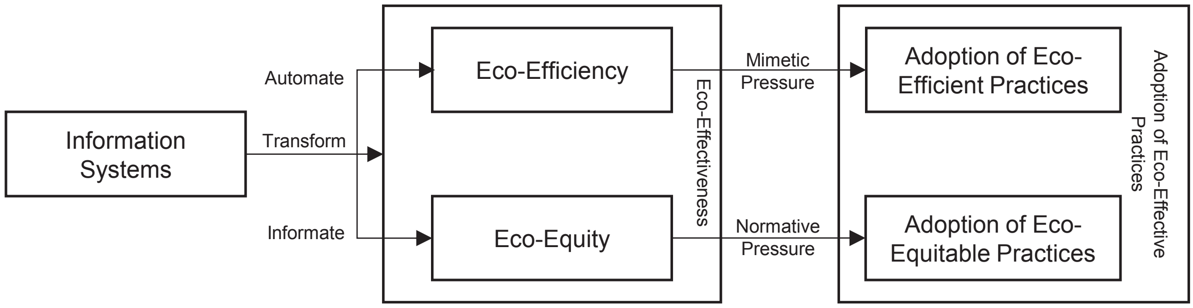
This sections gives a brief introduction about the role of information systems (IS) in the area of environmental sustainability, particularly the capabilities of IS to enable pro-environmental behavior change of individuals. In this context the design process of persuasive systems as an effective contributor to ESB is emphasized. The focus is set on promising design principles contributing to the optimal level of persuasion to be achieved by such a system.

1 Information Systems in the Context of Environmental Sustainability

The research field of Green Information Systems (Green IS) originates from the organizational context. Initially, the primary goal of this research domain was the reduction of negative environmental impacts of information technology (vom Brocke et al. 2013b; Dedrick 2010; Loeser 2013). As information technology and systems became increasingly critical for business processes and the creation of innovative business models and services, the volume of companies' IT-infrastructure drastically increased (Lyytinen and Rose 2003) concerning employee's workstations, back-end servers, production lines, etc. (Hilty et al. 2011). This volume of technology not only caused high costs for businesses due to acquisition costs and energy consumption but also lead to increased environmental harm (Dedrick 2010; Tushi et al. 2014). The rising energy demand of the infrastructure entailed soaring CO_2 emissions alloying the environmental life-cycle assessment of companies (Dedrick 2010; Loeser 2013; Tushi et al. 2014). Moreover, the disposal of outdated and broken systems generated huge amounts of electronic waste (Loeser 2013). To tackle these issues researchers deduced frameworks and guidelines for businesses to reduce the negative effects of existing and future IT-infrastructure on the environment (Loeser 2013). This research field became commonly known as Green IT, stressing the strong technological focus in terms of the impact of technical infrastructures on the environment (Hilty et al. 2011; Loeser 2013). Hence, Green IT was invariably concerned with the pro-environmental design of sourcing, operating, and disposal processes of infrastructural IT components (Loeser 2013; Melville 2010; Schmidt et al. 2010).

Gradually, the focus of research expanded from a strict technological view towards a system driven perspective and the exposure of their capabilities to contribute to environmental sustainability (vom Brocke et al. 2013b; Chen et al. 2009; El Idrissi and Corbett 2016; Loeser 2013; Melville 2010). Information systems were no longer solely viewed as environmental threats but considered as useful tools to actively help improving the environment. The concept of utilizing IS for pro-environmental practices became known as Green by IS/IT, respectively, later on widely accepted as Green IS (vom Brocke et al. 2013b; Chen et al. 2008; Dedrick 2010; Melville 2010). Historically, accordingly to Green IT, – Green IS emerged in the organizational context with the goal to design and produce green products in terms of the production process and the final outcome in form of products (Dedrick 2010; Hilty et al. 2011; Melville 2010). The designated role of information systems in this context is to support the achievement of organizational eco-effectiveness by transforming organizational relationships and their underlying institutional processes (see Figure A-6). IS-based solutions help to overcome organizational pressures regarding environmental problems by providing efficient technologies and tools to improve these processes. For example, IS allows to automate intra- and inter-organizational communication, e.g., by utilizing video-conferencing tools and electronic data exchange. This contributes to the environment in several aspects. The reduced need of physical interaction and materials contributes to the reduction of CO_2 emissions, e.g., caused by travelling, and pollution, e.g., reduced paper-waste (Chen et al. 2008; Watson et al. 2013). Moreover, IS can help to raise awareness of environmental problems and possible solutions by informing about such issues. For instance, employees can be informed about potential pro-environmental behaviors in the workplace that can help to overcome common environmental deficits. From another perspective, IS allow to monitor environmental data and report these information to the management. The data provided helps the management to initiate corresponding actions towards ecological improvements (Chen et al. 2008).

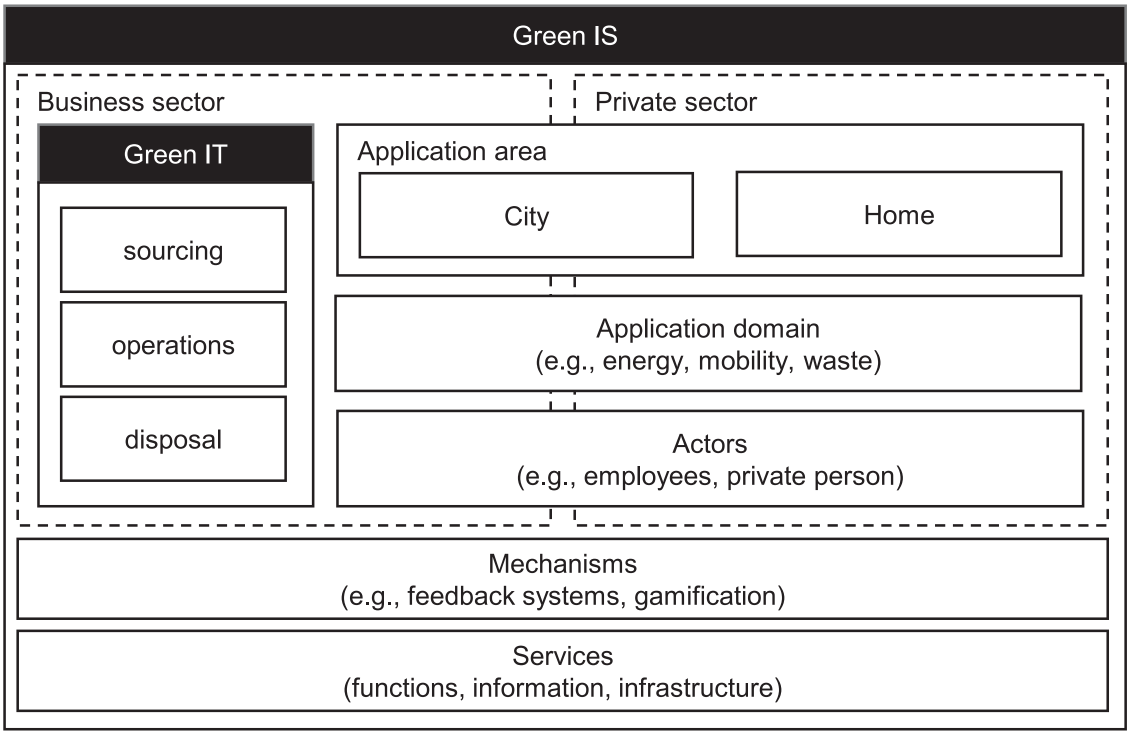
Figure A-6: The Role of IS for Environmental Sustainable Practices (adapted from Chen et al. 2008)



However, alongside the business sector, cities and particularly their citizen have a huge share on the production of greenhouse gas emissions (Lövehagen and Bondesson 2013) and the consumption of limited resources such as water and energy (Granath and Axelsson 2014). In conjunction with urbanization, climate change, and digitalization as global trends, cities gain an increased interest in the scientific field with the aim to reduce CO_2 emissions and saving resources by utilizing information and communication technologies (ICT) (Granath and Axelsson 2014; Lee and Lee 2014; Maccani et al. 2014). Consequently, the term smart city was established among researchers and in practice (Ojo et al. 2014). While the term is still fuzzy and lacks a consistent definition, the use of ICT and the topic of environmental sustainability are often described as a crucial part (Caragliu et al. 2009; Lövehagen and Bondesson 2013; Neirotti et al. 2014; Ojo et al. 2014). ICT can be utilized in several ways to reach the goal of CO_2 reduction and preserving resources (Kramers et al. 2013). For example, smart meter are considered to monitor the energy and water consumption in workplaces and private households (Corbett 2013a; Giurco et al. 2010); interconnected sensors can be used outdoor to monitor the environment and report the data sensed to the city administration, where the data is interpreted and actions are taken (Sanchez et al. 2014). In a similar fashion, citizen can be utilized as real-time, mobile sensor-nodes for monitoring purposes using their own devices such as smartphones or wearables (Ganti et al. 2011).

The general concept of Green IS is illustrated in Figure A-7. The different scopes of the research domain (business sector and private sector) are likewise addressed by appropriate mechanisms and services to achieve organizational eco-effectiveness and people’s pro-environmental behavior (Watson et al. 2013). These mechanisms are implemented as functions within a Green IS in order to provide the information required for the actor (user), and are embedded in or extent the prevailing organizational or municipal infrastructure (Hjalmarsson et al. 2011; Kurnia and Gloet 2012). The aggregation of functions, information, and infrastructure compose services offered to a user via an IS interface.

Figure A-7: Classification of Green IT and Green IS Based on their Scope



In the Green IS context information systems are primarily considered and used as facilitators, motivators, activators, and promoters for pro-environmental behaviors (Dahlinger and Wortmann 2016) in both specified scopes: the business-, and private sector.

The predominant implementation of Green IS utilize feedback mechanisms to keep an individual informed about environmental issues (El Idrissi and Corbett 2016). Generic feedback systems allow a dialog with the user and provide critical data for behavioral adaptions to reinforce pro-environmental behavior (El Idrissi and Corbett 2016). Typical implementations of pro-environmental feedback systems monitor user-behavior, e.g., resource consumption such as water or energy (Loock et al. 2013; Sønderlund et al. 2014), or causation of CO_2 emissions, e.g., due to travel behavior with the aid of sensors or by manual input (Flüchter and Wortmann 2014; Tulusan et al. 2012). The data gathered is processed and returned to the user with corresponding suggestions for change, e.g., in conjunction with data from experts or expert systems in order to reduce the individual environmental threat (El Idrissi and Corbett 2016).

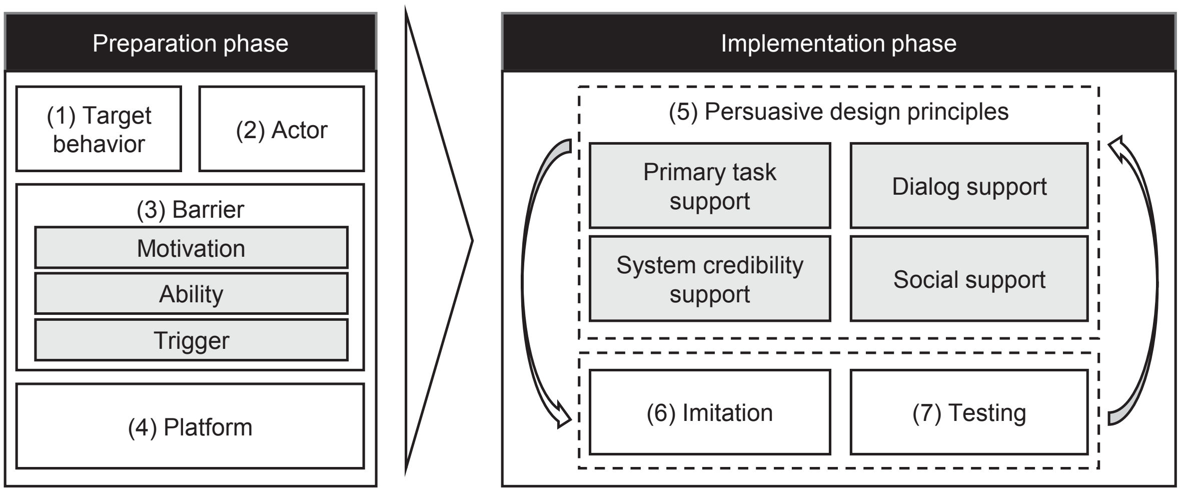
However, common feedback systems primarily serve as sole information provider and do not aim to further support the user beyond this purpose. In Contrast, advanced feedback based implementations with the aim to promote pro-environmental behavior often use game elements as an extension of the feedback mechanism to additionally increase the user's motivation (Huotari and Hamari 2012; Loock et al. 2013). Hence, the concept of gamification has been applied in several domains as such a mechanism (Hamari 2013; Kankanhalli et al. 2012). Gamification describes an approach that primarily attempts to influence user behavior by applying game-design elements to transform consumer activities in game-like experiences (Blohm and Leimeister 2013; Lounis et al. 2014). It is composed of both intrinsic and extrinsic motivation, where the intrinsic motivation aims to increase user satisfaction, conveyance of optimism, facilitation of social interaction, and provision of meaning; whereas extrinsic motivation aims at external goals like, but is not limited to, financial compensation (Blohm and Leimeister 2013). The gamification mechanism serves as a facilitator for the interaction between the user and the information system and addresses the motivational affordances of people regarding their motivational perspective on the system and its usage (Hamari et al. 2014; Zhang 2008). Thus, the design of systems with the goal to influence behavior needs to be aligned to the user's preferences. This concerns the user's expectations of the implemented feature's functionalities, and the perceived helpfulness to support their tasks. However, the compliance of implemented design principles depends on the individual, the underlying task, and the applied context (Zhang 2008). Therefore, different variants of game-mechanisms are used to target individual's varying motivational affordances of system usage (Hamari et al. 2014; Thiebes et al. 2014; Zhang 2008). The most common implementations of such game-mechanisms address the competitive and self-monitoring nature of people by designing applications using point systems, leaderboards, or achievements in form of virtual badges (Hamari et al. 2014). However, apart from the focus on playful design of information systems, perceived affordances of system helpfulness play a key role in the context of utilizing IS to persuade people towards behavior change (Kurz 2002; Lehto et al. 2012). Persuasive systems cover various functions to trigger and support behavioral change processes of their users (Lehto and Oinas-Kukkonen 2015; Oinas-kukkonen and Harjumaa 2009). The critical challenge for developers of persuasive systems is to design the application in such a way that the functions implemented address the user's needs and expectations in the best possible way (Lehto et al. 2012; Shevchuk and Oinas-Kukkonen 2016; van Vugt et al. 2006).

2 Persuasive System Design

Innovative and pervasive technologies allow the ubiquitous location-independent information supply in a timely manner (Woodruff and Mankoff 2010). Smartphones, tablets, and other smart devices such as wearables in form of smart watches or smart glasses accompany us in our daily life. These technologies offer multi-purpose platforms for data collection and information distribution (Davis 2012; Graml et al. 2011; Woodruff and Mankoff 2010). Intelligent and interactive applications running on those devices can help people to change behavior in various domains, e.g., health, education, or environmental sustainability (Filippou and Cheong 2015; Langrial et al. 2012; Shevchuk and Oinas-Kukkonen 2016).

Persuasive systems aim to increase an individual's likeliness to perform a targeted behavior change (Fogg 2009a). This persuasion is induced by appropriate measures to increase motivation, support a person's ability to engage in the change process, and the provision of proper triggers to initiate a specific behavior at the right time (Fogg 2009a). Equivalent to the general procedure of software development, the design and implementation process of persuasive systems follows a structured approach (Fogg 2009b; Oinas-kukkonen and Harjumaa 2009). The general development process can be divided into a structural preparation phase and a technical oriented implementation phase (see Figure A-8).

Figure A-8: Design Process of Persuasive Systems (adapted from Fogg 2009b; Oinas-Kukkonen and Harjumaa 2009)



The preparation phase covers coordination processes concerned with the strategic orientation of the artifact. Initially, the target group is specified which will be addresses by the system developed (Fogg 2009b). Different user groups have deviating demands on system requirements and require different types of interventions to induce behavioral changes (Balci et al. 2014; Kurz 2002). In this context it is also critical to specify the desired target behavior pursued by the application. Because behavior change poses a complex issue it is wise to break down the comprehensive change process into individual easy to execute tasks (Fogg 2009b; Oinas-kukkonen and Harjumaa 2009).

In order to design the corresponding functions as suitable as possible to meet the user's affordances, the individual prevailing barriers that prevent a person from engaging in the change process need to be identified and addressed accordingly. Reasons for failed engagement in the change process can lie in a general lack of motivation, limited abilities to perform the respective actions for change, or the absence of an appropriate and timely trigger (Fogg 2009a).

According to Fogg's Behavior Model (FBM) (Fogg 2009a) there is a trade-off situation between motivation and ability to perform a certain behavior. The users of persuasive systems can be highly heterogeneous and therefore differ in their motivation and ability to engage in the behavior change process and the underlying tasks. In an optimal scenario the system developer would address both barriers as good as possible. However, given the problem of heterogeneity of people's affordances, the functions to support both dimension need to be stressed differently for each user-group. For instance, one group might be highly motivated to perform the respective task but lacks the ability to do it. Hence, this group requires more emphasis on functionality to support the user to increase their ability or mitigate the prevailing barrier limiting the ability. Vice versa, people with low motivation and high ability require emphasis on functions to increase their motivation (Fogg 2009a).

When both motivation and ability are properly aided by the system the likelihood for a person to engage in the task is maximized (Fogg 2009a). However, according to the FBM the sole presence of motivation and ability alone might not be sufficient (Fogg 2009a). Fogg (2009a) suggests the implementation of concrete triggers that directly address the user about the opportunity to perform a certain action connected to the target behavior. Triggers are functions that support the user to perform a task at a given appropriate time with adequate instruments. For instance, the system can provide the user with motivational or instructional videos or messages to increase motivation or ability or use simple reminders (Fogg 2009a).

Hence, the selection of an appropriate technology channel as platform for the persuasive system has to be carefully considered (Fogg 2009b). In some cases it can be helpful and required to use stationary devices such as personal computers, e.g., due to high complexity or high demands for computational resources, i.e., for virtual realities. In other cases, the focus lies on spatial mobility and timeliness, e.g., the extensive use of scheduled triggers. Then the choice of the platform would favor mobile devices like smartphones, smartwatches, or other wearables.

The realization of persuasive systems is technologically driven by the implementation of concrete functions (Torning and Oinas-kukkonen 2009). Literature on the design of persuasive systems categorizes the recommended design principles in four general categories (Shevchuk and Oinas-Kukkonen 2016). The categories cover and describe suitable system principles (see Table A-5) for successful persuasion. The design principles describe concepts that are designated to be transformed into particular operational functions (Oinas-kukkonen and Harjumaa 2009; Torning and Oinas-kukkonen 2009).

Table A-5: Overview of Persuasive Design Principles (adapted from Oinas-Kukkonen and Harjumaa 2009)

Category	Persuasive Design Principles (concepts)
Primary Task Support	Reduction, Tunneling, Tailoring, Personalization, Self-Monitoring, Simulation, Rehearsal
Dialogue Support	Praise, Rewards, Reminders, Suggestion, Similarity, Liking, Social Role
Credibility Support	Trustworthiness, Expertise, Surface Credibility, Real-World Feel, Authority, Third-Party Endorsements, Verifiability
Social Support	Social Facilitation, Social Comparison, Normative Influence, Social Learning, Cooperation, Competition, Recognition

The categories cluster the design principles based on their purpose. Thus, concepts assigned to the category primary task support are concerned with the target behavior of the user (Torning and Oinas-kukkonen 2009). The design principles aim to customize the systems for the needs of the user in terms of information flow, complexity, and user-friendliness. For instance, self-monitoring allows the user to retrieve feedback about the own behavior and the impact on the target behavior (Oinas-kukkonen and Harjumaa 2009). Whereas the complexity of tasks to achieve the target behavior is broken down into simple, easy to follow tasks to reduce the complexity of the complete behavior change process (Oinas-kukkonen and Harjumaa 2009). Other concepts underline the importance of usability by tunneling or guiding the user through the entire change process, or the option to personalize the system regarding look and feel, and the selection of user-relevant functions (Oinas-kukkonen and Harjumaa 2009). Design principles of the dialogue support category focus on the interaction between the system and the user (Oinas-kukkonen and Harjumaa 2009). Praise and rewards are used to increase the user's motivation not only to engage in the change process itself but also in system use. Mechanism like gamification are often used as templates for the implementation of such functionalities (Koivisto 2013). Conformable to the FBM, reminders and suggestions for appropriate tasks also fall in this category as measures for successful intervention (Fogg 2009b; Oinas-kukkonen and Harjumaa 2009). For the conviction of behavioral change it is important that the supportive system is trustworthy and credible. Users could refrain from using a system if they feel that they could not trust it and that the information provided does not ground on reliable sources. Thus, system credibility aims to create trust by conveying the reliability and verifiability of the system to the user (Oinas-kukkonen and Harjumaa 2009). The last category, social support, intends to utilize the positive effects of social interaction and influence on the behavior change process (Oinas-kukkonen and Harjumaa 2009). As research from the psychological and social sciences show (see Section A.I.1.1) social interaction can have critical impact on the success of behavior change interventions. Thus, the assigned concepts involve the facilitation of social interactions through the technical implementation of cooperation, comparison, or competition (Oinas-kukkonen and Harjumaa 2009).

Successful design and implementation of persuasive systems does not only rely on well-derived theories and extensive frameworks but is also geared to the experiences, success, and problems of existing solutions (Fogg 2009b). Thus, it is recommended to observe, examine, and imitate prevailing systems from different domains to learn lessons about their issues and success, and to gain inspiration (Fogg 2009b). The selected concepts should be tested quickly and repeatedly in an iterative manner to ensure the adequateness of the implemented design principles in the given context (Fogg 2009b).

Although persuasive systems, and research about their design has a long history starting in the early 2000s (Fogg 2009b), – the application of such systems in the context of pro-environmental behavior represents a relatively young field in IS research (Shevchuk and Oinas-Kukkonen 2016). Therefore, little is known about the effectiveness of single design principles and the general attitude and acceptance, and willingness of users to use such systems in the context of environmental sustainability behavior.

II.3 User Acceptance and System Adoption

With the diffusion of information technologies and systems in the work environment and personal everyday life the need for measures to facilitate system adoption of the end-user became increasingly important (Davis 1989). A system – no matter how helpful it might be to support organizational processes or daily life activities – is only used if it meets the user's needs and affordances for usefulness and user-friendliness (Seidel et al. 2013; Volkoff and Strong 2013; Zhang 2008). Particularly, the constant increase of investments in business application architecture and the associated share of failed software introduction projects due to a lack of system acceptance and adoption by the end-user shows the importance of examining the user's perspective on newly introduced information systems (Dillon and Morris 1996; Neufeld et al. 2007; Sun and Zhang 2006).

The term user acceptance is defined as the willingness of individuals or user groups to employ information technologies or systems that support them with their tasks in a work-environment or undertakings in private life (Dillon and Morris 1996). User acceptance research aims to explain and predict the intention of a potential user to use certain systems as well as the actual use. The examination process covers opinions, reactions, and attitudes among various other factors as indicators for system adoption (Hung et al. 2006). The explanation and prediction of user acceptance constitutes one of the most mature and frequent research area in IS research, and one of the most challenging issue (Davis 1989; Venkatesh et al. 2003). A multitude of research models with numerous constructs emerged from various studies in different application domains, e.g., health, education, or business and industry leading to a substantial pool of options to examine user acceptance of IS (Venkatesh et al. 2003).

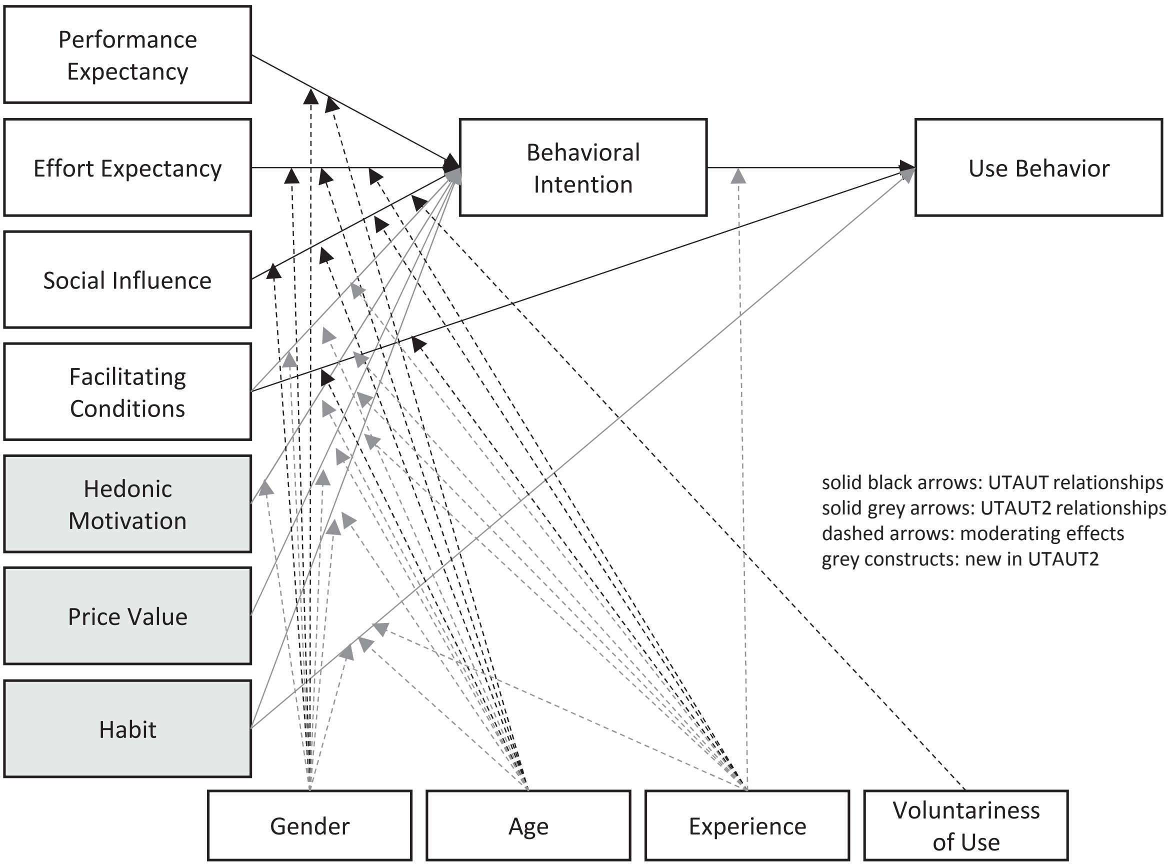
Historically, user acceptance in IS research derived from early studies in psychology and social sciences (Davis et al. 1989). Research models like the Theory of Planned Behavior (TPB) and Theory of Reasoned Action (TRA) form the foundation of current IS oriented user acceptance studies and their applied models (Davis et al. 1989). The first widely used adaption in this context constitutes the Technology Acceptance Model (TAM) by extending the basic concept of the TRA by a computer-system oriented perspective (Davis 1989). This IS perspective is represented by the integration of the two constructs perceived usefulness and perceived ease of use into the TRA (Davis 1989) developed by Fishbein and Ajzen (1975). These two constructs of the TAM (see Figure A-9) aim to quantify and measure system related characteristics with influence on a user’s decision for system acceptance (Davis et al. 1989). The construct perceived usefulness measures the perceived helpfulness a system provided to the user to execute the underlying tasks (Davis et al. 1989). Ease of use, on the other hand, mainly focuses on the interaction of the user with the system (Davis et al. 1989). Relevant indicators are, i.e., usability criteria such as interface design, user-system dialogue, or system-response (Davis et al. 1989). The TAM shows great potential and evolved as a robust tool to measure user acceptance of IS (Grover and Lyytinen 2015; Venkatesh et al. 2007).

Figure A-9: Technology Acceptance Model (adapted from Davis et al. 1989)

However, with the continuous evolution of acceptance research in the IS domain the need for more comprehensive models emerged in order to cover more potential influences on system acceptance, and thereby increase the explanation power for system acceptance and adoption (Venkatesh et al. 2007). Various iterations of the TAM were developed with the introduction of new constructs to address these requirements (Barki 2007; Venkatesh et al. 2007).

Ultimately the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al. 2003) emerged as comprehensive research model to examine and explain user acceptance of IS with high explanation power due to the integration of additional constructs and moderators (Venkatesh et al. 2003). One additional key goal of the UTAUT is the model's fit beyond the organizational context (Venkatesh et al. 2012). Whereas the TAM originates in the business realm with scope on mandatory enterprise-software use – the UTAUT is tailored for the use outside business boundaries, and makes it applicable to other domains with voluntary system-use scenarios, e.g., for consumer technologies (Venkatesh et al. 2012). This is distinctly embodied through the further extension of the UTAUT2 (see Figure A-10) by the introduction of the constructs price value, habit, and hedonic motivation (Venkatesh et al. 2012).

Figure A-10: Unified Theory of Acceptance and Use of Technology (2) (adapted from Venkatesh et al. 2003; Venkatesh et al. 2012)



The UTAUT2 constitutes the state of the art research model for the measurement, explanation, and prediction of user acceptance of information systems (Dwivedi et al. 2011; Williams et al. 2011). However, the research model serves as a suggestion for the effective and reliable measurement of user acceptance based on academically deduced constructs, and is highly adaptable in terms of the applied context. Thus, the substitution and extension of the model with different constructs, moderators, and varying relationships is a common practice (Williams et al. 2011).

B. Studies on User-Centric Environmental Sustainable Information Systems

After a thorough presentation of the thesis' overarching goal in Part A, the second part represents the corpus of this thesis. The defined research questions presented in Part A are successively answered in the following part. Part B is composed of three chapters (B.I-B.III) representing the core building blocks of this thesis. Each chapter is dedicated to one respective research question presented in section A.I.2. The first chapter examines the status quo (B.I) of Green IS research with two studies. In the second chapter of Part B a deep dive into behavioral theories and technical mechanisms is performed (B.II) with two additional studies. This second chapter sheds light on the supportive potentials of information technologies for pro-environmental behavior change. Finally, the third chapter (B.III) covers the design of user-centric Green IS solutions with focus on user acceptance with one study. All chapters of Part B together draw a holistic picture of the topic and add to the realization of the overarching research goal of this cumulative thesis.

I. Status Quo

The first building block of this cumulative thesis provides an overview about the status quo of Green IS research and existing practical advances to pursue people towards pro-environmental behavior. This chapter consists of two distinct studies with separate foci. The first study (B.I.1) examines the status quo of Green IS from the research perspective by conducting two distinct literature reviews about the state of the art of Green IS research in the smart city context. This approach aims to reveal current attempts and research gaps for the application of Green IS outside the organizational context. In this vein, the second study (B.I.2) addresses this research enterprise from a practical viewpoint. Study 2 analyzes the market about existing user-centric Green IS solutions and analyses the applications revealed along various dimensions.

I.1 Study 1: The State of the Art in Smart City Research – A Literature Analysis on Green IS Solutions to Foster Environmental Sustainability

Table B-1. Fact sheet of study no. 1

Title	The State of the Art in Smart City Research – A Literature Analysis on Green IS Solutions to Foster Environmental Sustainability
Authors	Benjamin Brauer*, Matthias Eisel, Lutz M. Kolbe Chair of Information Management, Georg-August-University Göttingen, 37073 Göttingen, Germany *Corresponding author. Tel.: +49 551 39 2 11 70. E-Mail address: bbrauer@uni-goettingen.de
Outlet	Proceedings of the 20th Pacific Asia Conference on Information Systems (PACIS), July 5-9 2015, Singapore.
Abstract	Environmental sustainability is one of the most critical issues worldwide, concerning every individual. The main objective in this area is to preserve scarce resources and reduce CO_2 emissions in order to prevent environmental degradation. In recent years the potential of information systems (IS) as a driver for environmental sustainability has emerged under the term “Green IS”. Given that cities represent a huge share of environmental degradation due to factors such as mobility, energy and water consumption, and waste production, the municipal domain offers huge potentials in terms of sustainability. The advent of smart cites is an attempt to address this concern. In this paper we aim to provide an overview of current publications on environmental sustainability in smart cities, as research in this field is still unstructured. This paper focuses on structuring the research field by providing a research framework to achieve a more holistic view on the application of Green IS. We distinguish between research performed by the IS community and that of related fields, such as urban development, and perform a cross-sectional, exhaustive literature analysis with almost 1,500 articles to uncover the differences and commonalities between the domains.
Keywords	Smart City, Green IS, Environmental Sustainability, Green Society

1 Introduction

Environmental sustainability presents a crucial topic in IS research (Watson et al. 2013) and is addressed in two different approaches: Green IT and Green IS (Loeser 2013). Whereas Green IT considers information technology (IT) to be a cause of environmental pollution, Green IS regards information systems and the inherent IT involved as a possible solution for reducing environmental degradation (Chen et al. 2009). Thus far, a plethora of research has been conducted in the field of Green IT with the goal of reducing CO_2 emissions caused by IT (Dedrick 2010; Tushi et al. 2014). Contrastingly, little research has been performed on Green IS – utilizing IS as an enabler for environmental sustainability (Melville 2010) – and the pace of research is still slow (vom Brocke et al. 2013a).

Though early calls for Green IS research within the IS community demonstrate the relevance of the topic and the important role of IS in fostering environmental sustainability, they mainly focused on the organizational context (Chen et al. 2009; Dedrick 2010; Melville 2010). However, alongside businesses and the energy sector (Watson et al. 2013), cities – and particularly their citizens – represent a huge share of the production of greenhouse gas emissions (Lövehagen and Bondesson 2013) and the consumption of limited resources such as water and energy (Granath and Axelsson 2014). In conjunction with urbanization, climate change, and digitalization as global trends, cities have been seeking to meet their climate targets by introducing information and communication technologies (ICT) (Kramers et al. 2013) while demonstrating increased interest in the scientific field with the aim of reducing CO_2 emissions and saving resources through the utilization of ICT (Granath and Axelsson 2014; Lee et al. 2013a; Maccani et al. 2014). Consequently, the term “smart city” was recently established among researchers and in practice. While the term still lacks a consistent definition (Ojo et al. 2014), the use of ICT and the topic of environmental sustainability are often described as crucial elements of its concept (Caragliu et al. 2009; Neirotti et al. 2014; Ojo et al. 2014).

IS can be implemented in various ways to reach the goal of CO_2 reduction and resource preservation (Kramers et al. 2013), leading IT corporations to see a potential market for smart city–oriented IT solutions for supporting city administrations in their endeavor toward a smarter city infrastructure (Paroutis et al. 2013). In this paper we aim to outline the current state of Green IS research in the domain of smart cities and identify the potentials of IS solutions, resulting in the following two research questions:

RQ1: *What is the state of the art of Green IS research in the smart city domain within the IS community?*

RQ2: *How do other research domains address the adoption of IS to improve environmental sustainability in smart cities, and how does this compare to the IS community’s approach?*

Thus, the goals of this research are to connect two emerging and promising research fields – namely, Green IS and smart cities – by providing insight into the employment of information systems for improving environmental sustainability in the municipal context and to identify shortcomings and gaps in existing research. Furthermore, we define the role of the IS community in this novel research field and answer the call for Green IS research by unveiling a new domain for Green IS research within the IS community. Based on our findings from the literature, we propose a conceptual framework to guide further research in the research field of sustainable information systems solutions in the smart city context.

The remainder of the paper is structured as follows. We first offer a brief insight into smart city and Green IS research and set the scope of the research process, which provides a foundation for the literature evaluation process. Next, we outline the process of literature selection and analysis before presenting and discussing the analysis results. We close with a short conclusion summarizing the key findings and offering an outlook for further research.

2 Related Work and Research Scope

The concept of smart cities is very broad and concerns a huge variety of tasks, including the improvement of governance processes, the optimization of service provision toward citizens, and the provision and management of information (Nam and Pardo 2011). However, this is just a small subset of what describes the idea behind building smarter cities. To date, the term “smart city” is not yet clearly defined (Lövehagen and Bondesson 2013), as it poses a complex area with several domains, actors, and processes, each with different goals (Kramers et al. 2013). This is further illustrated by the various terminologies that are used synonymously to describe the concept of supplementing urban structures with ICT in research and practice – intelligent city, knowledge city, sustainable city, future city, digital city, innovative city, etc. (Adepetu et al. 2014; Kutami 2014; Lee and Lee 2014; Qingrui et al. 2012; Rezendea et al. 2014) – based upon the respective goals pursued (Kramers et al. 2013). All these concepts strive to modernize cities by improving a city’s growth, service provision, infrastructure (Anttiroiko et al. 2013), and ultimately, its welfare, productivity, and quality of life (Nam and Pardo 2011; Shapiro 2014) by focusing on various key elements, such as knowledge transfer, improvement of infrastructural components, and environmental aspects. Technology plays a major role in all these concepts (Caragliu et al. 2009) and acts as an enabler for ideas and processes to attain the respective goals. Several frameworks and architectures have been designed to describe and sketch smart cities and structure further research agendas (Balakrishna 2012; Chourabi et al. 2012; Debnath et al. 2014; Gil-garcia et al. 2013; Jin et al. 2014; Nam & Pardo 2011; Su et al. 2011). Due to the novelty of smart cities as a research field, these approaches are rather generic and outline the general idea of smart city initiatives. For example, Balakrishna (2012) proposes a broad smart city architecture that consists of six dimensions – environment, economy, people, governance, living, and mobility – that are underpinned by three building blocks (sensors, network infrastructure, and data management) and autonomous decision making, reflecting the broad spectrum of this area. Based on existing research, we focus on a specific subset by assessing smart cities from the environmental dimension and are interested in the ecological goals pursued by the authors. We therefore distinguish between the reduction of environmental pollution, e.g., CO_2 emissions or waste, and the preservation of resources, such as water or energy (Granath and Axelsson 2014; Kramers et al. 2013), achieved by the utilization of information systems (Su et al. 2011), referred to in this context as Green IS.

The research field of Green IS has been garnering increased attention in the IS community within recent years. Green IS are defined as IS products that support the achievement of sustainability initiatives (Chen et al. 2009) as compositions of physical technological entities and software components. Furthermore, this definition can be extended by practices and processes that are enabled by these IS products and contribute to ecological performance improvements (Melville 2010). Vom Brocke et al. (2013) propose five directives for future Green IS research and development, arguing for intensified research concerning IS artifacts in order to address practical issues and for the consideration of insights and solutions from non-IS research fields to enrich IS research in this area. In this vein, we address these perspectives by focusing on concrete Green IS solutions from both the IS community and non-IS research areas that address environmental sustainability. However, the definition of the term “Green IS” in the literature is very vague; it is often merely described as an information system that contributes to environmental sustainability (Chen et al. 2009) and is thought of as an enabler for the change toward sustainable behavior (vom Brocke et al. 2013b). In order to widen the research of Green IS to other areas and away from the business focus, we strive to extend Green IS research to new potential application areas and thus increase the impact of sustainable IS solutions. Based on Watson et al. (2013), who defined the field of energy informatics as a subfield of IS and thereby narrowed the scope of Green IS to the energy sector, we define Green IS for the city context: *A Green IS in the smart city context supports city planners to promote environmental sustainability and provides citizens the opportunity to contribute to ecological improvements or triggers the change toward sustainable behavior*.

Thus, three dimensions arise as the foundation of our research interest (*information systems*, *environmental sustainability*, and *cities*) to address the questions of how, where, by what means, and by whom environmental sustainability can be achieved in urban structures. To provide the reader with an insight into our research focus and the literature selection and review process, we present a short definition of the individual key points to sharpen the scope of our research procedure.

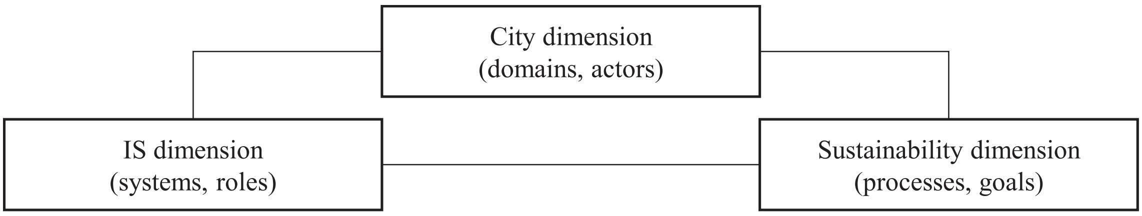
As we aim to assess the impact of information systems and their underlying technologies on ecological sustainability in the city context, we are exclusively interested in the contribution of IS to improving environmental sustainability. We therefore omit every article that focuses solely on social or economic sustainability as elements of the triple bottom line of sustainability (Dao et al., 2011). The focal points of this dimension are the goals pursued concerning environmental sustainability and the underlying processes, answering the questions of what can be done to improve sustainability and how these goals can be achieved from a strategic viewpoint. The classification concerning the sustainable contribution is conducted based on the three milestones of ecological sustainability: eco-efficiency, eco-ubiquity, and eco-effectiveness (Chen et al. 2008).

The city dimension is divided into domains and actors, as these are essential entities concerning the introduction of ICT solutions for improving environmental sustainability. The actors are either responsible for the utilization of IS or direct users, while the domains within cities are highly diverse and involve various key aspects concerning the fulfillment of sustainability goals. As a first approach to clustering solutions in terms of the application domain, we use the extensive and well-derived classification of smart city domains by Neirotti et al. (2014) – with adjustments toward the ecological focus of this paper – as a starting point for further assessment. In this context, the domains describe the areas within the city where IS are deployed to foster environmental sustainability and are represented by *transportation*, *infrastructure*, and *buildings*. The transportation domain covers all forms of mobility, e.g., public transportation; infrastructure comprises the provision and management of the basic needs of citizens, such as water supply, energy grids, and waste management; and buildings encompasses everything that addresses the consumption of resources or the production of emissions in public or residential facilities. The second part is represented by the actors involved, as we are interested in the audience of the IS solutions presented in the articles.

Regarding the IS perspective, we are interested in the strategic role and characteristics of the information systems used. The systems are categorized in automate, informate, and transformate (Dao et al. 2011; Dehning et al. 2014), according to their intended purpose. Automate refers to the execution of processes by ICT and the reduction of resources used to fulfill a task; informate provides information in order to adjust actions, e.g., decision support systems (DSS); and transform describes the redefinition of capabilities and processes to reshape and improve existing processes or generate new services (Chen et al. 2008; Dao et al. 2011; Thambusamy and Salam 2010).

The scope of research results in a research framework with three dimensions that form the basis of this paper's literature search and selection process (Figure B-1).

Figure B-1. Research framework



In this context, the city landscape with its inherent, diverse domains constitutes the research object along with the applied information systems and the sustainability-related goals. The literature is assessed along these dimensions regarding the utilization of information systems to foster environmental sustainability in the smart city context. The literature search and selection processes are described in the following section.

3 Methodology

In order to optimally categorize the existing literature, we conducted two exhaustive literature reviews based on vom Brocke et al. (2009). This approach emphasizes the literature-discovery process and guarantees an elaborated and well-documented selection of references that is reproducible by other researchers (Table B-2 and Table B-3). The analysis and synthesis of the literature was carried out based on Webster and Watson (2002). The results were then summarized in a concept matrix according to the three dimensions of focus (city, IS, sustainability) and assessed based on their contribution to the topic (Table B-4).

Table B-2. Outlets considered for the literature analysis within the IS community

Journal	Database	Long List	Short List	Final List
ACM Transactions Journals (ACMT)	EBSCOhost, WoS	3	-	-
Communications of the ACM (CACM)	EBSCOhost, WoS	53	-	-
Decision Support Systems (DSS)	EBSCOhost, ScienceDirect	145	5	2
Electronic Markets (EM)	WoS	-	-	-
European Journal of Information Systems (EJIS)	EBSCOhost, WoS	1	-	-
Human-Computer Interaction (HCI)	EBSCOhost, WoS	-	-	-
IEEE Software	EBSCOhost, WoS	5	-	-
IEEE Transactions Journals (IEEET)	EBSCOhost, WoS	81	14	3
Information & Management (I&M)	EBSCOhost, WoS	82	1	-
Information and Organization (I&O)	WoS, ScienceDirect	37	-	-
Information Systems (ISYS)	WoS, ScienceDirect	22	-	-
Information Systems Journal (ISJ)	EBSCOhost, WoS	1	-	-
Information Systems Research (ISR)	EBSCOhost, WoS	-	-	-
International Journal of Information Management (IJIM)	ScienceDirect	82	-	-
Journal of Information Technology (JIT)	WoS	-	-	-
Journal of Management Information Systems (JMIS)	EBSCOhost, WoS	2	-	-
Journal of Strategic Information Systems (JSIS)	WoS, ScienceDirect	46	4	-
Journal of the Association for Information Systems (JAIS)	EBSCOhost, WoS, AISeL	23	-	-
Management Information Systems Quarterly (MISQ)	AISeL	50	4	1
Management Science (MS)	EBSCOhost, WoS	3	-	-
Organization Science (OS)	EBSCOhost, WoS	1	-	-
International Conference on Information Systems (ICIS)	AISeL	115	17	2
European Conference on Information Systems (ECIS)	AISeL	148	3	3
	Total	***900***	***48***	***11***

In the *first analysis* we only examined leading IS literature, allowing us to categorize the existing articles and assess their diffusion in the IS community (*RQ1*). The *second analysis* covers the same topic but without limitation to this particular community. Thus, we made sure to elaborate the research topic in a holistic way by bridging the gap between the IS community and others, identifying differences and commonalities among them (*RQ2*). The keywords were selected based on the research interest, resulting in the keywords “Green IS”, “environmental sustainability”, and “smart city”. The next step was to search the literature with the selected keywords. Although the search string (“Green IS” AND “smart city” AND “environmental sustainability”) is very precise and would perfectly fit the interests, it would also omit potentially relevant articles. In contrast, using OR instead of AND might lead to results that are too broad. Therefore, we decided to use generic keywords, assuring that no literature was omitted, e.g., by having the literature use “sustainability” as an equivalent for “environmental sustainability” or, analogously, using the terms “digital city” or “sustainable city” instead of “smart city”. Hence, for the *first literature review* the keywords (“city” OR “cities”) AND (“smart” OR “sustainable” OR “sustainability”) were selected. The list of journals considered was inspired by Heinzl et al. (2008) and comprises the following outlets (Table

B-2): *ACM Transactions Journals*, *Communications of the Association for Computer Machinery*, *Decision Support Systems*, *Human-Computer Interaction*, *Information and Organization*, *IEEE Software*, *IEEE Transaction Journals*, *Information and Management*, *International Journal of Information Management*, *Management Information Systems Quarterly*, *Management Science, Organization Science*, *Proceedings of the International Conference on Information Systems*, and *Proceedings of the European Conference on Information Systems*. We thus reduce the chances of overlooking suitable contributions outside the core basket of eight journals. To fully cover these journals, we used the following databases: *AIS Electronic Library*, *EBSCO*, *Web of Science*, and *ScienceDirect.*

The results for the first review reveal an extensive list of 900 articles within the outlets considered, depicted schematically in Table B-2. To assess their relevance for the research endeavor, these articles were subject to review by the authors in terms of title, abstract, and keywords. Articles regarded as irrelevant for the further context of the paper were sorted out. After the first revision round, we obtained a short list of 48 articles with a resulting inter-coder reliability of 96.1%. Articles with differing assessments between the authors were discussed until concurrence was reached. Within the second revision round, the articles were thoroughly reviewed by the authors, with particular consideration of the requirements regarding IS, environmental sustainability, and smart cities; only articles that met these requirements were kept, resulting in a final list of 11 articles that served as the basis for assessment and discussion.

Analogously to the first review, which focused on the IS community, we conducted a *second review* without limitation to IS-related outlets. However, we used a different search string, as although we still wanted to examine IS solutions for fostering environmental sustainability in smart cities, the focus was no longer on the IS community. Therefore, we chose the following search string: (“information system” OR “information systems” OR “ICT”) AND (“city” OR “cities”) AND (“smart” OR “sustainable” OR “sustainability”) while the selection of databases remained constant.

Finally, both long lists were merged to keep only the additional findings. Again, after reviewing titles, keywords, and abstracts, we sorted out literature that did not meet the requirements, resulting in a reduction of the results from 592 articles to a short list of 108 and an inter-coder reliability of 90.7%. A tabular representation of the journals concerning the other research areas would be disproportionate, as the variety of the journals considered is large for this processing step. Therefore, we classified the journals according to their research focus (environmental science; energy and transportation; cities, buildings, and regional-science; technology and engineering; software and information systems; and miscellaneous); an overview of the articles related to these research areas is presented in Table B-3. Within the second round of revisions, the remaining articles were reviewed in detail; eventually, a final list of 24 articles was determined to be valuable for our research endeavor.

Table B-3. Classification of the journals considered without focusing on the IS community

Research Area	Database	Long List	Short List	Final List
Software and information systems	WoS, ScienceDirect, EBSCOhost, AISeL	202	20	4
Environmental science	WoS, ScienceDirect, EBSCOhost	175	45	7
Energy and transportation	WoS, ScienceDirect, EBSCOhost	51	14	5
Cities, buildings, and regional science	WoS, ScienceDirect, EBSCOhost	45	16	4
Technology and engineering	WoS, ScienceDirect, EBSCOhost	30	12	4
Miscellaneous	WoS, ScienceDirect, EBSCOhost	89	1	-
	Total	***592***	***108***	***24***

4 Results

The articles selected from the literature review for the IS community (Table B-2) and the non-IS research domains (Table B-3) were summarized and presented according to the proposed research framework in Figure B-1. The results indicate that all derived domains have been addressed by the literature of both research domains. However, the non-IS research domains contribute an additional domain that is not considered by IS research: urban planning. Furthermore, the classification yields an overview of the utilized information systems for the respective use cases. Although the IS and other communities are somehow aware of the ability of IS to foster environmental sustainability in the city context, approaches for addressing the problem are diverging.

Regarding the state of the art of Green IS solutions in the smart city domain addressed by the IS community (*RQ1*), the review of the top-ranked IS journals and conferences yields some interesting approaches for ecological improvements through the use of IS in a city context. However, given the importance of Green IS as a research field, the number of articles is still low. Despite our best efforts, we could not find any publication within the databases that directly addresses the deployment of Green IS in a smart city context. It seems that Green IS, or the deployment of ICT to foster environmental sustainability, has not yet made its way into the city context within the IS community. According to our framework, we categorized the selected articles along three dimensions: environmental sustainability, smart city, and Green IS (see Table B-4).

The results reveal that the corpus of published literature in the IS research domain primarily addresses city planners, who are either the city administration itself or service providers supporting municipal tasks (e.g., garbage collection or public transportation providers). In contrast, only four articles of the resulting set directly address citizens. The focus of the solutions employed lies on the development and utilization of information systems that support decision-making processes based on data collected from experts (Chamberlain et al. 2012) and citizens (Lovrić et al. 2013; Wagner et al. 2013, 2014) as well as self-collected data by city administration personnel (Rickenberg et al. 2013; Santos et al. 2011). Hence, six of the eleven solutions are decision support systems (DSS) that are deployed in the infrastructure and transportation domains. In the infrastructure domain, the DSS are used to identify sustainable wastewater solutions (Chamberlain et al. 2012) and optimize city service vehicle routing, i.e., trash collection (Santos et al. 2011). Within the transportation domain, the DSS are used to improve charging infrastructure for car-sharing stations – electric and otherwise – (Rickenberg et al. 2013) and advance public transportation services by integrating separate transport information systems (TIS) (Lovrić et al. 2013). Feedback systems are the second-most applied information system; they aim to motivate citizens to engage in more sustainable transportation alternatives, such as biking (Flüchter et al. 2014), or to shift toward the energy efficient use of household appliances (Liu et al. 2013; Loock et al. 2012, 2013). The main purpose of all these solutions is to collect, process, and provide information to trigger behavior change (feedback systems) or support decision-making processes (DSS). In addition to Chamberlain's DSS, three more articles go beyond the solely informing and aim to automate processes (Hounsell and Shrestha 2012; Lovrić et al. 2013; Santos et al. 2011). Hounsell and Shrestha (2012) propose an intelligent transport system with the goal of reducing passengers' waiting times by prioritizing buses at traffic signals, thereby increasing the attractiveness of public transportation through increased comfort. The approach considers the use of automatic vehicle location systems to facilitate the communication between buses and traffic infrastructure, e.g., the urban traffic control center. This is extended by Lovrić et al.'s (2013) solution of collecting and analyzing travel data gathered from customers' smart-card tickets to optimize public transportation services, resulting in lower waiting times and increased passenger comfort, and Santos et al.'s (2011) vehicle routing optimization. Furthermore, other IS solutions aim to trigger a transformation from conventional conditions toward the establishment of more sustainable innovations, such as the optimization of electric-vehicle charging (Wagner et al. 2013, 2014) or car-sharing infrastructure (Rickenberg et al. 2013) to promote the switch from individual car use to sustainable mobility alternatives.

Table B-4. Classification of the results from the literature analysis based on the proposed research framework[3]

Authors	Use Case	Type of Green IS	Environmental Sustainability			Smart City						Role of Green IS		
			Eco-efficiency	Eco-equity	Eco-effectiveness	Citizens	City planners	Transportation	Infrastructure	Buildings	Urban planning	Automate	Informate	Transformate
(Amado & Poggi 2014)	Utilizing regenerative energy sources	GIS		x			x			x			x	
(Ascione et al. 2014)	Energy demand planning on city scale	GIS	x				x			x			x	
(Battista et al. 2014)	Analysing energy efficiency intervention	Simulation software	x				x			x			x	
(Baz et al. 2009)	Settlement suitability analysis	GIS		x			x				x		x	
(Bridges 2008)	Urban forest analysis	GIS		x			x				x		x	
(Chamberlain et al. 2012)	*Sustainable wastewater solutions*	*DSS*	*x*				*x*		*x*			*x*		
(Flüchter et al. 2014)	*Motivating e-bike usage*	*Feedback system*		*x*		*x*		*x*					*x*	
(Girardin et al. 2010)	Energy requirement planning	GIS	x				x		x			x		
(Hilpert et al. 2013)	GHG emission tracking	Feedback system		x			x	x					x	
(Hounsell and Shrestha 2012)	*Bus prioritization at traffic lights*	*TIS*	*x*				*x*	*x*				*x*		
(Ki 2013)	Landscape and urban planning	GIS		x		x					x		x	
(Kodysh et al. 2013)	Utilizing regenerative energy sources	GIS		x			x			x			x	
(Kuzyk 2012)	Ecological footprint calculation	GIS		x			x			x			x	
(Liu et al. 2013)	*Motivating energy consumption reduction*	*Feedback system*		*x*		*x*				*x*			*x*	
(Loock et al. 2012)	*Motivating energy consumption reduction*	*Feedback system*		*x*		*x*				*x*			*x*	
(Loock et al. 2013)	*Motivating energy consumption reduction*	*Feedback system*		*x*		*x*				*x*			*x*	
(Lovrić et al. 2013)	*Load balancing for public transportation*	*DSS*	*x*				*x*	*x*				*x*		
(Mahmoud & El-Sayed 2011)	Sustainable urban development	GIS		x			x				x		x	
(Mastrucci et al. 2014)	Energy efficiency planning	GIS	x				x			x			x	
(Namdeo et al. 2002)	Traffic and emission modelling	GIS		x			x	x					x	
(Pandey et al. 2012)	Waste disposal location planning	GIS	x				x		x			x		
(Reiter and Marique 2012)	Residential energy use assessment	GIS	x				x			x				x
(Ren et al. 2013)	Sustainable urban development	GIS		x			x				x		x	
(Rickenberg et al. 2013)	*Discovery of car-sharing stations*	*DSS*			*x*		*x*	*x*						*x*
(Rybarczyk and Wu 2010)	Bicycle facility planning	GIS			x		x	x						x
(Rylatt et al. 2001)	Utilizing regenerative energy sources	GIS		x			x			x			x	
(Sánchez et al. 2013)	Autonomous street light adaption	Automated mgmt. system	x				x		x			x		
(Santos et al. 2011)	*Vehicle routing for urban trash collection*	*DSS*		*x*			*x*	*x*				*x*		
(Shin and Jun 2014)	Smart parking guidance	DSS			x	x		x						x
(Theodoridou et al. 2012)	Utilizing regenerative energy sources	GIS		x			x			x			x	
(Tibaut et al. 2012)	Travel planning	TIS			x	x		x						x
(Wagner et al. 2013)	*Charging station infrastructure planning for EVs*	*DSS*			*x*		*x*	*x*						*x*
(Wagner et al. 2014)	*Charging station infrastructure planning for EVs*	*DSS*			*x*		*x*	*x*						*x*
(Wang & Zou 2010)	Sustainable urban development	GIS		x			x				x		x	
(Winters et al. 2013)	Bike track planning	GIS			x		x	x						x
		Total	***11***	***18***	***6***	***7***	***28***	***13***	***4***	***12***	***6***	***7***	***20***	***8***

[3] Italicized entries are articles from the IS community.

The results concerning the second research question (*RQ2*) show that the vast majority of IS deployed in the non-IS community domains are geographical information systems (GIS) with a focus on collecting and monitoring environment-related data. This is surprising because this kind of IS is completely neglected within the IS community but could be explained by the particular focus of the other research domains such as urban planning, which is addressed by one-fourth of all articles. The corpus of the information systems employed within the non-IS research domains are concerned with energy management solutions (Amado and Poggi 2014; Ascione et al. 2014; Battista et al. 2014; Girardin et al. 2010; Kodysh et al. 2013; Kuzyk 2012; Mastrucci et al. 2014; Reiter and Marique 2012; Rylatt et al. 2001; Sanchez et al. 2014; Theodoridou et al. 2012) and the decrease of environmental deterioration in the context of urban planning (Baz et al. 2009; Bridges 2008; Ki 2013; Ren et al. 2013; Wang and Zou 2010). The articles regarding energy management cover solutions for city-wide energy requirement planning (Girardin et al. 2010) and optimized city illumination (Sanchez et al. 2014) on an infrastructural level, the reduction of energy use in buildings (Ascione et al. 2014; Battista et al. 2014; Kuzyk 2012; Mastrucci et al. 2014; Reiter and Marique 2012), and the evaluation and prediction of energy alternatives to supply buildings from regenerative energy sources (Amado and Poggi 2014; Kodysh et al. 2013; Rylatt et al. 2001; Theodoridou et al. 2012) in order to reduce CO_2 emissions caused by traditional energy production. Environmental deterioration is addressed via decision support processes supported by information provided from GIS. The underlying data is either self-collected (Baz et al. 2009; Ren et al. 2013; Wang and Zou 2010), provided by citizens (Ki 2013), or gathered via remote sensors (Bridges 2008). CO_2 reduction is also the primary goal of solutions employed in the transportation domain. The systems implemented monitor CO_2 emissions on a city-wide scale by utilizing sensors and extrapolations (Namdeo et al. 2002) or on an individual level within vehicles of a logistics company (Hilpert et al. 2013). While the characteristic of these solutions is rather passive, as they merely measure and display information upon which actions may be based, other solutions aim to address the root cause by reducing individual car use. This is achieved by promoting bicycle use through the implementation of a bicycle-route platform (Winters et al. 2013), the creation of a decision support system for city planners to assist in the planning process of bike facilities toward a multi-model city (Rybarczyk and Wu 2010), and the service integration of multiple transport information systems to promote and improve public transportation services (Tibaut et al. 2012). In case people do drive their own car, one solution supports the driver in finding a suitable parking spot, aiming to reduce search time and the resulting CO_2 emissions (Shin and Jun 2014).

Like the results from the IS community, the integration of citizens within the non-IS communities is very low. Overall, only 7 of the 35 articles reviewed (20%) consider citizens in their IS solutions at all. Given that the solutions in the non-IS fields are heavily data driven in order to provide important information inside the GIS applications, citizens were considered merely for the data-collection process, and the core role of the information systems employed was to informate, as it is within the IS literature.

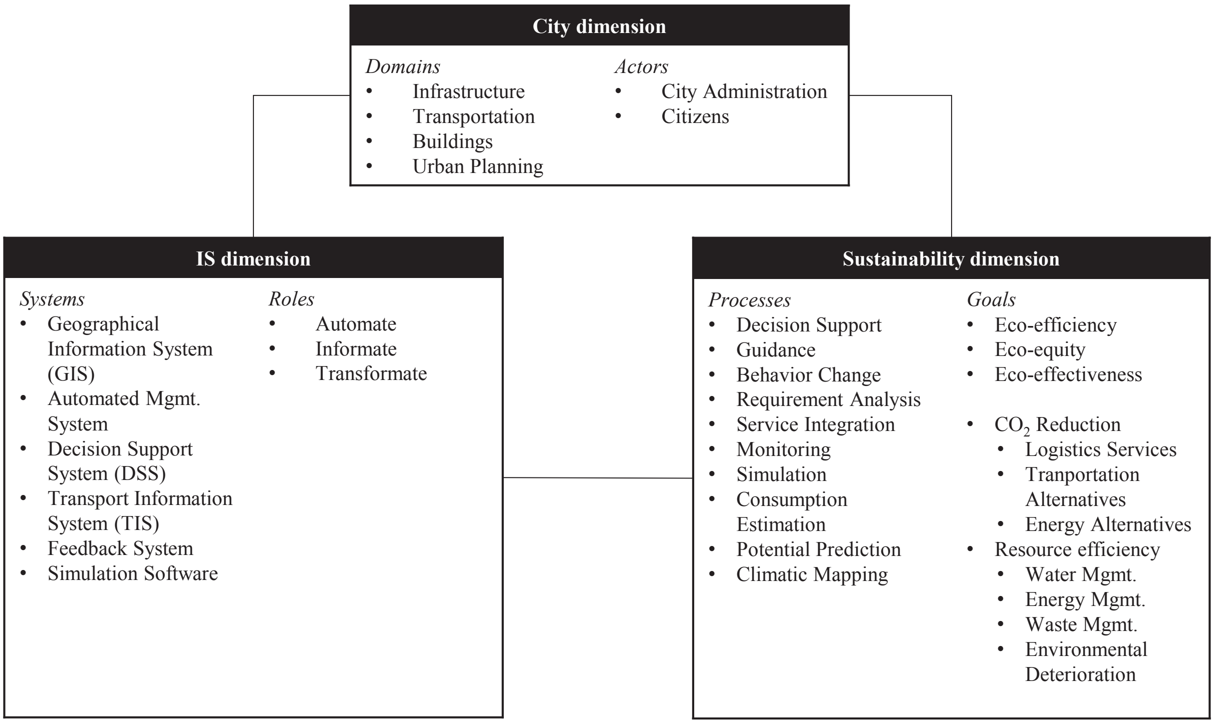
The distribution of information systems types between the two scopes of analysis is displayed in Table B-5, depicting the different foci of the respective communities in addressing the problem concerning the utilization of Green IS.

Table B-5. Types of information systems in the examined research fields

Information System	IS Community	Non-IS Communities
Decision Support Systems (DSS)	6	1
Geographical Information Systems (GIS)	0	19
Feedback System	4	1
Transportation Information Systems (TIS)	1	1
Automated Management System	0	1
Simulation Software	0	1
Total	***11***	***24***

The findings of the literature review extend our original research framework from Section 2, illustrated in the following figure (Figure B-2).

Figure B-2. Research framework extended with the results of the literature analysis



5 Discussion

The results of the literature analysis and the resulting final framework serve as a starting point for future research and initiatives regarding the implementation of Green IS solutions in the smart city context. It pinpoints existing employments of different types of information systems, processes considered, and sustainability goals. Researchers and practitioners can find out whether their intended projects have already been implemented and gain additional insights from existing research. Furthermore, the proposed solutions may serve as an inspiration for future sustainability initiatives and research endeavors.

The major difference between both research scopes is that the non-IS communities focus on the utilization of GIS to collect and monitor environment-related data. However, the systems employed primarily aim to display information and provide DSS-like functionality by guiding governmental decisions. These solutions have a rather reactive character, since they mainly serve as planning tools and actions are performed based on historical data. Therefore, these systems can be considered long-term solutions because the time span of data acquisition, processing, and taking action can be very lengthy. However, the literature – especially that from the IS community – also offers short-term solutions. Flüchter et al. (2014), Liu et al. (2013), and Loock et al. (2013), for example, use feedback systems to provide real-time visual feedback of energy consumption and CO_2 reduction to individual users with the goal of influencing them to behave more sustainably through proactive behavior. Despite the limited integration of individuals in the identified literature and the divergence of Green IS solutions between the different research fields, feedback systems were covered by both reviews and show promising results for short-term, proactive IS solutions to foster environmental sustainability. We therefore argue that the sort of information systems that directly address citizens can have large positive effects on environmental sustainability. Feedback systems could be implemented in various domains and fields within these domains, e.g., waste management (infrastructure), public transportation (transportation), water consumption (analogous to energy consumption in the building domain), and more. Given the sheer number of people in cities, even minor adjustments regarding a more sustainable behavior can scale up to huge effects.

Furthermore, non-IS communities emphasize the domain of urban planning, which remains unaddressed by IS research. Leaving this fact aside, both research fields share some commonalities. The building domain, for example, is addressed by both communities, though in a different manner. While non-IS researchers aim to determine optimal energy plans concerning consumption and supply on a spatial level as well as city wide by addressing city planners or energy suppliers, IS research focuses on the reduction of individual energy consumption in households by utilizing smart meter–based feedback systems. However, the implementations in the transportation domain are similar, as both research fields offer solutions for improving the transportation infrastructure (Rybarczyk and Wu 2010; Wagner et al. 2013, 2014; Winters et al. 2013) and contribute to an increased willingness to use public transportation or transportation alternatives (Hounsell and Shrestha 2012; Lovrić et al. 2013; Rickenberg et al. 2013; Tibaut et al. 2012). Approaches in the infrastructure domain vary the most among the commonly addressed city domains. In the broadest sense, both research fields share the goal of optimizing waste management by improving trash vehicle routing (Santos et al. 2011) and the location analysis for solid-waste disposal sites (Pandey et al. 2012) or wastewater management (Chamberlain et al. 2012). Overall, the building and transportation domains are the most frequented regarding the implementation of information systems to foster environmental sustainability. However, the solutions in the building domain are rather monotone, solely addressing energy management tasks. In contrast, the transportation domain has a high variance of targeted areas and solutions, and turns out to be a very promising domain with high potential for further research.

Another interesting finding within the results is that we could not find any mobile application–based solutions. Although this can be explained by the lack of focus on individuals in the articles discovered, mobile devices can still be utilized in the given scenarios. For example, pervasive computing devices such as smartphones or tablets can be used as sensor nodes (Ganti et al. 2011) to collect and provide data in a crowd-sensing manner (Ganti et al. 2011; Miorandi et al. 2013) for GIS- or DSS-oriented systems. Mobile applications could provide valuable services for inducing sustainable operations in the individual context, particularly in the context of feedback systems; we encourage further research in this direction along all domains discussed within this analysis. Furthermore, the results indicate that more than half of all IS solutions aim to informate a certain instance – be it the city administration, service provider, or citizens – in order to provide decision support for decision processes or feedback on behavior; few systems aim to automate or transformate tasks and processes to foster environmental sustainability. This could be explained by the lack of clearly defined processes regarding the achievement of urban sustainability goals. Hence, we argue for research on scenarios and IS solutions to fill this gap. Moreover, we encourage the design and development of user-centric IS solutions to directly support citizens' sustainable actions. While citizens constitute one of the most important assets of cities, few solutions within the literature reviewed focus on them, and the city administration takes no part in the whole system, e.g., as a moderator or sponsor, to proactively promote sustainable initiatives.

The sustainability goals in this paper are classified based on the conceptual model of IS and ecological sustainability by Chen et al. (2008). However, the framework and its proposed ecological milestones (eco-efficiency, eco-equity, and eco-effectiveness) are constructed for the organizational context and settled in the industrial sector, e.g., concerning cleaner production (Chen et al. 2008). According to the framework, the roles of information systems (informate, automate, transformate) are strongly coupled with the sustainability goals, e.g., the automation of production processes increases the eco-efficiency. However, this concept is not easily adaptable to the city context because there are little to no defined processes regarding the contribution to environmental sustainability and the production of goods cannot be automated to achieve eco-efficiency. In this paper we categorized DSS functionality and goal attainment as automate when the underlying algorithms and solvers directly contributed to the efficiency of the examined object, e.g., optimized vehicle routing leads to reduced CO_2 emissions (Santos et al. 2011). On the other hand, the feedback provided to a citizen about the potential reduction of CO_2 emissions by biking instead of using a car (Flüchter et al. 2014) yields transparency about individual behavior and has an educational character; therefore such feedback was considered as eco-equity. IS solutions were classified as eco-effective when a transition from the norm takes place, e.g., the switch from individual car use to car sharing (Rickenberg et al. 2013; Wagner et al. 2013, 2014).

This paper contributes to the theory of Green IS research by providing a foundation for further investigation of environmental information systems solutions in a new research field separate from the business focus within the IS community. It establishes a different perspective on both the potentials of IS-driven solutions to foster environmental sustainability across the borders of organizations as well as the benefits of integrating individuals to participate in the process of ecological improvement. Furthermore, we enrich the concept of smart cities by concentrating on a particular facet of urban information systems capabilities. Practitioners and city planners who are interested in contributing to environmental sustainability in the municipal context can use the findings of this paper as guidance for further efforts.

Although we performed the literature analysis according to our best knowledge and intention, a few limitations must be considered. First, the articles reviewed were limited to journals; aside from the leading IS conferences ICIS and ECIS for the literature analysis focusing on the IS community, research published in conferences proceedings or other outlets were not considered. It is therefore possible that fruitful contributions to the topic of Green IS in smart cities were omitted. Second, we focus on IS implementation or deployment, meaning that frameworks, models, or theoretical strategic measures were not taken into account within the review. Third, the final selection of literature was subjective, based on the authors' opinions; a classification of the literature by different authors may lead to divergent insights. Furthermore, the selection of the keywords for the search process limited the results regarding the broadness of other possible solutions. The keyword "information systems" is rather generic and likely does not reflect potential specific solutions that concern the non-IS research domains, as "information systems" or the keyword "ICT" might not be as common for these communities as they are for the IS community. Therefore, further research should focus on specific implementations of IS artifacts and their potential applications for particular tasks in the respective domains. Research in the field of Green IS in smart cities should explore the requirements – ideally by directly consulting the target groups, i.e., city planners/administration – to determine what kind of information is desired, which processes need to be supported, and what design principles for application development are postulated. Given the recent, immense technological innovations, including pervasive computing devices such as smartphones and tablets that have a multitude of sensors and are mobile, we recommend working out solutions that make use of these capabilities. Citizens could be used as mobile sensor nodes to gather data in a crowd-sensing manner (Cardone et al. 2013), feeding existing systems such as GIS tools or even creating innovative methods for ecological contributions (transformate). In this regard, there develops a need for a motivation mechanism (e.g., gamification) to incentivize the user to provide data to such a system (Ueyama et al. 2014).

6 Conclusion

This paper analyzes the current state of research in the domain of smart cities with a particular focus on the impact of Green IS on fostering environmental sustainability in the city context. The goal of this paper is to structure this research field to achieve a holistic view on the application of Green IS solutions in smart cities. To do so, we performed a cross-sectional, exhaustive literature analysis with almost 1,500 articles reviewed, distinguishing between research performed by the IS community and that conducted in related fields, such as environmental sciences. One of the central findings is the rising number of recently published articles, indicating that the field is garnering increased attention worldwide. In this regard, almost 75% of the final lists' articles were published within the last four years. The analysis of the literature reveals that the vast majority of information systems aim to support city planners in decision-making processes with the goal of reducing CO_2 emissions or preserving resources. The major difference between solutions produced by the IS community and those of other research domains is the frequent use of GIS tools outside of the IS community. However, both research domains have a low integration of citizens in their approaches, which we recommend emphasizing in future research projects. Based on the number and type of results, we argue that the research field of Green IS solutions in the city context is heavily underexplored and that the focus of Green IS research is oriented toward the organizational context, e.g., concerning cleaner production or greener business processes. Our findings provide evidence that little work has been conducted in this field. We believe that the requirements for solutions are unclear, and therefore the accessible technologies have not been utilized to a great extent. Furthermore, the role of the city within such a data-intensive construct is yet to be determined.

I.2 Study 2: Green by App: The Contribution of Mobile Applications to Environmental Sustainability

Table B-6. Fact sheet of study no. 2

Title	Green by App: The Contribution of Mobile Applications to Environmental Sustainability
Authors	Benjamin Brauer*, Carolin Ebermann, Björn Hildebrandt, Gerrit Remané, Lutz M. Kolbe Chair of Information Management, Georg-August-University Göttingen, 37073 Göttingen, Germany *Corresponding author. Tel.: +49 551 39 2 11 70. E-Mail address: bbrauer@uni-goettingen.de
Outlet	Proceedings of the 21st Pacific Asia Conference on Information Systems (PACIS), June 27th-July 1st 2016, Chiayi, Taiwan.
Abstract	Environmental sustainability is an important field in both research and practice. Governments and enterprises expend huge amounts of money and effort in attempting to reach their environmental goals, e.g., resource efficiency or the reduction of CO2 emissions. In the information systems (IS) community, the research field of Green IS has recently emerged, examining the potential of IS to foster environmental sustainability. In this paper, we focus on the capacity of mobile applications to support environmental concerned measures by performing a classification of existing mobile apps in the Google Play store. The goal of this explorative paper is to structure findings regarding the application of sustainable mobile apps from theory and practice in the domain of Green IS and to create an avenue for further detailed research on this matter. Therefore, we examine three research questions based on Green IS theory and the results of an extensive app store analysis. The article discovers suitable domains for the private use of sustainable mobile apps and discusses the adequacy of established Green IS roles from the business domain. Furthermore, the connections between applications and user goals are discussed in terms of motivational and acceptance-related factors of user engagement.
Keywords	Green IS, Mobile Apps, Environmental Sustainability

1 Introduction

The endeavor to improve environmental sustainability is garnering ever-increasing attention in IS research (Hilpert et al. 2014; Lei and Ngai 2013). Governments worldwide aim to reduce greenhouse gas emissions and propagate resource-efficient measures to achieve their sustainability goals (Simpson 2012). At the same time, the industrial sector strives to comply with new legal regulations, such as those relating to cleaner production (Dedrick 2010) or sustainable procurement (Min and Galle 2001). Furthermore, benchmarks are used to check for sustainable performance (Nunes and Bennett 2008). Organizations in general attempt to meet the regulatory or self-imposed environmental guidelines (Bengtsson and Ågerfalk, 2011; Chen et al., 2008, 2009; Dedrick, 2010). Some initiatives go beyond sole compliance with regulations relating to, e.g., waste reporting or energy-efficient production (Molla 2008) by promoting sustainable behavior in the workplace (e.g., energy management) (Raju et al. 2012) or the environmentally friendly driving behavior of employees (Tulusan et al. 2012).

Information and communication technologies (ICT) are generally a viable option to influence people's behavior. Examples from the health or education domain show that the utilization of mobile devices and apps can serve as successful interventions. Pervasive technologies such as smartphones or wearables support the provision of micro-learning apps allowing the user to study everywhere (Bruck et al. 2012), and systems concerned with the user's health can monitor user behavior and provide feedback for a healthier lifestyle (Lehto and Oinas-Kukkonen 2015). In the environmental context IS has also proven to be helpful achieving sustainability-related goals (Elliot 2007; Thongmak 2012), whether in the organizational context by supporting sustainable supply chain management practices and processes (Kurnia and Gloet 2012), by encouraging cleaner and resource efficient production (Dedrick 2010), or by promoting the transition towards sustainable mobility alternatives (i.e., electric mobility) by creating a novel technology driven innovative ecosystem (Hanelt et al. 2015; Yoo et al. 2012). Within the IS community, a dedicated research area addressing this topic has emerged in recent years. The concept of Green IS aims to utilize information systems (IS) to achieve and foster sustainability-related goals throughout various areas and domains with a strong focus on the business sector (vom Brocke et al., 2013; Chen et al., 2009).

While the utilization of Green IS presents huge potential on the corporate level (vom Brocke et al. 2013a), little research has been conducted regarding the application and potential of Green IS outside organizational boundaries (Brauer et al. 2015). However, the advent of digital technologies with comprehensive broadband Internet access and the penetration of mobile devices such as tablets, smartphones, and wearables contribute to today's ubiquitous access to information and the development of several novel services due to the nature of these devices (Junglas and Watson 2006). Open platforms such as the Google Play store foster the emergence of digital ecosystems that are not reserved exclusively for corporate organizations but also allow private actors to participate by generating new content (Yoo et al. 2012). Thus, the boundaries of Green IS must also be extended by considering actors of digital ecosystems outside organizational contexts. Mobile gadgets offer a variety of sensors and other hardware modules that enable the user to retrieve and send data to provide vital information (Zhang 2003) or gain personalized feedback (Froehlich et al. 2010). It seems reasonable to utilize these devices and their users to acquire and afford data and services that may contribute to achieving environmental goals. The advantage of utilizing mobile devices as an enabler for sustainable actions lies in its huge potential for scalability. Considering the sheer number of people owning a smartphone, applications that have even a tiny effect on resource efficiency or the reduction of greenhouse gas emissions could result in a greater impact than any organizational sustainability campaign might offer. Furthermore, these mobile applications can be used in daily life and are not limited to the workplace. Hence, we aim to answer the question:

RQ: How do existing mobile applications contribute to environmental sustainability?

Thus, in this paper we aim to provide an overview of existing mobile applications that aim to foster environmental sustainability – hereafter referred to as 'green apps' – and the corresponding application domains. We are interested in the goals, processes, and functions covered by the sustainable mobile applications to guide further advances in the area. By doing so, we aim to identify suitable application areas for sustainable mobile apps as well as recommendations for future implementations. Furthermore, we hope to increase the dissemination and improve the perception of existing applications and enhance the positive implications for environmental sustainability.

2 Theoretical Background

In the heyday of information systems serving as vital entities in organizational structures and their role as enablers for new services and business model innovations (Lyytinen and Rose 2003), people started thinking about the negative impacts of the underlying technologies in terms of the environmental aftermath. Hence, in the course of Green IT research, science and practice developed solutions to make technology greener and reduce their negative environmental impacts (Loeser 2013). But research did not cease at this point; gradually, the potential of IS to enable sustainable processes was explored and established, and Green IS research was born (Dedrick 2010). In the following paragraph we provide a brief introduction into the concept of Green IS and the work carried out on mobile applications as contributors to environmental sustainability.

2.1 The role of Green IS

The idea of Green IS emerged after the concept of Green IT proved its success in practice by reducing the negative environmental impacts of information technology (vom Brocke et al. 2013a; Dedrick 2010; Loeser 2013). After Green IT efforts made the use and production of IT significantly more sustainable, it did not take long to realize the possibilities of information technology for environmental advancements as well (Loeser 2013). At approximately 2%, the utilization of IT represents only a small share of global greenhouse gas emissions; the major goal of Green IS concerns addressing the cause of the remaining 98% (vom Brocke et al., 2013).

Newly designed Green IS ought to support sustainability-related goals and the underlying processes on both the operational and the strategic levels (Dedrick 2010). Hence, the IS must either directly contribute to environmental improvements or pave the path towards sustainable advancements by designing strategies (Loeser 2013), e.g., via supporting decision-making processes within management activities (Loock et al. 2011).

The mechanism of Green IS can generally be well described by analyzing the role of an information system and its believed impact on environmental relevant objectives. An IS can essentially take one of three roles: automate, informate, or transformate (Chen et al. 2008). Automate describes the active interaction with processes, where human labor is replaced by information systems and thus leads to greater efficiency. Informate regards the IS-aided provision of information based on collected data, e.g., in the form of feedback that supports decision-making processes or offers a better understanding of current circumstances. If these entities enable new opportunities for significant shifts of the current state, e.g., new products, services, or business models, the role of the supportive IS is referred to as transformate (Chen et al. 2008; Dao et al. 2011).

From the environmental perspective, these roles are strongly aligned with the overarching environmental goals pursued via IS utilization. According to Chen et al.'s (2008) IS-driven environmental sustainability framework, the three roles support the achievement of eco-effective practices by addressing the three milestones of environmental sustainability. Hence, automate facilitates the achievement of eco-efficiency by adapting IS for process automation. This not only affects production-like operation control but also the switch from conventional processes to IS-enabled flows, e.g., paperless document management (Chen et al. 2008). Second, eco-equity is influenced by informate in such a way that the provision and flow of information is supported by the utilization of information systems. The focus lies on the informative character of the IS used, yet the environmental process is still incumbent to the individual who receives the information provided. While automate and informate aim to "fix" the current situation by optimizing existing processes and providing feedback about the status, transformate attempts to replace the prevailing processes and conditions by introducing alternatives that "do the right things" (Chen et al. 2008) from the outset instead of adjusting the established practices.

To date, Green IS focuses on the organizational context. The majority of solutions target business-related circumstances, which can be attributed to the nature of IS research, with its roots in the organizational context. The sustainability element arises from the close relationship of Green IS to Green IT, which almost solely resides in the business sector. However, Green IS research has recently made its way outside organizational boundaries, demonstrating its potential in the private sector as well (Kranz and Picot 2011). Solutions for monitoring and reducing energy consumption in private households have been examined in various academic articles and have proven to be a successful measure for saving energy (Graml et al. 2011; Gustafsson et al. 2009; Loock et al. 2013; Watson et al. 2013). The IS employed are designed as feedback systems with the goal of changing the behaviors of individuals. Alongside residential energy saving, the transportation sector is addressed via solutions for monitoring CO_2 emissions or triggering mobility-related behavior changes by promoting biking instead of individual car use (Flüchter and Wortmann 2014). Even the supportive environmental potentials of mobile devices are not entirely new in IS research, as demonstrated in the following paragraph.

2.2 Research on environmental sustainable mobile applications

Like the Green IS solutions in the private sector mentioned above, some of the sustainable mobile applications that have been the subject of scientific articles are feedback systems. These green apps provide sustainability-related information to the user and focus on the energy and transportation sectors. Weiss et al.'s (2012) approach helps the user to monitor and control domestic energy consumption via smartphone. The app displays the current global and appliance-specific energy consumption and enables the user to initiate countermeasures. Within the transportation sector, Tulusan et al. (2012) use smartphones to provide the driver with eco-driving feedback and examine the impact of their app on fuel efficiency. Their study reveals that drivers using the app reduced their fuel consumption by 3.23%. In a different approach, Froehlich et al. (2009) examine whether individual mobility behavior can be influenced towards the use of more sustainable transportation alternatives. In their study, users were confronted with visual feedback regarding their environmental sustainable mobility behavior, e.g., by displaying a growing tree if they performed well or melting ice caps if not; the results are mixed but positive implications prevail. Apart from using the feedback mechanism, Alli et al. (2012) introduce an app to facilitate peer-to-peer car sharing with only zero-emission electric vehicles. To guarantee access to the vehicles, additional hardware is required; every vehicle is equipped with a GPS module to locate the car and a near-field communication (NFC) interface to open the door and start the car's engine. As a side effect, the application promotes the general use of electric vehicles by offering easy access for trial and use. Regarding electric mobility, Hanelt et al. (2015) also demonstrate the huge potential of mobile applications in supporting electric mobility as a sustainable mobility alternative. They provide an overview of existing apps that ease the use of electric cars by, e.g., providing general information about the technology or the availability of charging stations.

3 Towards Sustainable Mobile Applications

Based on the theoretical background and existing research in the area of sustainable mobile applications, we derive three research questions (RQ). These research questions are addressed by the results of the app store analysis and illustrated in the results section; they help to answer the overarching research question formulated in the introduction. The existing green apps are classified in an explorative approach in order to extract the basic key elements of sustainable mobile application development practices. While Green IS is well established in the organizational context and shows huge potentials (vom Brocke et al., 2013) little research has addressed individuals as potential users of sustainable information systems (Brauer et al. 2015). However, including the publicity in the Green IS ecosystem yields huge potentials for the further development of the Green IS research field and its contribution to the advancement of environmental sustainability (Brauer et al. 2015; Yoo et al. 2012). Hence, we expect there to be several domains offering great opportunities for sustainability-oriented information systems in the public domain, leading to our first question:

RQ I: Which application areas offer the opportunity for positive impacts on environmental sustainability by utilizing green apps?

By addressing this question, we strive to unveil and establish different application areas for public domain green app development despite the well-addressed areas of energy consumption and mobility behavior from research, and thereby drive the efforts of individuals and organizations to create and offer IS solutions that foster environmental sustainability practices.

According to Section 2.1, in Green IS research the three roles automate, informate, and transformate have been established over recent years to describe and formulate processes leading to the fulfilment of sustainability related goals: eco-efficiency, eco-effectiveness, and eco-equity (Chen et al. 2008; Dao et al. 2011; Thambusamy and Salam 2010). However, we argue that these roles and the inherent processes do not apply for the context of user-oriented, non-business use cases. The existing roles originate in the business/industrial sector with the intent of optimizing business processes, driving automation in terms of replacing human labor with IS, and providing critical information to increase efficiency and effectiveness (Chen et al. 2008). Hence, our second research question addresses the consideration of suitable roles to drive sustainable practices in the private sector:

RQ II: Are the existing roles from Green IS research (automate, informate, transformate) applicable to green apps for user-centric public domain use cases?

Based on the preceding research questions, we argue that the ultimate goals pursued by user-centric sustainability solutions are unclear and remain to be defined, as it constitutes a nearly untouched area in Green IS research. In this context, the goal-framing theory (Lindenberg and Steg 2013; Steg et al. 2014) claims that evolutionarily, three overarching goals evolved for human beings. The normative goal describes the aspiration to act accordingly – in this scenario, to behave environmentally friendly. Hedonic goals, on the other hand, cover the individual's feelings, e.g., seeking pleasure or excitement or avoiding unwanted efforts. Likewise, the gain goal is concerned with personal resources, such as status or monetary values (Steg et al. 2014). The theory states that the normative goal is contradictory to gain and hedonic goals in most cases (e.g., too much effort or monetary investment is required) and is often considered as the least favorable achievement. However, although the goals may contradict each other, the theory also states that if hedonic and gain goals are properly linked to normative goals, the positive effects are strengthened (Steg et al. 2014). Hence our third research question is as follows:

RQ III: Which goals are addressed by existing green apps, and how are these goals aligned with personal/individual goals?

According to goal-framing theory, goals relating to sustainability must be matched with the user's personal goals to release their full potential (Lindenberg and Steg 2013). This is a crucial part of the development process of such applications. Another vital element of application development with the goal of triggering or changing behavior is to comply with the users affordances (Deterding et al. 2011; Seidel et al. 2013), thereby strengthening the normative goal pursuit (Lindenberg and Steg 2013). The research questions presented above are examined in the course of the green app analysis and discussed in the results section.

4 Methodology

Before delving deeper into the methodological approach of the green app discovery and analysis processes, we outline our understanding of what constitutes environmental sustainability by refining the matter that will serve as the starting point for further analysis. This is followed by a brief presentation of the methodological approach conducted to categorize the apps identified in order to answer the above introduced research questions.

4.1 Refining environmental sustainability

A plethora of research has been conducted addressing environmental concerns. This affects not only IS research but also other research fields. However, when talking about sustainability, the predominant terms associated with it are resource efficiency and CO_2 reduction. While this cannot be argued with, it is a superficial perspective that focuses solely on the overarching objective, neglecting the granular underlying aspects. Therefore, we searched a scientific literature database (*ScienceDirect*) for publications with the search string “environmental sustainability” (similar to White, 2013). We chose this database because of its wide variety of outlets covered and the high number of publications within the various domains. To increase the relevance of the articles selected, we limited the search to abstract, title, and keywords, retrieving 1215 articles.

In the next step, all abstracts were copied into the text-analysis toolkit *AntConc* (Anthony 2014) to create a word list of the most common words. We used two open-access stoplists (New York University 2015; Ranks.nl 2015) to filter common English words from the results. The entire list comprised 11,322 word types. This list was cut down to keywords with a minimum of 50 occurrences, resulting in a list of 470 entries. In the final step, we removed keywords that did not reference environmental sustainability, such as “systems”, “analysis”, and “research”. Furthermore, we clustered similar terms – e.g., “power”, “energy”, and “electricity” – with new keywords and extended or combined them for further refinement. The final list is presented in Table B-7, displaying the total occurrences of each keyword. An asterisk indicates the primary keyword in the combination in terms of the number of occurrences.

Table B-7. Keyword list refining environmental sustainability

Keyword (Part 1)	Occur.	Keyword (Part 2)	Occur.
environmental* sustainability	2117	green* sustainability	162
energy* consumption	838	sustainable climate*	156
sustainable production*/construction	616	ecosystem	108
sustainable development*	508	pollution	88
water* consumption	494	ecological footprint*	86
soil* sustainability	253	sustainable transportation*	81
resource* efficiency	239	chemical* sustainability	80
CO_2/greenhouse emissions*	235	sustainable city*	74
sustainable food*	231	species* sustainability	68
fuel consumption*	226	forest* sustainability	63
waste	199	environmental degradation*	53

The selected keywords serve as search strings for the discovery process of the green apps. As the list indicates, environmental sustainability is a versatile term encompassing many aspects that play a role in environmental issues. If the term “environmental sustainability” were to be considered alone, important facets might be overlooked.

4.2 Green app discovery and analysis process

To examine the existing green apps, we conducted a comprehensive search process in the Google Play store using the keywords from Table B-7. We only considered applications with a German or English description text, allowing us to interpret the fundamental intention behind the applications.

The classification of the green apps was carried out according to Nickerson et al.’s (2012) *method for taxonomy development and its application in information systems*. The taxonomy-development method is an extensive procedure for classifying objects and is based on several iterations to identify characteristics, dimensions, and the attribution of objects to these entities. The entire process is composed of seven steps helping to guide the proper classification of objects (in this case, sustainable mobile apps). Due to page limitations, we only briefly describe our approach according to Nickerson et al. (2012) and refer to the source article for further details on the methodology.

As the first two steps of the classification process, we defined the meta-characteristics and ending conditions for the iterations. In this case, the goal of the classification is to derive guidelines for green app development. Thus, the meta-characteristic is composed of application developers and researchers in the Green IS research field as the audience and public domain orientation of the development process regarding the purpose. The ending conditions were chosen objectively as well as subjectively according to the original methodology (see Nickerson et al., 2012, p. 344). In this case, the conception of the dimensions is strongly bound to the research questions drawn. Hence, the dimensions (domains, goals, roles) were derived from the theoretical perspective. The characteristics, however, gradually emerged during the iterations of the taxonomy-development process until the final ending conditions were reached (step 7; no new findings). The classification process of the green apps was conducted by three researchers and performed as follows: Each researcher created a list with the application name and the Google Play store ID. The list was filled with a short description and a collection of supported functions, then individually assigned to an application domain, a suitable role for the underlying processes based on the application's functionalities and the sustainability goal. In the next step, the lists were merged and compared in terms of the domains, roles, and goals. Finally, the individually proposed classifications were discussed until a consensus was reached.

In contrast to the article of Nickerson et al. (2012), we refrain from a tabular representation of the classification of the apps identified (final taxonomy) because of the large number of applications. Instead, we focus on the discussion of the identified dimensions and characteristics (Table B-8 and Table B-10), as our aim is to provide development patterns rather than developing a thorough taxonomy of green apps.

5 Results

The analysis of the Google Play store for environmentally related mobile applications shows some interesting results. We identified 262 green apps from the search of all 22 keywords included in Table B-7. As we aimed to identify relevant application domains and derive universally valid insights, we categorized the identified apps by their goals and functionalities. The domains, roles, functions, and the respective number of results are listed in Table B-8.

In the course of *RQ I* we expect that – despite the abundance of research in the Green IS domain – numerous areas exist where public domain IS solutions could offer a significant contribution to environmental sustainability in the public domain. This research question is elaborated in the following, based on the findings of the app store analysis. The mobility sector emerged from our analysis as one of the most frequented domains. Applications in this area are concerned with promoting and offering services for sustainable mobility alternatives, such as biking, car sharing, or carpooling. Furthermore, they provide feedback about current mobility behavior and its impact on the environment. The energy domain includes apps regarding the sustainability and efficiency of buildings as well as the reduction of energy consumption in residential and organizational buildings by monitoring energy usage and providing relevant information. The focus is set on resource efficiency practices, either by suggesting the switch towards renewable energy sources or a change in consumption behavior. Similarly, apps in the water domain aim to reduce water consumption, but beyond this, some apps aim to track down and prevent water pollution by gathering and analyzing the data provided. Also concerned with resource efficiency is the food domain, as one of its central goals is to reduce food waste. Apps in this domain help to manage edibles in terms of expiration dates and the redistribution of leftovers. Moreover, some applications address the entire food chain from production to consumption and the environmental footprint of certain items as well as recommendations about sustainable food sources. The waste domain is subdivided into three parts in order to outline the corresponding goals and their processes in greater detail. The waste category itself is concerned with waste management, e.g., providing information about disposal locations and waste separation, and the prevention of littering. In contrast, the recycling domain helps to reduce waste and pollution by offering tips for waste disposal and disposal alternatives. This domain emphasizes the reuse of materials by providing recycling recommendations or connecting people to share their ideas and resources. Pollution primarily covers measures to inform citizens about the level of air pollution caused by traffic and industry. While the main purpose of most apps in this category is to protect the user from health-threatening contamination, the applications also strongly contribute to raising awareness about air pollution by visualizing the level of contamination at certain locations. Lifestyle apps influence the daily habits of a user and cover some of the domains already mentioned above. However, this domain also includes solutions that implement two or more entities of the other domains, which are therefore not assignable to any other category alone. These sorts of apps assist users in their everyday lives with the goal of reducing their carbon footprints by monitoring their behavior, e.g., regarding resource consumption or modes of mobility. Besides the aspects of the other categories, such apps also deal with activities such as traveling, shopping, or living and their impact on environmental factors. Unlike the aforementioned categories, the ecosystem domain does not address single selective areas – instead, it encompasses global issues such as global warming and climate change and protection in general. The main goal is to raise awareness about environmentally harmful practices, their aftermath, and the education of people about eco-friendly behavior. The last domain addresses wildlife, which involves both animals as well as their natural habitats. Solutions in this category aim to educate people about endangered animals and how to protect them. Another focal point in this domain is the collection of data, e.g., about the sighting of an endangered species or the count of trees in certain areas; such information is valuable for organizing and executing environmental concerning measures. The concrete functions implemented in the green apps are listed in Table B-8 and attributed to the respective roles and application domain.

Thus, the analysis of the Google Play store revealed 10 domains (Table B-8, first column) in which green apps could provide considerable contributions to increasing environmental sustainability by providing information, services, and tools to address various sustainability-related goals (see Table B-10).

Besides the discovery of suitable application areas for green apps in the public domain, the *second research question* (*RQ II*) is concerned with the identification of appropriate roles allowing eco-friendly applications to be developed. The roles are derived from the implemented functions of the green apps. The goal of this analysis is to guide potential and interested developers through the development process by offering various patterns for diverse types of applications based on existing implementations, which might be more helpful in initiating the planning and development processes than starting from scratch. Furthermore, the exploration of suitable processes in the public domain helps determine what exactly constitutes a green app for the public domain and separates it from ‘classic’ Green IS that is known from the business perspective. By recalling the roles or processes of Green IS in the business sector (see Section 2.1), we conclude that Green IS can contribute to environmental sustainability by improving efficiency and effectiveness through automation, the provision of relevant information, and the establishment of better (more sustainable) services. However, the question is whether these roles are transferable to the public domain setting. The short answer is – for now, unsatisfactorily – yes and no. While the functions identified within the app analysis yield approaches that are concurrent with the roles to informate and transformate, no application within the analysis could be assigned to the role automate. At this point, we do not want to argue that this role does not exist in this scenario; we are merely presenting the results of the analysis performed. Informate is the most employed role within the green apps identified (see Table B-9). The core purpose of the attributed apps is to retrieve information in form of, e.g., news or tips. However, another frequently employed functionality is the provision of tools or feedback systems (Flüchter et al. 2014) that monitor user behavior and provide suggestions for behavior adaptions, rendering these apps interactive. On the other hand, apps with the transformate role allow the user to change their routines by offering new services or switching to more sustainable products. This is very well illustrated within both the mobility domain, where numerous apps make sustainable modes of mobility available to the user, and the energy domain, where more efficient household appliances are recommended and controlled via smartphone for more efficient use. Because these processes are generally consistent with the classic Green IS roles, our initial question about their suitability in the public domain was answered in part with a “yes.” However, during the analysis three additional roles emerged: educate, gamify, and collaborate. The educate role is characterized by engaging the user in a learning process. Apps from this category use teaching materials to educate the user about environmental issues and how they can be prevented. In contrast to informate, the solutions are categorized as micro- or mobile learning applications (Bruck et al. 2012). Large parts of the gamify role also address the learning process by offering learning games. However, these apps were assigned to a separate category based on the consensus of the researchers that these apps do not qualify as classic micro-learning applications. Moreover, the gamify role contains solutions that are not typical games but implement gamification elements such as rankings or badges to stimulate app use (Blohm and Leimeister 2013; Deterding et al. 2011). Finally, the collaborate role is primarily composed of two elements: The first part is concerned with collecting data from users in a crowdsourcing manner (Massung et al. 2013). In this case, the smartphone senses or the user enters environmental data and uploads the information to a data hub. In the second scenario, users are encouraged to share ideas or actions with others via implemented social media components. Sustainable actions can be shared with friends on Facebook, Twitter, or dedicated communities in order to raise awareness, generate sustainable innovations, and promote sustainable behavior.

Table B-8. Categorization of green apps with the underlying processes and functions

Domain	IS Roles (Functions)
ecosystem (20)	• **collaborate** (*community to create sustainable innovations*) • **educate** (*tips and tricks to prevent global warming, Q&A, learning within interest groups, notes/slides on various topics*) • **gamify** (*quizzes, learning games, simulations*) • **informate** (*displaying worldwide carbon emissions and dangers of rising CO_2 emissions, news about climate change*)
energy (43)	• **educate** (*lectures, discussions, videos, teaching benefits of energy conservation*) • **gamify** (*learning game*) • **informate** (*tips and tricks, shopping guide for efficient appliances, consumption tracking/monitoring w/ diagrams, feedback systems, energy usage recommendations, infrastructure-planning simulation, consumption measurement, carbon footprint indicator*) • **transformate** (*controlling household appliances, calculating possible solar energy production, energy-efficient house construction planning*)
food (22)	• **collaborate** (*food donation marketplace*) • **educate** (*sustainable shopping behavior*) • **gamify** (*food-chain learning game*) • **informate** (*product chain information, recipes with leftovers, carbon footprint calculator, endangered species, sustainable restaurant guides, tips and tricks, sustainable food shopping guide, tracking expiration dates*) • **transformate** (*connecting farmers to markets*)
lifestyle (49)	• **collaborate** (*collecting and sharing green tips, comparing energy consumption figures, sharing sustainable practices, adding sustainable places)* • **educate** (*guides for sustainable travel, carbon footprint calculator, list of carbon footprints for common products, learning material for sustainable knowledge)* • **informate** (*general tips on sustainable behavior, monitoring own water and energy consumption, CO_2 emissions calculator, list of sustainable places, list of events regarding sustainability, checking whether a certain product is sustainably produced, list of sustainable city efforts*) • **transformate** (*sharing behavioral practices, point-based plan for sustainable behavior adjustment, indirect donations through the use of a sustainable search engine, appliance purchase assistant, sustainable job finder, sustainability agents reminding the user about sustainable tasks)*
mobility (45)	• **gamify** (*fuel efficiency competition, learning game to save fuel, CO_2 production competition*) • **informate** (*CO_2 calculator, driving behavior analysis tool, fuel efficiency calculator, tips and tricks regarding driving behavior, map for sustainable fuel stations, feedback system for driving behavior, air travel emissions calculator)* • **transformate** (*travel information system [TIS], bike sharing, displaying CO_2 footprint of different modes of transportation, ride sharing, e-scooter sharing, TIS with focus on eco-friendly multi-modal traveling options, offering e-mobility services, calculator for most efficient meeting location, promoting bike usage, e-taxi service)*
pollution (22)	• **collaborate** (*reporting air traffic pollution and the impact on weather, environmental noise reporting [e.g., caused by traffic], and environmental crimes [e.g., littering]*) • **informate** (*diagrams and warnings on air pollution, displaying water pollution levels)*
recycling (14)	• **collaborate** (*sharing boxes/containers, sharing second-hand products, recording and sharing recycling efforts*) • **gamify** (*recycling learning games)*

	• **informate** (*tips and tricks, finding recycling opportunities/locations, crafting tips for innovative products)*
waste (30)	• **collaborate** (*reporting littering, collecting municipal solid waste management data, collecting waste disposal opportunities and hints*) • **educate** (*strategies to reduce waste)* • **gamify** (*learning games to reduce waste production and teaching recycling practices)* • **informate** (*reminder, tips, and locations for waste disposal; calculator for possible GHG emissions saved due to properly disposed IT)*
water (10)	• **collaborate** (*reporting water quality and pollution*) • **informate** (*water consumption monitoring for daily behavior, sources for water pollution, tips and trick for water consumption reduction, information about beach water quality)*
wildlife (7)	• **collaborate** (*reporting abundance of species, collecting tree growth and distribution data and calculating environmental benefits*) • **educate** (*teaching about how to protect wildlife)* • **gamify** (*learning game about endangered species)*

As we have the data regarding user ratings and installation numbers available from our app discovery process, we attempted to infer the adequacy of the processes identified based on the information provided to determine whether users favor particular roles. However, as the data in Table B-9 reveals, there are only marginal differences regarding average user ratings and the mean number of installations. Due to this finding as well as the relatively heterogeneous group sizes of the roles, further statistical analysis concerning the differences among the roles cannot be meaningfully analyzed on a statistical level. Furthermore, the rating and installation numbers depend on factors other than just the role of the IS and its underlying functionalities, including non-functional requirements such as stability, usability, and performance (Glinz 2007) and – for the rating – the number of people who submitted a score.

Table B-9. Average user ratings and mean installation numbers based on the underlying IS role

	Number of Apps Covering this Role	Average Rating	Mean Installation Numbers
informate	146	4	500–1000
transformate	42	4	1000–5000
educate	22	4.1	100–500
collaborate	31	4.1	500–1000
gamify	21	4.1	500–1000

Hence, we recommend that further research be conducted regarding the acceptance of the identified roles, their adequacy concerning functional requirements, and their interactions with the established goals (see Table B-10). We argue that the assessment regarding acceptance and adequacy for implementing the IS roles must be examined separately from a concrete artifact in order to eliminate interfering factors such as non-functional components. However, regarding the initial question of whether the classical roles are suitable for this scenario, we conclude with a "no." While informate and transformate are covered by a large number of apps, 39% of the solutions identified do not fit into either of these two categories. Although only a weak indicator – as discussed above – the *new* emerging roles have a slightly higher average rating than informate and transformate. At this level of analysis, we conclude that these identified roles *can* have a stronger impact on the effects of green apps. However, further and more detailed analysis on this matter is necessary to gain real evidence.

The *third research question* (*RQ III*) illustrates the goals addressed by the green apps and how they are addressed by different goal frames. Generally, the goal of sustainability applications is to influence user behavior to be more eco-friendly. However, from the functional perspective, this goal is too abstract to be implemented and covered by a respective role and the underlying processes and functions. To guide developers and offer concrete sustainability goals supported by the right processes, we clustered the goals pursued by the green apps identified. Moreover, we analyzed the functions employed in terms of goal-framing theory (Lindenberg and Steg 2013) and illustrate how the respective sustainability goal (normative goal) can be supplemented with hedonic and gain goals to increase the effect of the applications (see Table B-10).

Table B-10. Sustainability goals and interaction of goal frames

Normative Goal	Goal Frame Activated	Compatibility Approach
animal protection	hedonic	donations
carbon footprint reduction	hedonic gain	collecting points, (team) rankings, donations rewards (coupons), fuel (money) saving
data collection	hedonic	badges, ranks
ecosystem education	hedonic	learning quiz game (competition)
pollution reduction	hedonic	points, rewards
raising awareness	hedonic gain	awards, rewards saving energy costs
resource efficiency	hedonic gain	rankings and levels, badges and points, donations saving money (fuel, energy)
resource protection	–	–

The analysis reveals that few applications (16) attempt to address a different goal frame aside from the actual normative goal of improving environmental sustainability by implementing dedicated functionalities. Most of these applications implement gamification elements to motivate and engage the user in using the app (Deterding et al. 2011). These apps award badges and points to the user based on their sustainable actions, e.g., collecting data about noise levels, reducing CO_2 emissions by using sustainable modes of transportation, or exhibiting energy-efficient consumption behavior. These mechanisms aim to make the user feel good about his or her actions and thus address the hedonic goal frame. Besides the game-like experiences, some apps allow the user to make donations, which also adds to the positive individual feelings (hedonic goal frame). Other applications use feedback mechanisms (see Table B-10) to visualize and attempt to change user behavior. Such applications provide information based on current behavior, such as energy, food, water, or fuel consumption, and display the potential impacts on the user in terms of, e.g., health issues or monetary expenses. These applications aim to address the user's gain goal frame by presenting information concerning resources. If a user is particularly resource oriented, then his or her gain goal will be active, meaning that this user would be more inclined to use the app if functionalities to support this goal frame are implemented (Lindenberg and Steg 2013). This applies analogously for the hedonic goal frame. Thus, the user will implicitly pursue the normative goals (environmental sustainability) when attempting to reach his or her goals.

At the beginning of elaborating our second research question, we raised the question of what actually constitutes a green app. Based on our findings, we define a green app as an information system that supports the user in performing sustainable actions. A green app implements at least one of the roles identified – informate, transformate, educate, collaborate, or gamify – to provide processes and functions for fulfilling sustainability-related goals. These goals should be aligned with motivational concepts via individually addressed goal frames to further engage the user in using the app.

6 Discussion

In this paper we aim to provide an overview of existing user-centric Green IS solutions from IS research and practice. We are interested in the addressed application areas, supported processes and functions of the apps, and how these apps support goal attainment. The findings of this article shall help to guide future research and practical implementations in the research field of pervasive and persuasive technologies to contribute to environmental sustainability and thereby help reducing the negative environmental effects of personal behavior.

The Google Play store analysis for applications addressing environmental sustainability-related issues provided numerous results for various sustainability goals with a wide range of functionalities. However, the utilization rate of these solutions is very low, with 76% of the apps being downloaded and installed fewer than 5000 times on average, yet with a value of 4.0, the average rating of all apps identified is relatively high (with 5.0 as the highest). As the low installation numbers of the apps reveal, it is not enough to create an app and upload it to a distribution platform. Moreover, the presence of so many rarely used sustainability-oriented applications on the market indicates that there is a lack of coordination and information diffusion. The low utilization of the applications and the availability of different solutions for the same purpose creates competition, thereby limiting the potential of the apps. A central platform as a unique moderator could increase the awareness and engagement by organizing the apps into one large group. For example, cities could launch a sustainability campaign and provide a green app with its inherent capabilities as a service. The city would thus serve as a trustworthy, well-known, and accepted platform for a sustainability initiative (Walravens and Brussel 2013) and would pose as a smart city by offering services and infrastructure to support sustainable practices (Brauer et al. 2015). Furthermore, this would enable third parties to offer such services to the city administration, thus reducing governmental efforts and establishing competencies for the service provider that would help further improve the services. As the analysis also indicates, solutions for the public domain with the goal of increasing environmental sustainability should emphasize interactive functionalities. All three emerging IS roles go beyond the possibility of retrieving information or the provision of services. Therefore, green apps should consider the implementation of interactive design patterns with social elements.

The majority of the applications identified are generally concerned with altering an individual's behavior. To successfully trigger such behavioral change, several factors are necessary: Important elements to be investigated include which behaviors should be altered, which factors are relevant (e.g., normative concerns or habits), which interventions could be applied (e.g., addressing multiple goal frames simultaneously), and the effects of such interventions (Steg and Vlek 2009). We consider the intervention to take a strategic role and provide an example regarding the motivation to participate in such a sustainable initiative in order to carry out the idea. If a company or city propagates sustainable behavior, it can be effective in incentivizing users for engagement (Stern 2000). While there are always some people who are extremely concerned about the environment, others might indeed have a fundamental interest in undertaking more sustainable behaviors but require a final push for engagement and yet others might be completely uninterested in behavioral change (Steg and Vlek 2009). The second group can be considered the most important target group because they yield the greatest potential for change. Due to their nature, the first group has little room for improvement and is generally willing to expend a little more effort for the greater good. The last group would be entirely unimpressed about such a campaign and requires significant effort for engagement (e.g., financial rewards). In contrast, it might be easier to convince the second group to participate in such an initiative by merely offering motivational incentives that address additional goal-frames (hedonic, gain), which do not necessarily have to be cost intensive. The implementation of concepts such as gamification (Deterding et al. 2011; Law et al. 2011) is promising; designers can motivate people by offering game-like elements as part of the green app, such as rankings for competitions or badges and other (non-monetary) rewards (Blohm and Leimeister 2013; Hamari 2013). If such functionality were to be implemented, a central platform could help control the actions performed and the outputs from the mechanisms, e.g., a company- or city-wide high score list or an overview of badges per participant to ensure and foster further engagement via public awareness.

7 Limitations and Future Research

As the analysis only scratches the surface of the utilization of mobile applications to foster environmental sustainability there are some limitations of this research. The results regarding the domains, IS roles, and goals depend on existing apps. Hence, there might exist other meaningful characteristics that are omitted in this study. Moreover, we only considered the Google Play store for our analysis – apps from other platforms, e.g., Apples app store might address additional areas and provide different findings. However, the analysis offers a first overview of existing solutions. The goal of this article is to create an avenue for further research on this matter and improve the utilization of mobile devices in contributing to environmental sustainability. Future research should focus on single solutions and examine the effect of addressing different goal frames as well as their impacts on application acceptance and the personal affordances of the user. Moreover, we encourage the examination of the identified roles implemented by the green apps in terms of their adequacy and user acceptance. As acceptance plays a major role in the adoption process of IS, an examination of the contribution of single mechanisms on system adoption should be performed to increase green app acceptance. Despite the consideration of goal-frame alignment and the implementation of motivational and incentive mechanisms, the analysis yielded many applications with social media functionality allowing the user to share ideas and start discussions on the topic of environmental sustainability. This is illustrated particularly well by the collaborate role. As social interaction cannot be attributed with certainty to the hedonic and gain goal frames, we recommend further examination of the social aspects in such applications. While the broadness of solutions identified illustrate the theoretical contribution of green apps to environmental sustainability, the true effect of these solutions is not measured in this study. Thus, we recommend further studies investigating and measuring the effect of such implementations with appropriate measurements such as perceived personal sustainable awareness. Moreover, it would be interesting and important to examine the reasons for the low download (usage) rates. Hence, empirical, qualitative studies with test-subjects and the apps identified in this analysis should examine the concrete adequateness of the apps regarding roles, goal-frames, usability, and application areas.

8 Conclusion

In this paper we assessed the potentials of mobile applications to contribute to environmental sustainability and provide a holistic perspective by performing an extensive classification of existing apps. The analysis of the Google Play store reveals that there are already many applications available. However, the investigation also indicates that the applications available are rarely used, although the user ratings are predominantly positive. This indicates that the awareness and diffusion of these applications is rather low. As the richness of application domains and supported functions identified indicate, the utilization of mobile devices and apps can have manifold positive impacts on environmental issues. However, the results also shows that there is still much potential for these apps to be improved, especially regarding processes for motivation and the organizational support to conduct mobile app based sustainability initiatives.

II. Theories and Mechanisms

In the second building block of this thesis the two studies (B.II.1 & B.II.2) are concerned with theories and mechanisms in the context of environmental sustainable behavior (ESB). The first study (B.II.1) of this chapter analyses existing behavioral theories, psychological barriers, and mechanisms in the context of pro-environmental behavior change. Furthermore, the study provides a theoretical framework for the design of user-centric Green IS to form sustainable communities through the utilization on information systems. The second study (B.II.2) of this building block takes one particular behavioral theory to induce pro-environmental behavior change and examines it in context of the use of a user-centric Green IS. Both studies together aim to structure existing knowledge about ESB theories and their practical application through concrete Green IS implementations.

II.1 Study 3: Towards IS-enabled Sustainable Communities – A Conceptual Framework and Research Agenda

Table B-11. Fact sheet of study no. 3

Title	Towards IS-enabled Sustainable Communities – A Conceptual Framework and Research Agenda
Authors	Benjamin Brauer*, Lutz M. Kolbe Chair of Information Management, Georg-August-University Göttingen, 37073 Göttingen, Germany *Corresponding author. Tel.: +49 551 39 2 11 70. E-Mail address: bbrauer@uni-goettingen.de
Outlet	Proceedings of the 22nd Americas Conference on Information Systems (AMCIS), August 11-14 2016, San Diego, USA.
Abstract	The trend of urbanization leads to several environmental problems such as shortage of resource, pollution, and rising carbon emissions. In the smart city context sustainable communities are considered as promising measures to tackle these issues. The technological evolution of the recent years offers versatile opportunities to convince people in their behavior and the potential of information systems to support ecological improvements gains increasing importance and interest in research. In this paper we propose a theoretical framework for the design of citizen-centric environmental sustainable information systems to build sustainable communities in smart cities. The framework considers theories and counter measures from psychological, social, environmental, and IS science to create a holistic architecture for green IS implementations. The goal is to drive further research and practical implementations in this domain.
Keywords	Green IS, Smart Cities, Sustainable Communities, User-Centric Framework

1 Introduction

The population density has been increasing over the last decades and the trend of this development prevails; more and more people live in cities rather than in sub-urban areas (McDonald 2008). This trend, generally referred to as urbanization, brings several problems with it, especially regarding environmental concerning issues (McDonald 2008; Washburn and Sindhu 2009). In order to address the imminent shortage of resources and increasing carbon emissions, several counter measures are already considered. Despite the obvious actions of acquiring more resources (e.g. water, energy sources) and lowering carbon emissions by introducing $C0_2$ friendly appliances (solar-powered light systems) or modes of mobility (e.g. e-Busses), alternative measures gain increasing importance. A very promising way to reduce the negative impacts of higher population numbers in urban environments is by influencing people's behavior (Kollmuss and Agyeman 2002; Kurz 2002; Stern 2000). At this point cities and their inhabitants can have a major effect when the organization of sustainable communities takes place (Lövehagen and Bondesson 2013; Portney 2005).

In the context of smart cities the denotation 'smart community' is often used to conceptualize the basic idea of sustainable communities. Although the definition of a smart community is more comprehensive. Smart communities inherit their properties from the general description of what constitutes smart cities. While there is no unique and overarching definition, there are three key factors that can be referred to as fundamental components. A smart city encompasses technological, institutional, and human factors (Nam and Pardo 2011). Thus, smart communities have a strong bond to governmental instruments and policies and aim for generating knowledge and creativity. In this context information technology plays a vital role to supplement the required processes and underlying infrastructure (Bengtsson and Ågerfalk 2011; Nam and Pardo 2011; Tranos and Gertner 2012). Sustainable or smart communities are composed of different neighborhoods and interest groups sharing their ideas on sustainability relevant topics and engaging in collaborative activities to reach a common goal (Nam and Pardo 2011; Xia et al. 2014).

On one hand, citizen-centric application of information systems (IS) has barely taken place in IS research regarding environmental sustainability in the city context (Brauer et al. 2015). On the other hand, cities deploy user oriented information systems to offer easier accessible or additional services to their citizens to make governance tasks more comfortable and to increase the quality of life as well as to optimize internal processes (Neirotti et al. 2014). In addition, pervasive mobile technologies such as smartphones, tablets, and wearables offer plenty opportunities to persuade and influence individual's user behavior (Woodruff and Mankoff 2010). In the smart city context the city can take a moderating role to connect users (citizens) and possible additional partners (businesses) as sponsors into a sustainable community with the goal to improve environmental sustainability. Therefore, the city can serve as a platform (Walravens and Brussel 2013) for initiatives, and communication for collaboration by utilizing information technology to trigger behavioral changes of their citizens. As it is the case in various application areas where pursued goals do not directly add to the user's own profit, mechanisms are required to motivate the potential participants and to drive engagement with long-term positive effects.

In this paper we provide a theoretical framework that helps create a holistic approach towards the creation of city-wide sustainability related campaigns through the help of their citizens. The framework considers multiple actors and system architecture in the context of environmental sustainability. The long-term goal is to encourage the development of green IS in the smart city context focusing on every individual, but also to incorporate partners from business and industry. Moreover, we present a research agenda for future studies in this area to drive further development of user-centric sustainable IS-design for sustainable communities.

2 Barriers and Influencing Factors of Eco-Sustainable Behavior

Before we discuss the opportunities for improvements on environmental sustainability provided by information systems, we take a deeper look in the theory behind environmental sustainable behavior in order to identify the prevalent problems which are often faced in this context. The discrepancy between environmental concerns of individuals and their final engagement in environmental actions is often referred to as value-action gap, and describes the prevailing issues in-between the two states of worrying about the environment and appropriate performance (Barr 2007; Blake 1999; Flynn et al. 2009). These inherent barriers are divided into an individual and social context comprising factors that prevent a person from acting sustainable based on their personal characteristics but also institutional circumstances and the influence of other people (Blake 1999; Kollmuss and Agyeman 2002). Gifford collated an extensive and thoroughly list of psychological barriers (see Table B-12) that play an important role for environmental sustainable behavior change (2011).

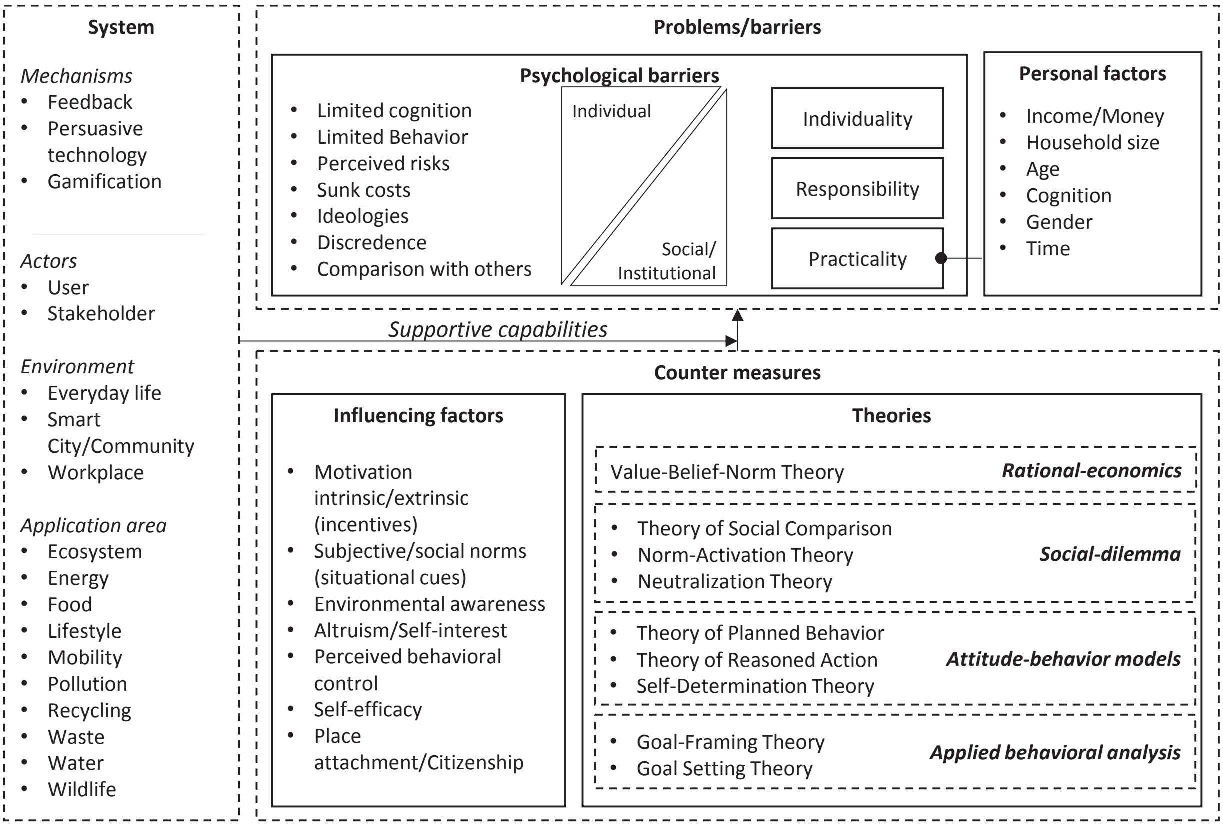
Table B-12. Psychological barriers of sustainable behavior

Barrier	Description
Limited cognition	Limited knowledge about the state and threat of climate change, which leads to uncertainty about taking action and serve as a justification for inaction. This causes people to doubt their perceived behavioral control and self-efficacy regarding the outcome of their actions.
Ideologies	Some people hold a view that nature will go its way and does not need human intervention. Others are content with their lifestyle and cannot see how a change in their behavior could have any positive impact on either their or the life of others. Likewise, some people expect that there will be technological solutions soon that solve the prevailing ecological problems and that further personal efforts are a waste of personal resources (e.g. time or money).
Comparison with others	People compare themselves with others in nearly every life situation (Festinger 1954). If social peers do not comply with one’s sustainable behavior it can lead to undesired and unexpected negative response and result in damage of reputation, self-esteem, and self-confidence (Corral-Verdugo et al. 2014). Moreover, if others do not act sustainable it may arise the question why one should engage in a more sustainable lifestyle to make the world a better place (Corral-Verdugo et al. 2014). Contrary, social interaction can have the opposite effect. If other people around oneself act sustainable, the pursuit of such behavior can become desirable (Lindenberg and Steg 2013).

Sunk costs	Past behavior may be connected with costly investments, e.g. for household appliances. Thus, past behavior and investments can be considered as sunk costs, if a more or less sudden behavioral change impends.
Discredence	Many people share the opinion that climate change does not exist and distrust governmental and scientific statements about climate change and its impact. This can lead to the belief that climate related programs are useless or inadequate and create mistrust in governments, programs, and even other people.
Perceived risks	There can be doubts about the effectiveness of actions taken, e.g. due to limited knowledge or certainty. Hence, the person might question whether financial investments in a more ecological appliance is worth it or if the outcome of an action satisfies the time spent.
Limited behavior	The belief that other countries or places have a higher share of the negative ecological impacts can lead to a lower willingness making an effort. The same applies for a lack of identification with the place where a person lives and their community. Additionally, rebound-effects can occur, e.g. the purchase of a more sustainable car results in more car-use or inefficient driving because it is thought to be sustainable.

Generally, these factors can be assigned to the categories *individuality*, *responsibility*, and *practicality* (Kollmuss and Agyeman 2002). The individuality-dimension covers barriers that arise from the characteristics of a person, their attitudes, and temperament. Responsibility encompasses factors that make a person believe that s/he has no influence on the ecological situation and should not be in charge of taking actions. The reasons are manifold and originate from a lack of efficacy, trust in others, or limited (perceived) possibilities. The practicality-dimension describes institutional and social limitations, e.g. a person might not have the financial or temporal capacity to act sustainable. Respectively, there can be a lack of fundamental and valuable information or encouragement (Blake 1999; Kollmuss and Agyeman 2002). All these psychological factors are also influenced by personal circumstances as mentioned above, e.g. financial risks. Personal factors like income, household size, age, educational level and even gender can affect the success of behavioral change efforts (Fogg 2009a; Zhang et al. 2015).

Figure B-3. Problems and counter-measures of environmental sustainable behavior



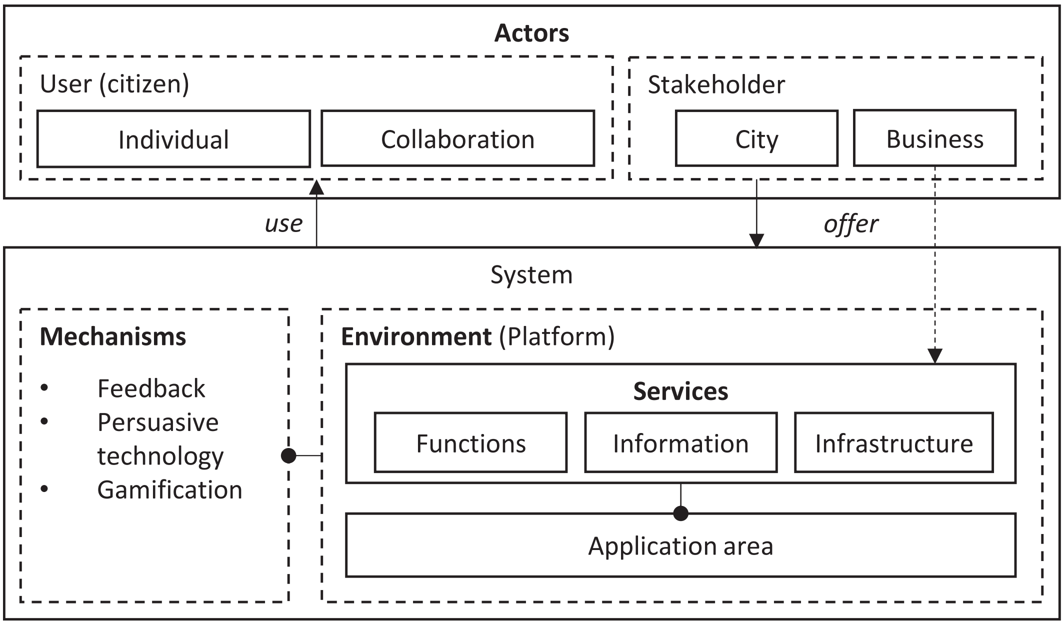
Psychological, social, and environmental science covered the topic of environmental sustainable behavior change in great extent during the last years and it became an extensive research field. Particularly the theoretical perspective is well-studied due to the application of various theories to explain and predict behavior change processes. Figure B-3 illustrates the complexity of the driving forces behind environmental sustainable behavior change approaches with an overview of applied theories in the context. The theories are attributed to the four general psychological approaches of environmental sustainable behavior (Kurz 2002). It would be inappropriate to label a theory or concept improper because it does not hold for a certain case; what works for some people might not necessarily work for others and vice-versa. Thus, concrete implementation should always consider conflicting theories and concepts. A theoretical concept of this circumstances has been applied in the ecologic-behavior context in form of the goal-framing theory (Lindenberg and Steg 2013). The theory states that individuals have manifold goals and expectations regarding their behavior. An intervention should ideally address the normative-, gain-, or hedonic goal-frame. Hereby, a person’s motivation is activated based on his/her preferences, e.g. monetary/health benefits (gain), fun/well-being (hedonic), or the targeted purpose (normative, e.g. environmental sustainability). On a more specific level regarding goal-achievement, the goal-setting theory argues that quantifiable goals should be variable and geared to individual’s cognitive and institutional possibilities (Locke and Latham 2006). Otherwise, motivational potential is lost and future engagement is in danger.

The existing theories give a very good idea about what factors need to be considered for successful behavior change interventions. The goal of IS-based solutions should be to take advantages of the identified influencing factors (see Figure B-3) and address the psychological barriers given above as substantial as possible. The following section discusses suitable approaches where IS can offer a good contribution to build sustainable communities.

3 Towards an IS-Enabled Framework for Sustainable Communities

In this section we propose a theoretical framework for the design of eco-IS to support the establishment of sustainable communities with the goal to trigger sustainable behavior change of people. The design is not targeted on specific technical implementations but rather takes a holistic view. Besides the presentation of concrete examples to tackle the prevailing issues of the psychological realm, we focused on this area from an organizational perspective. Figure B-4 illustrates the conceptual design of the proposed IS-based framework (System) as introduced as a supportive measure in Figure B-3 (left-hand side).

Figure B-4. Framework for IS-enabled sustainable communities



The single components of the framework and their interaction with the influencing factors from theory as well as their potential impact on the psychological barriers are discussed in the subsequent sections.

3.1 Components of the Framework

The proposed framework consists of four key-components: *Actors*, *Environment*, *Services*, and *Mechanisms*. The actors are divided in users and stakeholders, where stakeholders provide a system to foster environmental sustainable behavior of users. The institution that offers the system should be centralized, trustful, and able to reach a large group of people. As mentioned above cities have potential to create communities. Since it is always the goal of municipal governments to improve local sustainability (Kutami 2014), they should take a leading role for such initiatives by serving as a platform for their citizens (Walravens and Brussel 2013). However, cities often do not have the funds or technological competencies/infrastructure to run such initiatives on their own. Consequently, it is commendable to cooperate with local partners from the business or industrial sectors.

The environment describes the service platform integrating all available sustainability interventions and serves as the interface to the user. It can be implemented as a browser-based web-application, a mobile application for smart devices (smartphone, tablet, or smartwatch) or a combination of both. Each single service has a dedicated purpose and is a discrete module inside the platform. The platform – or runtime-environment – provides the interfaces required to easily add additional service modules. The advantage of this architecture lies in its flexibility and centrality. Equal to an online-marketplace like Amazon, a centralized platform could positively contribute to the diffusion of sustainable IS-solutions and a rise of awareness (Ghazawneh 2010; Walravens and Brussel 2013). Furthermore, the distribution of innovative sustainable IS will be simplified.

Services running within the environment are sets of functions, information, and infrastructure required to offer a sustainable intervention. They are attributed to a specific application area (see Figure B-4) like the mobility sector and use different mechanisms to drive user engagement – the supportive capabilities of appropriate mechanisms are discussed in the next section. The environment-service architecture allows partners from business and industry to offer their products in a very comfortable fashion. An electric utility company, for instance, could sell smart-meter products and use the prevalent platform to offer a service module to let the costumers monitor, compare, and eventually adapt their consumption behavior, and by this reach more people or potential clients. While this sounds inconsistent with the company's goal to sell power at first, it could add additional value to the service of power supply, and in this way lead to higher customer satisfaction and retention (Kuo et al. 2009).

In order to design the service modules as sustainable interventions they require appropriate functionality. Hence, the selection of proper mechanisms is crucial for the intervention's success regarding the prevailing psychological barriers. Green IS research examines the capabilities of information systems as contributor to environmental sustainability (vom Brocke et al. 2013b). Nevertheless, the mainstream of research focuses on business related topics such as sustainable production and supply chain management and less on the public sector (Brauer et al. 2015). The existing literature in this area primarily addresses two application domains: energy and transportation. In the transportation domain such solutions aim to influence the driver behavior regarding fuel efficiency by providing feedback about the impact of driving behavior on fuel consumption and the resulting Co_2 emissions (Tulusan et al. 2012). Other approaches use IS based interventions and feedback mechanism to promote sustainable mobility alternatives such as bike usage (Flüchter and Wortmann 2014) or provide solutions to track their overall mobility behavior as a combination of different modes of mobility and give information about the total ecological impact of the applied mobility behavior (Froehlich et al. 2009). In the energy domain smart meter and information systems are run to track and visualize energy consumption of households. These applications are utilized to persuade users regarding their energy consumption behavior and examine the effects of social normative feedback on electricity consumption by the consumption-comparison of e.g. neighbors or friends (Loock et al. 2012). Besides the utilization of feedback- (Flüchter and Wortmann 2014; Loock et al. 2012) and persuasive systems (Oinas-kukkonen and Harjumaa 2009), gamification can be used to motivate and incentivize sustainable behavior and community collaboration by IS (Flüchter and Wortmann 2014; Lounis et al. 2014).

3.2 Supportive Capabilities of Information Systems

The prior sections give an overview about the complexity of the field of environmental sustainable behavior. Building sustainable communities is a complex task. Based on existing research we identified two central areas which are discussed in the following. First there is the need to drive engagement for sustainable behavior on an individual level and second, the promotion of social collaboration. These two scopes are not mutually exclusive but rather complement each other. The motivation of people towards engagement in sustainable activities is not an easy task and there is no blueprint for the perfect solution because people are different. As the theory shows, there are many factors that have an impact on a person's attitude and ultimately on behavioral change. However, as indicated above, IS can have huge potential to overcome the prevailing barriers by facilitating the factors that can have a positive influence on people and help to convince them towards more sustainable behavior. A major problem concerning environmental sustainability is that many people are not aware of existing problems and the impact of their behavior on the environment. People need information; but it is hard for them to find suitable solutions if the problem is unknown. Thus, a holistic sustainability oriented information system could provide all the information necessary and help to understand the situation. Existing literature on the application of IS in the ecological context provide three approaches to address this issue: sole information provision, feedback on personal behavior, and persuasion (Flüchter and Wortmann 2014; Froehlich et al. 2010; Tulusan et al. 2012). The most basic way to tell people what is sustainable or not, and what sustainable behavior could look like is by providing general information. This could be guides, articles, life-hacks, etc. actively consulted by the user or passively provided by, e.g. social media. While this could be very helpful in terms of effectiveness, the existing psychological barriers are very likely to cause a person to refrain from engagement. The information might be given but a person does not belief that s/he can have a positive impact on the environment (Gifford 2011). This can be covered with the implementation of feedback mechanisms to monitor, evaluate, and report user-behavior (Froehlich et al. 2010). This approach enables an interaction between the system and the user and can address several barriers that sole information provision cannot achieve. Personalized feedback can trigger awareness about own behavior (Loock et al. 2013) and foster self-interest in personal decision processes (Gifford 2011). A person can view the impact of her/his actions in numbers, e.g. the amount of CO_2 saved by using sustainable travel modes (Froehlich et al. 2009) or visual, e.g. by the use of augmented technology to show air quality (Kim and Paulos 2009).

Nonetheless, for some people ecological goals have minor importance but this does not mean that they would not engage in sustainable activities by any means. As the goal-framing theory suggests, people have varying objectives and therefore require different motivational processes to trigger their interest (Lindenberg and Steg 2013). Accordingly, as an example, a service module for sustainable mobility alternatives should not only provide feedback about the amount of CO_2 emissions saved but also about potentially saved money compared to individual car-ownership or fitness related functions for e.g. bike-use to promote health-related motives. The pursuit of one of these goals different from the sole aim to reduce CO_2 emissions implicitly leads to the same result and therefore a positive impact on the environment. This can happen without having the person know that s/he engaged in sustainable activities at all and hence does not result in a burden for this person. Basically, an implementation of a service module should always consider a way to shift the intrinsic motivational aspects towards individual personal characteristics in order to reach a broader target group.

Another common way for motivation is triggered extrinsically and often instantiated through incentives (Barr 2007). Incentives can have many faces: materialistic, solidary, and purposive (Zald and Ash 1966). Since materialistic incentives like money or goods are always hard to realize because the unavailability of necessary funds – especially in a context like environmental sustainability –, solutions should focus solidary and purposive implementations. In the recent years gamification has been proven to be a successful mechanism to trigger motivation in various areas such as education, work, health, and sustainable consumption (Hamari et al. 2014). Gamification uses game-like elements in non-game contexts (Blohm and Leimeister 2013; Hamari et al. 2014), e.g. high-score/ranking lists to trigger competition, collecting badges/virtual rewards, and many more (Hamari et al. 2014). Besides individual motivation gamification also helps to foster social collaboration among communities (Lounis et al. 2014). People can work in groups to e.g. become a winner of a competition. Moreover, people see the actions and the amount of actions performed by others. These can lead to situational cues where people recognize sustainable behavior in their area and makes it more likely that they also engage in sustainable actions (Lindenberg and Steg 2013) to participate in positive behavior and contribute to the community. In this context cities can benefit from their urban structure. Studies showed that sustainable behavior of people is more likely to take place if they feel an attachment to their environment (Pol 2002), e.g. a village, city district, or local community. A system could utilize this factor and give information and feedback about sustainability related topics in people's vicinity. Furthermore, in the context of gamification, tasks or missions could be assigned inside the system using incentives, e.g. awards, badges, points, etc. and trigger a sustainability competition between different areas.

However, motivation alone is not necessarily sufficient to engage people in the desired behavior (Fogg 2009a; Mustaquim and Nyström 2014). Personal factors such as lack of time, limited financial resources, cognition, etc. play an important role regarding the ability of people to engage in certain tasks or behavior (Fogg 2009a; Zhang et al. 2015). A system aiming to persuade people towards a certain behavior has to make sure that their abilities are met (Fogg 2009a). System design is crucial and can help to overcome personal factors which information, feedback, or motivational mechanisms cannot address. As time can be a very scarce resource, an application must be simple and fast to use – complex menus or excessive input should be avoided (Fogg 2009a). Same applies for e.g. monetary and cognitive needs, since the potential users are very diverse in terms of age or educational level. Thus, some people might not have the funds to perform certain action or do not understand what is to be done (Fogg 2009a; Mustaquim and Nyström 2014). When fundamental motivation is given and the right measures to care for the user's ability are applied it can still be necessary to trigger an action to engage the persuasion (Fogg 2009a). Examples can be drawn from fitness and health applications that are frequently used nowadays, where a user receive e.g. a message prompt to get up and walk a few minutes (Cercos and Mueller 2013) or to eat healthy (Purpura et al. 2011). Such triggers can be incorporated with feedback information, e.g. if the amount of water-use is very high compared to recent behavior or others in the area – maybe a behavioral adoption should be considered; or the gamification mechanism, e.g. in form of a mission to collect extra point for a person's area by riding a certain distance by bike. This could motivate a person to take the bike to work instead of the car which was probably the initial intention.

4 Summary and Outlook

This article provides a design pattern with key components that can be considered in the design phase of an application aiming for ecological behavior change with a user-centric perspective. Existing research shows that it is important to address psychological barriers, influencing factors, and design principles given above for better results regarding behavioral change. Contrary to the corpus of existing research in this area we focus on forming sustainable communities. As shown above, this includes a combination of individual concerning attributes as well as for the interaction of people, groups of people, and their interaction with their environment. This encompasses not only governmental infrastructure but also business and industry. Hence, our goal is to include these actors and environmental characteristics into the framework. We argue that a holistic solution in a centralized municipal context can have higher potential than a diffusion of loose individual applications with different characteristics in various domains. However, this assumption has to be investigated.

While the underlying theory and their application in the context of sustainable behavior has a long history – their application and research in the IS domain constitutes a rather young field. Some approaches have already been made but their application is still limited to only few – yet promising – areas such as the energy and transportation domain. Nevertheless, there are more areas where citizen-centric information systems can have huge positive impacts on the environment, e.g. waste-management (recycle, reuse, reduce), life-style, water-usage (equal to energy consumption), and more. In the following we propose an agenda for future research in this particular domain of IS-use to foster sustainable communities in the context of sustainable (smart) cities.

- The sheer complexity of barriers and influences are obstacles for concrete practical implementations. This poses a challenge for future research in this area. It is wise to break down single thematic problems into smaller parts as prior research already did for single theories, mechanisms or interaction between user and system (HCI). However, future research should also consider the implementation of various approaches in parallel and examine them regarding synergy and exclusion. This will help to create more precise design patterns for future implementations. In this context more research should focus on the acceptance of such systems. This includes the consideration of various context-factors such as the role of place attachment, different combinations of motivational mechanisms, or social aspects. We encourage as well the investigation of other theories from different domains and their applicability in this context.

- For building sustainable communities, the later point is of great importance. While some studies examine social norms in their research models (Steg and Vlek 2009) or use social components inside an artifacts (Flüchter and Wortmann 2014; Froehlich et al. 2009; Loock et al. 2013; Tulusan et al. 2012) the concrete effect of social factors is yet unsought. Future research should examine the positive effects of social elements as well as their drawbacks. How can social components like social-media, interaction, or collaboration contribute to environmental sustainability? Is there a word-of-mouth effect? What is the role and potential of IS? In addition, it is interesting to find out if the positive effects can overcome the negative effects of social norms, and what practical implementations could look like.
- In this article we accord great relevance and potential to cities and their role as platform operator and moderator of an initiative. Forthcoming studies should aim to examine the abilities of cities to take that role and whether there is a positive effect of this construct opposed to the implementation of single independent solutions. As we sketched the role of partners within the framework, we urge researchers to find solutions how business and industry could be integrated within this context. Important questions include the willingness of enterprises and local businesses to engage in such initiatives and their role as promoter or supporter, e.g. by offering incentives/discounts to users.
- Incentives and motivational mechanisms play an important role as stated above. However, in the context of environmental sustainable behavior and the characteristics of this framework research should examine the suitability of implementations in this particular scenario. Different mechanisms could work or fail in varying application domains. Studies should evaluate the effect of materialistic, solidary, and purposive incentives. While the goal is to establish implementations that require little to no financial input, alternative options are also of interest if first said will not work. Micro-payments as used by Google for their survey app (Geidner and D'Arcy 2015) could be an interesting approach, especially if the preceding point about business integration is feasible. Bitwalking[4] for instance pays their users money (bitwalking dollars) for recording their walked distance with their app. The currency can be redeemed in a dedicated online store for various goods. For non-materialistic motivation gamification has been discussed within this paper. The gamification mechanism offers several dynamics to initiate motivational processes. Only little research has been performed about the suitability of certain implementation so far and deeper investigation is required. Moreover, other approaches might exist that

[4] http://www.bitwalking.com/

have been implemented in other areas successfully. Interactions of different approaches are also of interest, e.g. the combination of gamification as a motivator and micro-payments as an incentive.

- Finally, we want to encourage more practical work in this field with concrete implementations. This encompasses specific implementations to evaluate, e.g. the suitability of IS-application in certain eco-related domains and both the evaluation of mechanisms, and the holistic approach as suggested in this article. While the theoretical work offers great contribution to the understanding of concepts and dynamics only practical implementations and their evaluation can show if IS can really contribute to user's eco-behavior change and helps to learn lessons for future implementations.

5 Limitations and Conclusion

This paper yields some limitations. We did not perform an extensive literature review of general psychological or social theories on behavior change and motivation. The main reasons were the complexity and broadness of these research domains. The scope in this paper is the application of theories and influencing factors in the ecological domain. Same applies for the implementation of IS-artifacts, more precisely the adoption of mechanism for eco-behavior change. In the same way, no research of practical implementation outside scientific research has been conducted, e.g. municipal sustainability initiatives. Thus, possible existing IS-based solutions might have been overlooked. We proposed a theoretical framework for the design of citizen-centric environmental sustainable information systems to build sustainable communities in smart cities. The framework considers theories and counter measures from psychological, social, environmental, and IS science to create a holistic architecture for green IS implementations. The goal is to drive further research and practical implementations in this domain.

II.2 Study 4: The Role of Goal Frames Regarding the Impact of Gamified Persuasive Systems on Sustainable Mobility Behavior

Table B-13. Fact sheet of study no. 4

Title	The Role of Goal Frames Regarding the Impact of Gamified Persuasive Systems on Sustainable Mobility Behavior
Authors	Carolin Ebermann*, Benjamin Brauer Chair of Information Management, Georg-August-University Göttingen, 37073 Göttingen, Germany *Corresponding author. Tel.: +49 551 39 2 11 74. E-Mail address: eberma@uni-goettingen.de
Outlet	Proceedings of the 24th European Conference on Information Systems (ECIS), June 12-15 2016, Istanbul, Turkey.
Abstract	This study analyzes the motivational processes of a gamified persuasive system in an initiative to encourage sustainable mobility behavior by promoting bike usage. To increase motivation and drive sustainable behavior, the design of persuasive systems is gradually advancing. Game-based functions are often implemented to transform the user experience through playful interactions. This paper explores whether the functions implemented within gamified persuasive systems really fulfill an individual's goals and needs by analyzing the impact of the user's personal goals on gamified persuasive system usage and the desired outcome in the domain of sustainable mobility behavior. The theoretical basis for this study comes from the goal-framing theory as well as the perspective of functional affordances. The results in this work indicate that the functions implemented are only partially compatible with user goals. Furthermore, the results demonstrate that the influence of goals on sustainable mobility behavior can be increased through the implementation of specific functions within a persuasive system.
Keywords	Persuasive System, Gamification, Goal-Framing Theory, Sustainability, Affordances

1 Introduction

Climate change and our responsibility for its effects on the equilibrium of global ecology has become a central issue in today's society. If no actions are taken, worldwide temperatures are expected to increase by over two degrees by 2035 (IEA 2007) due to a 27% rise in carbon dioxide emissions since 2000 (Filcak et al. 2013). Recent studies indicate that a large part of these emissions are caused by human activities, with the transportation sector responsible for 14% of the total CO_2 emissions (IEA 2007). Despite recent political efforts to reduce these emissions (e.g., tax regulations, road tolls), the number of cars per household is still increasing while the use of other transportation options, including walking and cycling, drops (Filcak et al. 2013). These concerning numbers highlight the possibility of changing future developments by shifting individual mobility habits. Thus, it is clear that people should be motivated to change their mobility behavior in order to reduce greenhouse gas emissions; the question is how this can be achieved. It is therefore the duty of various research disciplines and policymakers to determine a way to galvanize people into engaging in more sustainable mobility behavior (Gifford 2011; Osbaldiston and Schott 2011).

In an emerging area of IS research referred to as Green IS, researchers aim to address environmental problems by improving information supply and stimulating behavioral changes through offering better solutions and information as well as employing incentive mechanisms (e.g., Hilpert et al. 2013; Watson et al. 2010). Accordingly, Green IS can be helpful to motivate people to change their personal mobility routines. Currently , various persuasive systems have been applied to achieve a shift towards a more sustainable behavior (e.g., Björkskog et al. 2010; Shiraishi et al. 2009) with the goal to reinforce, change, or shape attitudes or behavior (Fogg 2002; Oinas-kukkonen and Harjumaa 2009). For example, Tulusan et al. (2012) developed a smartphone application with a feedback mechanism to improve fuel efficiency. The 50 corporate car drivers under investigation improved their overall fuel efficiency by 3%, even without direct financial incentives.

The success of such persuasive IS is fostered by the emerging digital society, who grow up with the wide availability of computers, video games, digital music players, and mobile phones (Myers and Sundaram 2012; Prensky 2001; Yoo 2010). Due to their continual interaction with IS, this generation has special needs, wishes, expectations, and behaviors concerning IS and require IS design that supports social life, gratification, feedback, and playful experience (Myers and Sundaram 2012). Hence, the design of persuasive systems is gradually advancing to increase motivation and drive sustainable behavior. Especially, the implementation of additional game-based functions to transform the user experience through playful interactions is often performed in different contexts (Blohm and Leimeister 2013). However, to the best of our knowledge, no empirical study has explored whether the implemented functions within gamified persuasive systems really fulfill an individual's goals and needs. Consequently, the desired motivational process to encourage sustainable behavior is questionable (Huotari and Hamari 2012). Prior research has already addressed this issue and pointed out the importance of user perceptions and goals in determining the value of persuasive systems (Huotari and Hamari 2012).

In this paper we address these research gaps in an explorative attempt by analyzing the impact of users' goals on gamified persuasive system usage and the desired outcome in the domain of sustainable mobility behavior. In this respect, our paper focuses on the following questions: First, to what extent are the functions implemented compatible with the user's goals? And second, what is the relationship among the user's goals, the functions used, and the desired sustainable behavior outcome? The theoretical bases for this study are the goal-framing theory (Lindenberg and Steg 2007) and the perspective of functional affordances (Markus and Silver 2008). Functional affordances describe the capabilities of technical artifacts to support an individual's targeted actions (Markus and Silver 2008), meaning that an information system only serves as a helpful instrument if it satisfies the expected tasks. In Green IS, functional affordances have primarily been studied in organizational contexts using a qualitative approach (Seidel et al. 2013) – not in the context of gamified persuasive systems in the private sector. Therefore, further research about functional affordances in the domain of Green IS is necessary, as affordances are very technology and user specific (Strong et al. 2014). The goal-framing theory is well established and has been applied successfully in psychological research regarding sustainable behavior. The theory is concerned with the alignment of personal goals and a given – generally less appealing – goal due to increased efforts or expenses (Lindenberg and Steg 2007).

In this study the gamified persuasive system is represented by a website with various functions of a sustainability initiative in Germany that aims to increase bike use and thus reduce CO_2 emissions. In 2014 the initiative had over 86,000 registered participants from more than 280 communes, organized in 6,905 teams during the entire timespan from May 1st to September 30th. The participants cycled an overall distance of more than 16 million kilometers, saving 2,360 tons of CO_2.

The findings of this study are transferable to other implementations of gamified persuasive systems with the goal of motivating sustainable behavior and contributing to a successful design. Our research helps to increase the understanding of the motivational process of gamified persuasive systems and the impact of such systems on individual behavior.

2 Theoretical Background

2.1 Persuasive systems

Persuasive systems are designed and applied to change behavior through the use of information technology. They are intelligent approaches interacting with human behaviors and have the clear aim of influencing these behaviors in a desirable direction (Fogg 2002). In the domain of sustainable behavior, persuasive systems are often deployed in the energy sector (e.g., Liu et al. 2013; Loock et al. 2013). For example, Fischer (2008) conducted a literature review of 25 publications appearing between 1987 and 2007 that examined the effects of persuasive systems on electricity consumption, consumer reactions, attitudes, and wishes concerning the design of the persuasive system. In the mobility domain, the application of persuasive systems is on the rise (e.g., Flüchter et al. 2014; Tulusan et al. 2012). For example, Froehlich et al. (2009) created a mobile phone–based application that aims to expand personal awareness of mobility behavior. Graphical rewards, depicted by pop-up icons, are earned by using green transportation alternatives, such as buses, trains, bikes, carpooling, or walking. Their results reveal that the artifact increases participants' awareness and stimulates or even strengthens their reflection about transportation activities. However, all studies were conducted with only small sample sizes, putting the significance of the results in question.

To increase the motivation of engagement towards sustainable behavior even further, game functions are used as an extension of persuasive systems to transform people's behavior through playful experiences (Blohm and Leimeister 2013). This so-called gamification approach (Lounis et al. 2014) aims to satisfy various evolution-dependent goals or needs by integrating an assortment of game-based functions into a persuasive system. Needs are conditions within an individual that are essential and necessary for the maintenance of life and the nurturance of growth and well-being (Zhang 2008). Table B-14 illustrates the relationship between game-based functions and their underlying needs.

Table B-14. Overview of different types of game-based functions in relation to the needs they meet, in reference to Blohm and Leimeister (2013)

Game-based functions	**Needs/Goals**
Documentation of own behavior	Exploration
Point systems, badges	Collection
Ranking list	Competition
Levels, reputation points	Status acquisition
Group tasks	Teamwork
Time pressure, task, mission	Challenge
Avatar, virtual worlds	Development, organization

The trend of employing gamified functions in non-game environments has become widespread in various areas, including innovation, marketing, education, sustainability, employee performance, health, and social change (Hamari et al. 2014). Several studies have proven gamified design of persuasive systems to be a successful tool for motivating users in various contexts (e.g., Jones et al. 2014; Kampker et al. 2014; Thiebes et al. 2014). However, most of these studies either investigate the short-term impact on behavior of a specific persuasive artifact with several implemented functions (Hamari et al. 2014; Kankanhalli et al. 2012) or review evaluated functions within existing artifacts (e.g., Lee et al. 2013b; Oduor et al. 2014; Simões et al. 2013). Previous studies solely examined fundamental questions about the success, types, design elements, and definitions of gamified persuasive systems with the aid of case studies (Schlagenhaufer and Amberg 2015). Quantitative studies yield predominantly positive effects of gamified persuasive systems and studied outcomes, whereas qualitative studies indicate that the motivational process behind the gamified persuasive system is more complex than most studies often suggest (Schlagenhaufer and Amberg 2015). Thus, there is a need for more detailed research on the underlying motivational process of single implemented functions within the persuasive system in a quantitative approach on the basis of fundamental interdisciplinary theories (e.g., Kankanhalli et al. 2012; Torning and Oinas-kukkonen 2009).

2.2 The concept of affordances in the context of a gamified persuasive system

Affordances are generated by the features of an artifact as well as the user’s attributes and potential (Pozzi et al. 2014). In the IS domain, affordances are summarized as the concurrence of organizational goals and capabilities with the features of an applied IT artifact to fulfill a certain purpose (Pozzi et al. 2014). The theory of motivational affordances is applied in the context of gamified persuasive systems (Deterding 2011; Hamari et al. 2014; Tan et al. 2015; Weiser et al. 2015) in order to justify their motivational processes. Motivational affordances are perceived when the implemented features of an IS trigger and satisfy the user’s needs (Zhang 2008), just as gamification intends to do (see Table B-14). Thus, users are more engaged in their actions and feel enjoyment (Zhang 2008). However, the outcome of these gamified persuasive systems is questionable (Huotari and Hamari 2012). It is suggested that the insular usage of gamified applications does not necessarily lead to the desired affordances, because users may experience the same functions differently (Huotari and Hamari 2012). Weiser et al. (2015) created a taxonomy of motivational affordances for the design of persuasive systems in the domain of sustainable mobility behavior. However, they advise against the non-reflected application of the taxonomy and highlight the strong dependency of affordances on contextual factors, e.g., the users’ characteristics and their personal needs and goals.

To explore the impact and motivational process of the functions implemented within a gamified persuasive system on each user, we propose the concept of functional affordance as a more suitable alternative. As suggested by Markus and Silver (2008), this concept is very fitting for analyzing why the effects of IS may differ in various contexts. When affordances enable or constrain actions in a given organism or organization, the affordances of an artifact are described as functional (Hutchby 2001; Leonardi 2013). Thus, functional affordances build a bridge between an IS artifact and users, providing the opportunity to describe the variable effects of IS usage for different users (Balci et al. 2014). Past studies about functional affordances, however, focus not on the individual user but rather on the mechanism connecting IS features with networks in organization and thus on collective and shared affordances, i.e., group-level affordances (Balci et al. 2014; Savoli and Barki 2013). To emphasize the individual user, the concept of *perceived* functional affordances (PFA) was introduced (Savoli and Barki 2013). The concept of PFA considers functional affordances perceived by each individual in reference to his or her own goal; each user generates a “mental image of its capabilities and constraints (i.e. its PFA)” (Savoli and Barki 2013, p. 3) during the interaction with an IS. Hence, PFA can trigger user’s actions, determining the respective outcomes based on IS use. Thus, PFA can enable or prevent the desired outcomes of the IS use (Savoli and Barki 2013). Several prior studies underline the importance of examining PFA on an individual level by triggering affordances in reference to the personal goals of each user in order to reach the desirable outcome (Strong et al. 2014; Volkoff and Strong 2013).

2.3 The role of goals in behavior change interventions

The key point of the PFA is the goal-oriented action process that is responsible for perceiving the possibilities of an IS for each user (Savoli and Barki 2013). Individual behavior changes – as one goal of persuasive systems – are also described as calculated, goal-directed processes in which the individual must perform various actions to achieve the intended goal (Heckhausen and Gollwitzer 1987). According to the transtheoretical model of change (DiClemente and Prochaska 1998), behavior change is described as “a process in which individuals actively invest effort in setting or activating goals, developing and enacting strategies to achieve these goal, appraising process, revising goal and strategies according” (Bamberg and Schmidt 2013, p. 152). In reference to the model of action phase (Heckhausen and Gollwitzer 1987) the first and most pivotal task in behavior-change processes is creating a goal intention. In case of sustainable behavior, this task is often conflicted because the different individual needs and goals seem to differ strongly (e.g., the choice between convenient or environmentally friendly travel) (e.g., Bamberg and Schmidt 2003; Lindenberg and Steg 2007). In this relationship, Lindenberg and Steg (2007) developed the goal-framing theory to study how individuals can be motivated to shift their behavior towards greater sustainability although conflicts in goals exists.

The general assumption of this theory is that user’s goals, as mental constructs, must be activated in order to influence behavior (Lindenberg and Steg 2007, 2013). Cognitions and motivations are unified in overarching goals (e.g., Moskowitz and Grant, 2009). When overarching goals are activated, the cognitive processes guide our attention, brain activity, as well as the selection and processing of information (Förster et al. 2005; Gollwitzer and Bargh 1996). Thus, these cognitive processes affect motivation by inhibiting other goals, influencing fondness, and governing the criteria we use to assess whether a goal can be realized (Carver and Scheier 2002; Ferguson and Bargh 2004). Steg et al. (2014) distinguish between three overarching goal frames: hedonic, gain, and normative. When a hedonic goal frame is activated, people are attentive to factors that affect, e.g., their moods, feelings, energy levels, and atmosphere. This is relevant as several theories demonstrate the influence of affects and emotions on motivation and behavior (e.g., Nayum and Klöckner 2014; Rezvani et al. 2015; Zhang 2013). The aim of the gain goal frame is to protect and increase individual resources. Activation of this goal frame causes one to select information related to costs and benefits according to scarce resources. Hence, rational choice theories, such as the theory of planned behavior (Ajzen 1991), are often applied to predict such behavior. People who activate the normative goal frame act for the public welfare, disregarding costs or hedonic aspects. The fundamental theory of the normative goal frame, the norm-activation model (Bamberg and Schmidt 2003), focuses on normative concerns and was originally developed to explain altruistic behavior (e.g., Hopper and Nielsen 1991).

According to the goal-framing theory, interventions are more effective when the activated goal is addressed in the given situations (Steg et al. 2014). Generally, there are two basic strategies for encouraging sustainable behavior. First, the expected outcome of sustainable behavior can be changed before the individual performs an action (Steg et al. 2014). As sustainable behavior is often associated with high costs and efforts, this behavior is rendered undesirable when the gain and hedonic goal frames are not supported (Steg et al. 2014). The second strategy aims to strengthen the normative goal frame through situational cues and the activation of special norms (Steg et al. 2014). Several studies have indicated that observations of norm-violating behavior increase the likelihood of personal norm-violating behavior (e.g., Cialdini et al. 1990). Therefore, situational cues showing other people breaking norms with their behavior weakens the individual’s normative goal frame and their striving to further satisfy their gain and hedonic goal frames (Keizer et al. 2008). However, situational cues can also encourage individuals to act more norm compliant based on positive observations (Keizer et al. 2008).

Previous studies have shown that hedonic and gain goals could support the normative goals because sustainable behavior can increase the status of an individual and result in positive emotions (Noppers et al. 2014; Venhoeven et al. 2013). Therefore, Steg et al. (2014) suggest that interventions successfully encourage sustainable behavior when hedonic and gain goals are also triggered, as long as normative goals are supported. Therefore, hedonic and gain goals must be linked to normative goals (Steg et al. 2012, 2014). However, the effectiveness of multiple goal frames on sustainable behavior has not yet been proven and must be further examined (Steg et al. 2014).

3 The Impact of Goal Frames and Affordances in Persuasive Systems on Bike Usage

In this study the desired sustainable behavior is heavy bike usage, measured by the distance traveled in kilometers. According to the goal-framing theory, only the activated normative goal frame leads to increased bike use over time (Lindenberg and Steg 2007). However, as mentioned above, recent studies on the goal-framing theory indicate that the combination of hedonic or gain goals and the normative goal frame can further increase the willingness to behave more sustainably –in this case, to travel a greater distance by bike (Steg et al. 2012, 2014). In this regard, previous studies have point out the importance of further research to investigate which combination of activated goal frames result in sustainable behavior (Steg et al. 2012, 2014). Therefore, we address the following research question:

RQ 1: Which combination of the hedonic or gain goal frame with the normative goal frame results in heavy bike usage?

To analyze the motivational process of a gamified persuasive system on bike usage, we use the goal-framing theory in combination with the concept of functional affordances. In this study we understand a gamified persuasive system as an intervention to encourage sustainable mobility behavior. As mentioned above, the goal-framing theory acts on the assumption that two basic strategies for intervention exist to encourage sustainable behavior. We assume that these strategies can also be applied by gamified persuasive systems. Moreover, we suggest that bike use can be encouraged if the implemented functions of the gamified persuasive system change the expected outcome of riding a bike (Steg et al. 2014). For example, a function displaying the money saved by cycling leads to a change towards the perceived costs and efforts of biking. Consequently, the gain goal frame is activated alongside the normative goal frame (Steg et al. 2014). Furthermore, the functions of the gamified persuasive system can be applied as situational cues that indicate whether other people are complying with norms, which also influences the individual's behavior as discussed above (Keizer et al. 2008). For example, ranking lists offer the possibility of observing one's own performance in comparison to the performance of others.

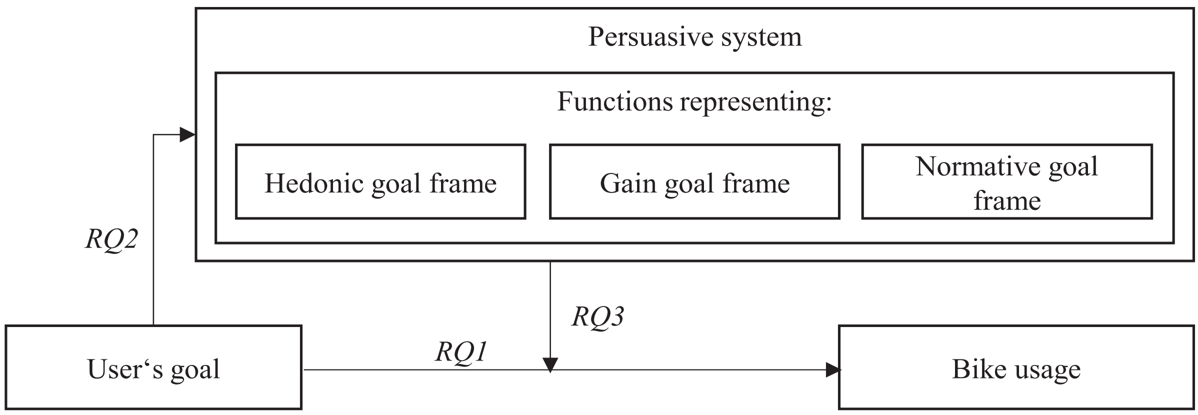
This idea is basically in line with the assumption of the concept of perceived functional affordances, where the interaction with a gamified persuasive system can trigger certain actions and thus determines the desired outcomes (Savoli and Barki 2013). However, this proposition must be put in perspective because – according to the concept of affordances – the implemented functions of a gamified persuasive system are only perceived and used if the user's pursued goals supply the desire affordances (Pozzi et al. 2014). Therefore, it is possible that individuals only use functions that are in line with their pursued goals and thus the activated goal frame. Hence, individuals pursuing a hedonic goal will probably never use the functions associated with the normative goal frame. To verify this assumption and clarify the interaction of pursued goals and activated goal frames on function usage as well as its effect on bike usage, we address the following research questions:

RQ 2: Do participants only use functions according to their pursued goal?

RQ 3: How do the used functions of the gamified persuasive website moderate the impact of the various pursued goals on bike usage?

The following figure illustrates the research model.

Figure B-5. Research model



4 Research Design and Method

4.1 Attribution of goals and functions to goal frames

It is assumed in this study that a goal frame is active when the participants pursue one specific goal, which can be assigned to a respective goal frame. The goals are supported by the design of the initiative's website with a variety of graphics, functions, and information. The assignment of the goals and functions is based on existing literature in the domain of persuasive systems and the goal-framing theory (Blohm and Leimeister 2013; Lindenberg and Steg 2007). Table B-15 illustrates the attribution of the system functions to the user's concrete goals and the respective goal frame classification.

Table B-15. User goals and the website functions in the respective activated goal frames

Goal frame	Participant's goals	Functions of the website
Hedonic	Self-exploration	Documentation of own behavior: Participants can fill out a calendar (time and distance traveled per day).
	Competition	Ranking list: Participants can compare themselves to the team performance. Furthermore, the participants can compare the performance of their team with the performance of other teams within the commune and the performance of their commune with the performance of other communes.
	Collaboration	Group tasks: The participants take part in a team within their related commune. The participants can use social media functions to communicate with each other.
Gain	Cost reduction, health promotion	Display of mileage.
Normative	Climate protection	Displays CO_2 savings.

As illustrated in Table B-15, the gamified persuasive website studied implements several designs to address the two above-mentioned strategies for encouraging sustainable behavior (Steg et al. 2014). First, the website aims to change the expected outcome of cycling by visualizing, e.g., a high position within the ranking list as a result of heavy bike usage to satisfy hedonic and gain goals (Steg et al. 2014). Second, the website with its various functions can be understood as a situational cue for norm activation. For example, a participant might notice that other participants in the team are acting norm compliantly and satisfying the normative goal frame, leading him or her to overthink his or her actions and triggering the willingness to change his or her behavior. Therefore, the designers try to encourage the normative goal frame through the well-applied conjunction of functions supporting the gain, hedonic, and normative goal frames.

4.2 Sample and data-collection procedure

The use of the website is voluntary and took place over a 21-day period between May and September 2014. The starting point was chosen independently by each local commune. The teams were self-selected and self-organized within their respective communes. We asked all participants (*N* = 86,000) of the initiative via e-mail to fill out a 15-minute online survey in three instances over the total timespan. The first survey was due three days before the initiative began for their commune. The second was to be submitted one week into participating in the initiative and the third one month after the initiative ended. All three surveys were completed by 973 participants. However, we only considered active participants who used the website more than 5 times a week, leading us to a final sample of 248 participants.

The first questionnaire contained inquiries concerning age, gender, household size, related commune, mobility possibilities in their household, highest education, and date of birth. The age within the sample ranges from 17 to 78 years (mean: 47 years) with a 40% share of females. Most of the participants live in a two-person household (32%), followed by nearly equal distributions of one- (21%), three- (19%), and four-person (20%) households. Only 6% of the participants live in a household with 5 or more people. More than half have a university degree (51%), while 12% have a general qualification for university entrance and 20% have a general certificate of secondary education. Furthermore, the first survey contained single-choice items (Haladyna and Rodriguez 2013) with preset dichotomous options (no [1] or yes [2]). Each goal that initiated participation in the initiative was listed separately (second column of Table B-15). The participants could decide whether each goal was relevant to them. Table B-16 illustrates the participant's goals in accordance with Table B-15.

Table B-16. Participants' goals

	Participant's goal	**Numbers of participants (%)**
Hedonic goal frame	Collaboration (H_Col)	29 (11%)
	Competition (H_Com)	77 (31%)
	Self-exploration (H_Sel)	72 (29%)
Gain goal frame	Cost reduction (G_Cos)	66 (27%)
	Health promotion (G_Hea)	183 (74%)
Normative goal frame	Climate protection (N_Cli)	148 (60%)

In the second survey, the participants were asked to answer a multiple-choice question with interval-scaled preset options about their average frequency of website use in general as well as the functions they used on the website per week (see third column of Table B-15). The participants could choose between the following options: never, 1–2 times, 3–4 times, 5–6 times, 7–8 times, 9–10 times, and more than 10 times. In all three surveys the participants had to specify their mobility behavior in order to analyze the development during the initiative. Hence, we could calculate the distance traveled by bike in kilometers for each participant.

4.3 Statistical analysis in reference to the research questions

We used SPSS Version 23.0 to analyze the data gathered. The data cleaning and calculation took place in three steps: First, the structure and distribution of the data was analyzed and verified with the aid of descriptive statistical approaches to identify outliers and failed data records. In the second step, we proved the requirements of the analysis of covariance (ANCOVA; Huitema 2011), i.e., the normal distribution of the dependent variables (DVs) with a histogram and a Gaussian distribution curve as well as the homogeneity of the variance using the Levene test (Levene 1960). Afterwards, we tested the research questions with the ANCOVA across various random factors. The ANCOVA analyzes whether the sample mean of a DV, i.e., frequency of function usage (*RQ 2*) or total distance traveled by bike in kilometers (*RQ 1*; *RQ 3*) are the same across all levels of a dichotomous independent variable (IV), i.e., activated goal (all *RQs*) and function usage (*RQ 3*). While calculating the ANCOVA, the impacts of other irrelevant variables on the DV were statistically controlled. This means that the part of the variance explained by the irrelevant variables regarding the error term was removed, thereby yielding a more powerful test (Huitema 2011). Because some participants had more than one goal, we had to control the impact of the other irrelevant goals and used functions for the examined case to study the impact of the specific goal on both function usage (*RQ 2*) and bike usage (*RQ 1*). For the analysis of *RQ 3* both functions as well as goals were controlled. For *RQ 3*, the frequency of function usage was applied as an independent variable and therefore had to be transformed to a dichotomous variable. Hence, the function use of less than five times per week was coded with "1" and five times or more was marked with "2".

5 Results

First, the structure and distribution of the data was analyzed and verified with the aid of descriptive statistical approaches. There were no invalid records from missing data. Due to page limitations, only the nearly significant ($p \leq .10$) and significant ($p \leq .05$) results are presented in the following paragraph. The first requirement of the ANCOVA, the normal distribution of the DVs, i.e., bike usage and frequency of function use, is proven successfully. Table B-17 illustrates the results of the Levene test (Levene 1960) as the second requirement of the ANCOVA by analyzing the homogeneity of the variance. The non-significant deviation of homogeneity of the variance is given in most cases.

Table B-17. Results of the Levene test

RQ	***Goal(s) (function)***	***F-value***	***dfe***	***dfs***	**p-*value***
RQ 1	*H_Com and N_Cli*	*2.649*	*3*	*244*	*0.050*
RQ 2	*H_Com (Ranking)*	*0.831*	*1*	*233*	*0.363*
	H_Com (Display of mileage)	*0.146*	*1*	*233*	*0.702*
	H_Com (Documentation)	*1.425*	*1*	*245*	*0.234*
	H_Com (Group task)	*1.289*	*1*	*228*	*0.257*
	H_Sel (Ranking)	*0.456*	*1*	*233*	*0.500*
	N_Cli (Display of CO_2 savings)	*5.323*	*1*	*228*	*0.022*
RQ 3	*H_Sel (Ranking)*	*3.033*	*3*	*244*	*0.030*
	H_Com (Rankings)	*1.440*	*3*	*244*	*0.232*
	N_Cli (Ranking)	*3.045*	*3*	*244*	*0.029*
	N_Cli & H_Coll (Display of CO_2 savings)	*0.569*	*7*	*240*	*0.780*
	N_Cli & G_Hea (Display of CO_2 savings)	*2.187*	*7*	*240*	*0.036*
	N_Cli & G_Cos(Display of CO_2 savings)	*0.769*	*7*	*240*	*0.614*
dfe= Degrees of freedom regarding the effects; dfs= Degrees of freedom regarding the sample size.					

To prove the impact of the interaction between the activated normative goal frame and a specific gain or hedonic goal frame on the distance participants traveled (*RQ 1*), we employed the ANCOVA. The calculations show that the activated hedonic goal frame interacts with the normative goal frame in a nearly significant manner ($F(1, 247) = 2.80$, $p = .096$). The activation of both the normative and hedonic goal frames via the concrete goals "competition" and "climate protection" led to a greater distance traveled than the activation of a single or no goal frame. Table B-18 displays the results of first-order interaction effects between different goal frames (*RQ 1*).

Table B-18. Results of the interaction effects of the ANCOVA (RQ 1; N = 248)

	With an activated H_Com	**Without an H_Com**
With an activated N_Cli	57.24 (44.12)	38.79 (34.33)
Without an activated N_Cli	40.67 (35.77)	45.12 (36.14)

The between-subjects analysis of the participants' function usage with and without a specific pursued goal (i.e., hedonic, gain, or normative) were also examined with the ANCOVA while the other specific goals were controlled (*RQ 2*). The results show significant main effects of the activated hedonic goal "competition" on the use of the ranking list function ($F(1, 246) = 28.98$, $p = .000$) as well as the mileage display function ($F(1, 246) = 10.17$, $p = .002$). The functions "ranking list" and "display of mileage" were primarily used by participants with the active hedonic goal "competition." Furthermore, the pursuit of this goal appears to lead to an increased use of the documentation function ($F(1, 246) = 2.70$, $p = .100$) as well as the group task function ($F(1, 229) = 3.29$, $p = .071$) to a nearly significant degree. Hence, participants with the activated hedonic goal "competition" used both functions more often. Table B-19 illustrates the results of *RQ 2* regarding the activated hedonic goal "competition."

Table B-19. Results of the main effects of the ANCOVA (RQ 2; N = 248)

Function usage	**With activated H_Com**	**Without activated H_Com**	**F-Value (*p*-Value)**
Ranking list	4.1 (1.68)****	2.95 (1.59)****	28.98 (.000)
Display of mileage	5.03 (1.92)***	4.39 (1.28)***	10.17 (.002)
Documentation function	4.88 (1.26)*	4.64 (1.11)*	2.70 (.100)
Group task function	3.37 (1.86)*	3.04 (1.64)*	3.29 (.071)
*****p ≤ 0.001; ***p ≤ 0.01; **p ≤ 0.05; *p ≤ 0.10.*			

Moreover, the pursued hedonic goal "self-exploration" has a nearly significant main effect on the use of the ranking list function ($F(1, 234) = 3.57$, $p = .060$). This goal resulted in an increased frequency of use of the ranking list function ($M_{with\_H\_Sel} = 3.49$, $SD = 1.67$; $M_{without\_H\_Sel} = 3.27$, $SD = 1.73$). Additionally, the pursued normative goal "climate protection" has a significant main effect on the use of the CO_2 savings display function ($F(1, 229) = 13.25$, $p = .000$). Here, the activated normative goal led to an increased use of this function ($M_{with\_N\_Cli} = 3.91$, $SD = 1.63$; $M_{without\_N\_Cli} = 3.03$, $SD = 1.86$).

In *RQ 3* we studied the effect of the interaction between the random factors "with and without a specific activated goal" and "with and without a specific frequent function use" on the distance participants traveled. We again used the ANCOVA in order to control for the other specific goals and functions. As a first significant first-order interaction, the pursued hedonic goal "self-exploration" was identified ($F(1, 247) = 5.129$, $p = .024$). This goal led to a reduced distance traveled if the participants used the ranking list five or more times a week. Contrastingly, frequent usage of the ranking list function or the sole pursuit of the hedonic goal “self-exploration” increased bike use. Furthermore, there are two nearly significant first-order interactions between the pursued normative goal “climate protection” as well as the hedonic goal “competition” with the frequent use of the ranking list function (hedonic: $F(1, 247) = 2.67$, $p = .104$; normative: $F(1, 247) = 3.30$, $p = .071$). Participants pursuing the hedonic goal “competition” or the normative goal “climate protection” and using the ranking list function five or more times a week had the highest values for distance traveled. Table B-20 shows the first-order interaction effects for the various activated goals and the use frequency of the ranking list function on the distance participants traveled (*RQ 3*).

Table B-20. Results of first-order interaction effects of the ANCOVA (RQ 2; N = 248)

Activated goals	Ranking list use	No ranking list use	F-Value (*p*-Value)
With H_Sel	37.88 (22.73)**	47.42 (22.73)**	5.129 (.024)
Without H_Sel	51.85 (50.68)**	35.64 (38.21)**	
With H_Com	52.60 (47.60)*	32.73 (43.43)*	2.67 (.104)
Without H_Com	42.04 (39.31)*	40.16 (32.96)*	
With N_Cli	51.33 (52.40)*	35.08 (30.50)*	3.30 (.071)
Without N_Cli	41.24 (26.84)*	44.24 (41.35)*	
**$p \le 0.05$; *$p \le 0.10$.			

The results also show two significant second-order interactions affecting the distance participants traveled (collaboration: $F(1, 248) = 4.15$, $p = .043$; gain: $F(1, 248) = 4.35$, $p = .038$). In this case, the pursuit of the normative goal “climate protection” in combination with the hedonic goal “collaboration” and the frequent use of the CO_2 savings display function increased the distance traveled ($M_{with\_H\_Col;\ with\_N\_Cli;\ with\_CO2} = 66.18$, SD = 38.06; $M_{without\_H\_Col;\ without\_N\_Cli;\ without\_CO2} = 40.84$, SD = 28.00). In contrast, the pursuit of the normative goal “climate protection,” the gain goal “health promotion,” and the frequent use of the CO_2 savings display function led to a lower distance traveled ($M_{with\_G\_Hea;\ with\_N\_Cli;\ with\_CO2} = 39.52$, SD = 33.74; $M_{without\_G\_Health;\ without\_N\_Cli;\ without\_CO2} = 51.20$, SD = 19.34). A further second-order interaction between the pursued normative goal “climate protection,” the gain goal “cost reduction,” and the frequent use of the CO_2 savings display function emerged with only near significance ($F(1, 248) = 2.84$, $p = .093$). Here, the two goals pursued and the frequent use of the display of CO_2 savings function decreased the distance traveled ($M_{with\_G\_Cos;\ with\_N\_Cli;\ with\_CO2} = 36.73$, SD = 27.36; $M_{without\_G\_Cos;\ without\_N\_Cli;\ without\_CO2} = 46.04$, SD = 37.77).

6 Discussion

This study analyzes the motivational process of a gamified persuasive system, which was developed as part of an initiative aiming to motivate individuals to get involved with sustainable mobility behavior through promoting bike use. In this respect, we are first interested in the compatibility of the participant’s goals with the functions implemented. Here, the measurements regarding *RQ 2* indicate that there do exist single suitable functions to support the pursued hedonic goals “competition” and “self-exploration” as well as the normative goal “climate protection”. The data is partially in line with the assumption of the concept of affordance, in which the features of an artifact and the participants' goals generate the user's affordances, thereby influencing the use and perception of the IS (Pozzi et al. 2014).

As expected, participants pursuing the normative goal "climate protection" frequently used the designated function "display of CO_2 savings". However, while participants with the goal "competition" often used the ranking function, they also regularly used the functions "display of mileage", "documentation", and "group task", which were not originally designed for this purpose. This holistic impact of the goal "competition" on function usage could be explained by the fact that the other functions, i.e., "display of mileage", "documentation", and "group task" may also provide information about one's own status, which is necessary for a competition with other participants.

Furthermore, unexpectedly, participants with the pursued hedonic goal "self-exploration" used the ranking list function more often than participants without this goal did. The ranking list function may offer the possibility to observe one's own behavior in comparison to others. Such information could be more interesting for self-exploration than information about the time and location of bike usage offered by the documentation function, which was originally designed to support this goal.

Moreover, the pursued hedonic goal "collaboration" as well as the gain goals "health promotion" and "cost reduction" do not determine the function use. These findings could be a result of the gamified persuasive system design. The display of mileage function should support the two gain goals; however, this function requires calculations made by the participants in order to draw conclusions about the health promotion and cost reduction effects of bike use. Hence, these functions require additional effort from the participant in contrast to the other functions. This circumstance could cause a misfit between the participant's pursued goal and both offered functions. Furthermore, to satisfy the hedonic goal "collaboration", the persuasive system offers a link to popular social media applications and a message function allowing participants to communicate with their team members. According to the data about function usage, the participants with the concrete goal "collaboration" might have favored the idea of being part of a team over the option of communicating with their teammates via a message service.

These findings make the assumption of Blohm and Leimeister's (2013) about the relationship between game-based functions and their addressed needs and goals debatable (see Table B-14). They suggested that the goal "competition" is supported by the ranking list function and that the "self-exploration" goal is satisfied by the documentation function. However, at this point we do not argue that this assumption is wrong. It merely shows that the success of theoretically appropriate implementation of a mechanism depends on individual needs and the technical implementation in regards to user's affordances and usability.

This findings underlines the importance of a user-centric approach for IS design, meaning that the functions should be developed in reference to the users' goals and needs (Gabbard et al. 1999). Additionally, the fit between goals, needs, and functions should be continuously evaluated in course of the artifact-development process (Peffers et al. 2007). Moreover, future research investigating the relationship between a user's goals and function usage of other artifacts in different contexts is needed. Our approach is based on the assumption of the theory of affordances, in which both the features of an IS as well as user goals determine the function usage. Nevertheless, previous IS studies have indicated that further factors such as emotions (e.g., Beaudry and Pinsonneault 2010), personal characteristics (e.g., Sun et al. 2008), and technology types (e.g., Wang and Scheepers 2012) play a role in determining the use of an artifact. Therefore, there could be further variables that are relevant for the participants' function usage but are not investigated in this study; they should be considered in future research.

Another objective of this study is to examine the relationship between an individual's goals, used functions, and the initiative's desired sustainable behavior outcome. To do so, we determined how a combination of contradicting goal frames can lead to heavy bike usage. The findings of *RQ 1* are in line with the assumption that the effectiveness of sustainable behavior could be further increased if multiple goal frames were activated (Steg et al. 2012, 2014). The activation of the normative and hedonic goal frames via the concrete goals "competition" and "climate protection" results in higher values for distance traveled than the activation of one or none of these goal frames as previous studies indicated. Nonetheless, to the best of our knowledge, the application of single cues to satisfy one or various goals and thus leading to sustainable behavior has not yet been studied in behavioral science or IS research (Steg et al. 2014). In this case, more research is needed to determine how these goals could be linked to each other – e.g., with functions within a persuasive system to increase sustainable behavior.

This research gap is addressed in *RQ 3* by the impact analysis of the effect of the participants' pursued goals and functions used on distance traveled. Our findings indicate that the combination of either the normative goal "climate protection" or the hedonic goal "competition" with the frequent use of the ranking list function can lead to the greatest distance traveled. This result highlights the importance of the ranking list function for encouraging sustainable behavior. However, designers should be cautious in applying ranking lists in persuasive systems. In this scenario, participants with the pursued hedonic goal of "self-exploration" and the frequent use of the ranking list function had a lower distance traveled than participants with either a frequent use of the ranking list function or the sole activation of the hedonic goal "self-exploration". As suggested above, ranking lists allow the user to perceive his or her own behavior in reference to others. While this information is probably more valuable than the information regarding the time and location of bike usage offered by the designated documentation function, it could also cause social pressure. This assumption is based on the self-determination theory (SDT; Deci and Ryan 1985) which is also applied in studies of persuasive system design. The SDT suggests that autonomically determined behavior leads to a more persistent behavior change than extrinsically determined motivation, in terms of pressure (Deci and Ryan 1985b). Furthermore, prior studies about game-based persuasive systems have shown that the motivational effect of ranking lists is inconsistent. While ranking lists lead to positive behavior changes in some contexts, they fail in others – sometimes even resulting in negative effects due to demotivation or the fear of failure and public exposure (Christy and Fox 2014; Codish and Ravid 2014; Domínguez et al. 2013). The different impact of ranking lists on behavior regarding the pursued goals identified in this study could be a possible explanation for the inconsistent findings about the effectiveness of ranking lists in previous investigations. Therefore, the consideration of such precarious functions should be taken carefully into account in persuasive system design. In this relationship, designers might consider peculiarity of user's goals when implementing ranking lists in persuasive systems in order to encourage sustainable behavior.

The results also suggest that the pursued normative goal "climate protection" in combination with the hedonic goal "collaboration" and the frequent use of the CO_2 savings display function increases the distance traveled. In contrast, the pursued normative goal "climate protection", the gain goal "health promotion" or "cost reduction", and the frequent use of the CO_2 savings display function led to lower distances traveled. In this regard, previous studies have indicated that interventions should trigger the hedonic goal frame instead the gain goal frame in combination with the normative goal frame to successfully reach sustainable behavior (Steg et al. 2012). The findings confirm this assumption –, but further research is needed to determine the impact of different goals on sustainable behavior moderated by the functions studied in controlled settings.

The study poses some limitations that should be considered when using these results to validate the theories and practical implications applied within. The measurement of the constructs is based on self-reports and not measured by objective data. Moreover, a clear operationalization of how the respective goal frames are activated is necessary to further elaborate the true impact of combined activated goal frames on sustainable behavior. In this regard, further research for the development of suitable measurements for activated goal frames is required. In this relationship, we suppose that the participants are conscious of their goals before the initiative starts. Furthermore, we suggest that the pursued goals are responsible for the activation of specific goal frames and assign single pursued goals to each goal frame. This assignment is based on existing literature, but the connection is still unexplored; however, a first attempt on this matter is made in this study. In addition, the main effects and interactions calculated are only nearly significant ($p \leq .10$) in some cases. Furthermore, in four cases the second requirement of the ANCOVA, i.e., homogeneity of the variance, is not fulfilled. Additionally, no control group is considered to allow for a comparison of the distance traveled without a persuasive system.

7 Conclusion

Summing up, we can state that the functions implemented are partially compatible with user goals. The functions studied are not suitable for triggering the gain goal frame in this scenario, unlike the hedonic goal "competition" and normative goal "climate protect". Furthermore, the results reveal that a combination of the hedonic goal "competition" and the normative goal "climate protection" leads to a positive impact towards sustainable behavior. We could show that the impact of the hedonic goal "competition" as well as the normative goal "climate protection" on sustainable behavior is moderated by the function of ranking list.

Furthermore, the implementation of the CO_2 display function is critical if the participants pursue the normative goal alongside the gain goal “cost reduction” or “health promotion”. However, additional investigation is needed to validate the results concerning the impact of pursued goals and functions used on diverse desired behaviors – particularly in different contexts.

III. User Acceptance

The last building block of this cumulative thesis looks at user-centric Green IS from the acceptance perspective. In contrast to the studies in chapter B.II this last study is concerned with the acceptance of user’s to adapt concrete user-centric Green IS solutions rather than with the theories and processes leading to successful behavior change as examined in the second building block (B.II). Study 5 (B.III.1) examines a virtual artifact as a user-centric Green IS in form of a persuasive system to induce pro-environmental behavior change. The design of the artifact is based on findings from the preceding studies of this thesis in connection with the state of the art of persuasive system design based on recent research in this field. The central research question of this last building block is how user-centric Green IS should be designed in order to increase the likelihood of system acceptance in the daily routine of people.

III.1 Study 5: An Acceptance Model for User-Centric Persuasive Environmental Sustainable IS

Table B-21. Fact sheet of study no. 5

Title	An Acceptance Model for User-Centric Persuasive Environmental Sustainable IS
Authors	Benjamin Brauer*, Carolin Ebermann, Lutz M. Kolbe Chair of Information Management, Georg-August-University Göttingen, 37073 Göttingen, Germany *Corresponding author. Tel.: +49 551 39 2 11 70. E-Mail address: bbrauer@uni-goettingen.de
Outlet	Proceedings of the 37th International Conference on Information Systems (ICIS), December 11-14 2016, Dublin, Ireland.
Abstract	In the recent years Green IS research aims to utilize information systems (IS) to influence people towards sustainable behavior change in a user-centric manner. Emerging pervasive technologies such as smartphones, wearables, and the diffusion of Internet of Things (IoT) devices offer manifold innovative opportunities to address people and influence behavior. Lately, the design of persuasive IS became popular in IS research aiming to optimize the utilization of these new technologies to further improve the behavioral influence of people. While few implementations with the goal to foster environmental sustainability already show positive potentials – substantial limitations exist. A major shortcoming of existing user-centric Green IS studies is that these systems are primarily used in experimental settings. Thus, system use is predominantly mandatory. In this study we focus on the acceptance of user-centric persuasive Green IS and show the positive potentials of persuasive design principles on the acceptance of environmental sustainable IS.
Keywords	Persuasive Systems, Green IS, UTAUT, IS Acceptance/Adoption

1 Introduction

Environmental sustainability poses as an increasingly important topic in governmental policy and research. In recent years, leading politicians and entrepreneurs have stressed the importance of sustainable thinking and behavior (Santiago 2015). The manifold of negative impacts from current behavior conducted by the industrial/public sector not only affect environmental degradation in the form of resource depletion, and pollution, but also pose a threat to wildlife and human health (IPCC 2007; Vlek and Steg 2007). On a governmental, municipal, and organizational level, several activities have already taken place to address environmental problems and reduce negative impacts on the ecosystem. For instance, organizations aim to improve their CO_2 footprint through cleaner production or sustainable supply chain management strategies; national or municipal governments run campaigns to transform public transportation utilizing sustainable mobility solutions, for example by promoting electric mobility or individual car use alternatives (Brauer et al. 2015; Wagner et al. 2014). Alongside the business and industrial sectors, cities and their populations play a significant role in environmental degradation due to high energy and resource consumption, and CO_2 emissions, e.g., caused by transportation (Lövehagen and Bondesson 2013).

While research regarding sustainable development in the enterprise domain has a long history in information systems (IS) research, the focus in a city context constitutes a relatively young research area (Brauer et al. 2015). Within the last two decades Green IS research gained raising attention and importance pertaining to IS research (vom Brocke et al. 2013a; Hilpert et al. 2014). Green IS describes the utilization of technologies and systems to both enable and foster ecological sustainability (vom Brocke et al. 2013b; Malhotra et al. 2013; Melville 2010). However, prior to recent years, Green IS primarily focused on business and industries in an attempt to ‘greenify’ processes, products, and services. With the advent of smart cities Green IS research spread to the public sector, therefore helping to identify and support new solutions for sustainable improvements and development. In this context, there is an increasing prevalence in the IS domain of potentials in information systems to influence individuals towards more sustainable practices. IS artifacts were designed to monitor and influence people’s energy consumption (Loock et al. 2011, 2013), driving behavior (Tulusan et al. 2012), and resource consumption (Khansari et al. 2014). This research could demonstrate huge potentials and positive effects of such implementations on the environment. However, the amount of research is still low despite the huge potentials (Brauer et al. 2015; Malhotra et al. 2013).

Emerging technological innovations contributing to the population mobilization such as tablets, smartphones, and wearables offer new opportunities to interact with users, and thus, help to pursue personal goals (Klasnja et al. 2009; Tscheligi and Reitberger 2007). In the health sector, mobile technologies are already widespread, supporting users towards healthier lifestyles (Boontarig et al. 2014; Lehto and Oinas-Kukkonen 2015). Smartwatches record various information, such as heart rate or walked distance, while persuading a behavioral change in the user, e.g., exercising more (Yoganathan and Kajanan 2013). Persuasion is multi-faceted and comprising a manifold of possible implementations. However, prior research has revealed particular design patterns in the field of persuasive systems design that pose vital elements for implementation, which are recommended for consideration during the design phase of such systems (Fogg 2003; Oinas-kukkonen and Harjumaa 2009). Existing research in the domain of Green IS focuses on influencing and changing user behavior by primarily examining the general aptitude of information technology to enable and foster sustainable practices. However, the built artifacts contain only limited features to support the user in specified tasks. Thus, the evaluation of other potential design elements and mechanisms are omitted in these studies. Moreover, the design of these experiments limit the application of these systems to a single use-case, e.g., energy consumption or driving behavior, utilizing mandatory systems for the test subjects during the experiment.

The later point poses a crucial factor when considering the design of sustainable IS in a voluntary everyday-life setting. The designed and evaluated applications in existing studies might be successful in regards of quantifiable results, such as saved energy or CO_2 emissions, but it leaves the question whether these systems would have been installed and used voluntarily. Furthermore, questioning which design elements have a significant share in the acceptance decision of a potential user. Moreover, a study about the application of a persuasive IS in the health sector conducted by Lehto and Oinas-Kukkonen (2015) showed promising results. However, the authors also claim that design issues existed and further attention should be paid in this area to comply with the user's needs. Acceptance research can provide valuable insights in the decision process of user's choices to accept and use an IS, and ultimately engage in behavioral change processes (Venkatesh et al. 2002). Acceptance and adoption research poses an increasingly important research field in the IS domain due to the rising development and diffusion of technological innovations, especially in the consumers segment (Segura 2015; Venkatesh et al. 2012). Within IS research the 'Unified Theory of Acceptance and Use of Technology' (UTAUT) has become a popular and often used research model measuring the acceptance of technologies and information systems, including the influence of external factors on adaption decision (Dwivedi et al. 2011; Williams et al. 2011). In this paper we aim to learn the effects and influences of persuasive design principles on the acceptance of persuasive environmental sustainable systems (PESS) by conducting structural equation modeling (SEM). Thus, we aim to gain insights about user requirements and the relationship of persuasive design principles, as well as indicators relevant for system acceptance and adoption in answering the question:

RQ: How do persuasive design principles influence the acceptance of user-centric Green IS?

This information will help design a future system of sustainable systems applicable in a real-world context, free from experimental restrictions and limitations such as involuntariness of use and freedom of application domain. Hence, we address an untouched area in Green IS research with a user-centric real-world focus. In this case user-centric means the direct addressing of individuals in different contexts. In contrast to the predominant corpus of literature in the area of Green IS research with focus on organizational processes or strategic decision making – this approach highlights the individual person as the user of a Green IS. Hence, system acceptance analysis within this paper aims to reveal design patterns helping to create Green IS solutions with focus on user acceptance and adoption (Corbett 2013a;

Graml et al. 2011). The findings of this analysis will help design and establish user-centric Green IS in different areas such as business and smart city environments. Furthermore, the findings about the adequateness and weight of influence on system acceptance are transferable to other application areas, such as health or education.

The remainder of the paper is structured as follows. First we give a brief introduction in environmental sustainable behavior and the potentials of IS which include focusing on persuasive technologies, followed by an insight of technology acceptance and adoption research. We continue with the presentation and deduction of our research model, followed by the hypotheses and the deployed research methodology. In the final step, the results are presented and discussed, and we close with a short conclusion.

2 Theoretical Background

2.1 Environmental Sustainable Behavior and Persuasive Technologies

Performing environmental sustainable behavior might sound like an easy task on the first thought, but there are many barriers that can hinder a person from engaging in sustainable activities (Gifford 2011). Psychologist, sociologists, and environmentalists performed a great amount of research on this topic in the recent years (Barr 2007; vom Brocke et al. 2013b; Flynn et al. 2009; Gifford 2011; Kollmuss and Agyeman 2002). In their studies numerous problems and barriers have been identified that might keep an individual from engaging in sustainable practices. Personal factors such as age, education, and limited resources (money and time) have an impact on a person's ability of sustainable actions (Fogg 2009a; Zhang et al. 2015). For instance, some people might not have the financial possibilities to purchase an eco-friendly car, more sustainable household appliances, or sustainable sourced food. Others might be wealthy but do not have the time to concern oneself with this subject. Many people are not even aware of environmental threads and have no idea how they could contribute to environmental sustainability (Gifford 2011). Apart from cognitive and materialistic limitations (Fogg 2009a; Gifford 2011; Zhang et al. 2015) motivation and societal components play an important role in sustainable behavior adoption processes (Barr 2007; Lindenberg and Steg 2013). A wide variety of behavioral theories and research models consider social norms as a construct and point out the influence of other people on the attitude and intention of behavior change in the context of environmental sustainability (Steg and Vlek 2009; Vlek and Steg 2007). Generally, motivation takes an important role within the entire process towards sustainable behavior and helps to overcome prevailing barriers (Fogg 2009a; Gifford 2011; Kollmuss and Agyeman 2002). Motivational processes can be triggered either intrinsic, e.g., by making people feel good about their actions and the resulting outcome – or extrinsic due to the implementation and distribution of materialistic or virtual rewards or incentives (Davis et al. 1992; Easley 2013; Graml et al. 2011; Stern 2000).

Over the recent years Green IS has become a comprehensive research field within the IS community. In this domain the supportive capabilities of information systems are examined regarding their potential to positively contribute to environmental sustainability (vom Brocke et al. 2013b; Malhotra et al. 2013; Melville 2010). As of late, Green IS research addresses sustainable behavior of individuals in a user-centric manner (vom Brocke et al. 2013b;

Flüchter and Wortmann 2014; Graml et al. 2011). Information systems are used in an attempt to influence everyday-life behavior of people towards more sustainable practices (vom Brocke et al. 2013b). However, the use of information systems to influence people's behavior in IS research is still low and predominantly takes place in the domains of residential energy consumption and the mobility sector (Brauer et al. 2015). In the energy domain IS are used to monitor household energy consumption and provide feedback to the user (Graml et al. 2011; Loock et al. 2013; Oppong-Tawiah et al. 2014; Weiss et al. 2012). Smart metering technology in combination with presentation layers for user interaction have become a frequently addressed area in Green IS research.

In order to motivate people in the usage of the provided IS and to facilitate energy reduction practices the concept of gamification has recently also been applied to such infrastructures. In this scenario game-like mechanisms such as ranking list were implemented to allow users to compare their energy consumption to neighbors or friends and thus create a competitions as a social element to reduce the energy use (Loock et al. 2013). Similar approaches have been conducted in the mobility sector with the goal to reduce CO_2 emissions by influencing driving behavior and the change to more sustainable modes of transportation. Mobile applications are utilized to monitor driving behavior and provide information about fuel-efficiency and carbon emissions (Tulusan et al. 2012). Other systems aim to motivate people to switch from individual car-use to public transportation or bike-use by providing information about the negative environmental effects of car-use compared to more sustainable alternatives (Flüchter and Wortmann 2014; Froehlich et al. 2009). E.g., a visual representation of a growing or dying tree was used to indicate the sustainability of a person's mobility behavior (Froehlich et al. 2009). Hence, monitoring and feedback mechanisms as well as game-elements can be said to play an important role in the concept of persuasive systems. However, they constitute only a small part of potential design principles. Persuasive systems aim to address individuals with various design-elements in order to increase their likeliness to perform a certain target behavior (Fogg 2009a).

Previous studies already demonstrate the potentials of persuasive systems for behavioral change and their impact on adherence and user engagement (Lehto and Oinas-Kukkonen 2015). They are successfully applied in various areas such as education, health, or personal well-being (Corbett 2013b; Langrial et al. 2012; Lehto and Oinas-Kukkonen 2015; Stibe and Oinas-Kukkunen 2014). The progressive dissemination of mobile devices such as smartphones and wearables act as additional drivers for the distribution and success of persuasive systems as they have shown to be a helpful tool for interventions and persuasion (Langrial et al. 2012). However, being a relatively young research field (Lehto and Oinas-Kukkonen 2015; Mustaquim and Nyström 2014), the design of persuasive systems regarding appropriate features has still room for improvement (Langrial et al. 2012; Lehto and Oinas-Kukkonen 2015; Wiafe et al. 2011). Different application areas might require to stress other features to increase the effect of persuasion. Moreover, existing studies primarily focus on the evaluation of single applications and their direct effect on behavior change processes in particular areas. Compared to the dominant application area of health, the ecological domain is underrepresented in persuasive system research despite its high potentials as exhibited by other application domains.

Theories of sustainable behavior change and the potentials of persuasive design features complement each other in great extend and offer various possibilities for user intervention. Prior to the development and evaluation of concrete (persuasive) artifacts it is wise to examine the general acceptance of such systems. As part of the design phase of system development this step helps to determine promising design features to be implemented in the final artifact. Existing studies on persuasive design principles provide a substantial and comprehensive foundation. Oinas-Kukkonen and Harjumaa (2009) propose four conceptual design principles for successful persuasive system design: primary task support, dialog support, system credibility support, and social support, with seven concrete proposed design features for each category (see Appendix). These design principles have been derived carefully over years by experts in the field of persuasive system design and represent the state of the art in persuasive design research (Torning and Oinas-kukkonen 2009). In this study we analyze the effect of these design principles on the general acceptance of PESS. Thus, we aim to gain insights about user requirements and the relationship of persuasive design principles and indicators relevant for system acceptance and future adoption.

2.2 Acceptance Research and the UTAUT2

The acceptance of technologies and systems poses an important field in many domains. For instance, the introduction of new office software in the workplace, technological innovations for private end-users such as in-car entertainment, virtual reality goggles, or technology driven services require a process to determine whether these technological advances or innovations are congruent with the user’s expectations and desires (Venkatesh et al. 2003). In the IS community acceptance/adoption research constitutes a comprehensive area dedicated to analyze the cause, influence, and identification of factors to draw and improve the acceptance of information technologies in various application areas (Venkatesh et al. 2003). In IS research the terms adoption and acceptance are often used synonymously (Bagozzi 2007), describing the willingness of a person to use a certain technology. However, acceptance does not necessarily cause adoption. A person might accept a certain technology or system based on, e. g., positive emotions, but adoption does not happen for different reasons. This phenomenon is called the intention–behavior gap (Maier et al. 2012; Mohiyeddini et al. 2009) and poses an important issue in acceptance and adoption research.

Acceptance and adoption research in IS gained rising momentum in the early 90’s with the introduction of Davis’ (1989) ‘Technology Acceptance Model’ (TAM). TAM showed great potential for the prediction of the intention and actual use of systems and has proven to be superior to Ajzen and Fishbein’s common and widely used theory of reasoned action (TRA) (1977) when examining IS adoption (Venkatesh et al. 2007). The TAM is based and build upon the TRA and tailored for the explanation of determinants for technology acceptance (Davis 1989). While TRA focuses on general beliefs and behavioral intentions or attitude – the TAM takes technological factors into account in form of adequacy of the system to fulfil a certain task (perceived usefulness) and usability (perceived ease of use) of the system

(Davis 1993, 1989). Due to the changing nature of technology, IS-adoption research remained an important research field and different factors influencing the acceptance of systems emerged. Hence, TAM was gradually extended with constructs and variables that can have an impact on user's attitude and intention to employ a certain system and to achieve a better fit of the model (Legris et al. 2003; Venkatesh et al. 2000). TAM was primarily used in the business sector, e.g., for office automation software or system development applications and showed some flaws in other areas, e.g., when students or non-business areas were involved (Legris et al. 2003). In their meta-analysis of TAM-usage Legris et al. (2003) encouraged the extension of TAM with additional constructs and variables to tackle these shortcomings and thus increase the explanation of the model for system-usage beyond the average 40%. However, the extended model TAM2 still inheres business focus as the extensions by the constructs job relevance and output quality indicate. On the other hand, the consideration of subjective norms and image as a social factors as well as voluntariness of use add to the broadness of the model and the potential application in other areas.

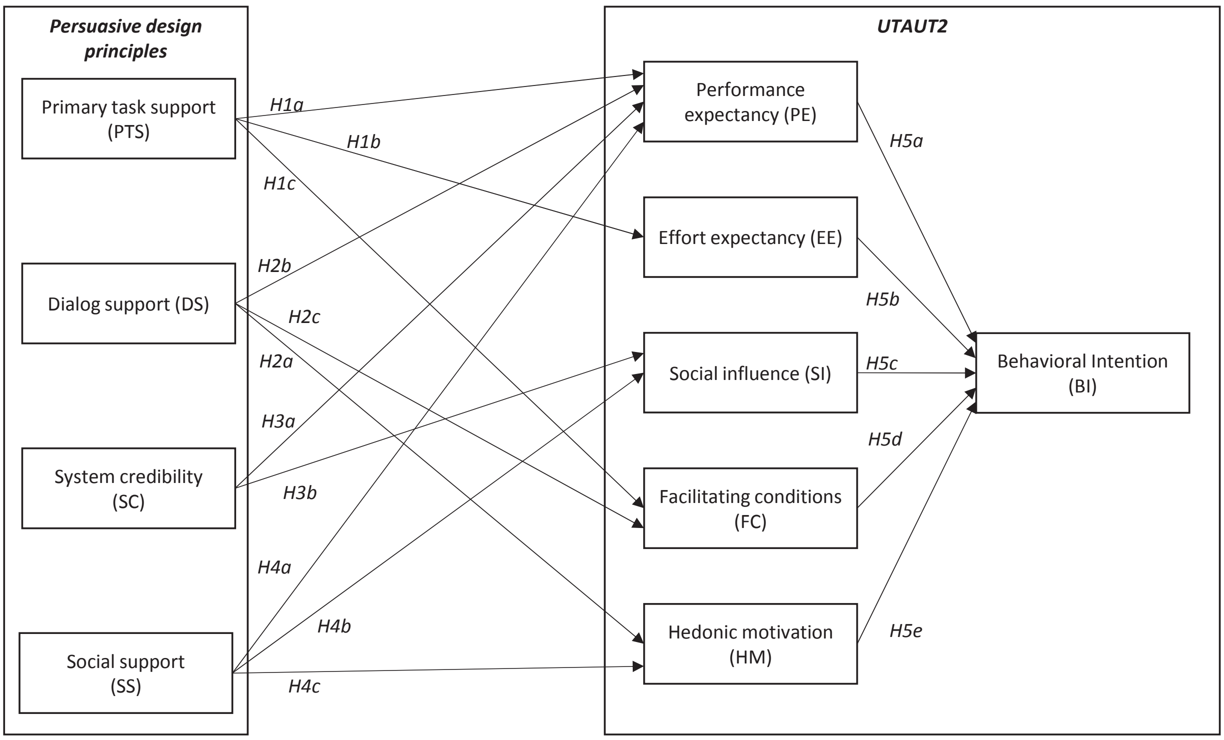
The 'Unified Theory of Acceptance and Use of Technology' (UTAUT) emerged as a result of the combination of previous technology acceptance models and theories with the goal to increase the explanation of technology acceptance behavior (Almatari et al. 2013; Kang et al. 2008; Waehama et al. 2014). Studies showed that UTAUT can explain over 70% of all technology acceptance behavior and helps to understand the influencing factors of the acceptance of new technologies (Waehama et al. 2014). The original UTAUT model introduced by Venkatesh et al. (2003) includes the four constructs performance expectancy, effort expectancy, social influence and facilitating conditions as determinants for behavioral intention of system use and actual system use behavior. The construct performance expectancy describes the level of usefulness of the examined system for the user. It indicates the appropriateness of the system regarding the support of the underlying task executed by the user (Venkatesh et al. 2012). Effort expectancy on the other hand deals with the effort that has to be facilitated when using the system. For example, the stress and cognitive capacity needed to operate the system (Venkatesh et al. 2012). Social influence considers the influencing effect of social peers on the decision to use a system. In a social context individuals tend to adapt their behavior to comply with the opinions and views of their surroundings. Exemplarily, a person might refrain from using an app that helps to achieve a sustainable lifestyle because close friends think that it would be uncool (Venkatesh et al. 2012). The last construct is facilitating conditions and it describes the perceived availability of the required infrastructure to use the system. This can pertain either technological factors such as the possession of a required hardware to use a certain software or service – or personal factors such as time or money to use or obtain the system (Venkatesh et al. 2012).

In an extension of the original UTAUT three additional constructs were added to the model. A key reason for this extension was to address the aforementioned shortcoming of the classic models and theories with sole business focus (Venkatesh et al. 2012). Hence, the constructs hedonic motivation, price value, and habit were added to the research model (UTAUT2) to improve the fit of the model for the consumer use context (Venkatesh et al. 2012). In this context hedonic motivation addresses the fun and pleasure perceived by the user of a certain technology or systems. Prior studies show that hedonic motivation directly influences the acceptance and use of technology (Heijden 2016; Venkatesh et al. 2012). Within the extension of UTAUT2 price value is defined as the tradeoff between perceived benefits for the user and the costs caused by the use of the technology. Because the UTAUT originates from the organizational context, a strict distinction between the technologies' value and usage-cost was not needed as employees typically do not have to pay for system use. In a consumer-based environment, where the technology represents a service, the user has to consider the cost/benefit tradeoff. Thus, price value can have an effect on the behavioral intention of technology use (Venkatesh et al. 2012). Habit, as the third newly introduced construct to UTAUT2, is concerned with the experiences of people in technology use. Habit can affect the behavioral intention of technology use due to previous encounters with similar technologies and can cause automatic behavior based on existing experience. Hence, the user might become more inclined to use a given technology (Venkatesh et al. 2012).

3 Research Model and Hypotheses

As we aim to predict the behavioral intention of users to utilize IS as a trigger for environmental sustainable behavior, we integrate persuasive constructs with the UTAUT2. The four persuasive constructs *primary task support*, *dialog support*, *system credibility support*, and *social support* are drawn from Oinass-Kukkonen and Harjumaa's (2009) conceptual design of persuasive systems. The center of our interest lies in the effect of persuasive design concepts on system acceptance and the connected intention to use the system in the context of environmental sustainable behavior change. The proposed and examined research model is illustrated in Figure B-6.

Figure B-6. Research model



The persuasive constructs are shown on the left-hand side and the UTAUT2 model on the right-hand side. We decided for the use of UTAUT2 for the acceptance part because we consider it most suitable compared to other existing models such as the Technology Acceptance Model (TAM) and the original UTAUT as outlined in the preceding paragraph. As described above TAM primarily focuses the perception of usefulness and usability, and is rather applied in contexts where systems usage has a mandatory character, e.g., the introduction of a new enterprise system, and lacks the suitability in other contexts (Bagozzi 2007; Barki 2007). While further extensions of TAM come close to UTAUT2 in terms of constructs; UTAUT2 has an overall better thematic fit for our use-case due to its voluntary characteristics and consumer focus (Venkatesh et al. 2012). Constructs such as image, job-relevance, computer self-efficacy, perceived external control, or computer anxiety of TAM are of less relevance in this setting due to the nature of the system and the application area. Furthermore, UTAUT2 has proven to be the predominant tool to examine the explanation of technology acceptance behavior (Almatari et al. 2013; Waehama et al. 2014).

Despite the adequateness of UTAUT2 minor changes to the model were performed. First, we removed the construct use behavior because there is no concrete IS artifact which covers all the considered persuasive design principles which can be used as a representative artifact for comparison (Brauer et al. 2016). Furthermore, the habit construct was dropped because a PESS poses a relatively novel approach and thus makes a habitual use unlikely. The evaluation of the research model is based on a conceptual design of how a PESS should be implemented deduced from the available body of literature and our previous study on the analysis of existing environmental sustainable apps (Brauer et al. 2016). Thus, real-world usage behavior cannot be measured appropriately. However, recent studies indicate that the intention to use serves as a good predictor for actual usage (Segura 2015). Second, the construct price value is omitted since a PESS is initially considered as a charitable application and therefore it would be free to use. Lastly, the persuasive design constructs are added to the UTAUT2 model. According to Davis (1993), system design features can have an indirect effect on the attitude towards using a technology. Hence, the extension of the UTAUT2 model by constructs of persuasive system design is eligible (Segura 2015).

The persuasive system constructs are modeled based on Oinas-Kukkonen and Harjumaa's (2009) design categories for persuasive system design. The respective items of each of the four constructs are the design principles of the corresponding category as proposed by Oinas-kukkonen and Harjumaa (2009). The used items representing the persuasive design principles are illustrated in the Appendix. The design principles are briefly described below and followed by the derivation of the hypotheses concerning their relationship to the UTAUT2 constructs.

The first category *is primary task support* and contains design principles that help users to reach their goals. While this can generally be said about all categories, the main focus lies on the customization of the information system regarding system usage and user–system interaction. A potential user of a PESS might not necessarily have a strong ecological attitude per se and could be introduced to such a system by friends, family, or colleagues. However, if the first contact is made, the design of the system can foster further user engagement by addressing individual interests, needs, and personal affordances (Seidel et al. 2013). Some ecological goals can be in line with other goals with higher interest to the respective user than a positive contribution to environmental matters (Lindenberg and Steg 2013). An economically person, for instance, aims to save money in various circumstances. If a system could help to engage that person in higher bike-usage instead of private car use both goals can be reached. The person saves gas money and at the same time CO_2 emissions. Personalization does not only affect a person socially, emotionally, and cognitively (Blom and Monk 2003) but can also be more convincing (Gonzales et al. 1988; Kurz 2002) and lead to better outcomes (Berkovsky et al. 2015). A common approach for the provision of personalized information is performed by monitoring and feedback mechanisms (Boontarig et al. 2014; Lehto and Oinas-Kukkonen 2015; Oppong-Tawiah et al. 2014; Toscos et al. 2006). The observation of behavior, e.g., mobility or resource consumption is reflected to the user with the corresponding effects (Flüchter and Wortmann 2014; Froehlich et al. 2009; Loock et al. 2013).

H1a: Primary task support has positive impact on performance expectancy

Personalized feedback can be provided quantitative in the means of saved emissions and resources or a visual interpretation of collected awards (Flüchter and Wortmann 2014; Froehlich et al. 2009; Loock et al. 2011). The diversity of goals stated above can lead to the attainment of sustainability goals even if they are not directly pursued by the user. Addressing different personal goals is a promising way to overcome psychological barriers of sustainable behavior (Lindenberg and Steg 2013). Many people perceive sustainable behavior as a burden and link it with negative attributes and thus would refrain from the use of an information system in this context because it could require additional effort (Lindenberg and Steg 2013). However, a well-designed and comprehensible assistive information system could also help to reduce the perceived effort of environmental sustainable practices as examples from the health and educational domain show (Filippou and Cheong 2015; Lehto and Oinas-Kukkonen 2015).

H1b: Primary task support has positive impact on effort expectancy

A persuasive system with the ability to propose proper actions and interventions can overcome a lack of perceived cognitive and materialistic resources (Fogg 2009a; Ham and Midden 2010). Thus, the attitude that a tool helping to reach environmental sustainable behavior is hard to find, or creates additional temporal or monetary investments, can be reduced.

H1c: Primary task support has positive impact on facilitating conditions

Dialog support can be seen as the core element of persuasive systems as the interaction with the user constitutes the focal point of the system's architecture (Oinas-kukkonen and Harjumaa 2009). Persuasive system design is generally based on three pillars responsible for successful persuasion (Fogg 2009a). The persuasion of a specific behavior requires the motivation of an individual to perform this behavior. However, even if the willingness of such behavior is given – the ability of the person to conduct this behavior might be lacking. These two factors influence each other and have a direct effect on the adaption of target behavior.

A successful persuasive system affects either one of these factors, or both at a time (Fogg 2009a). Studies about the use of information systems in the context of environmental sustainable behavior could already show that the utilization of praise and rewards can have a positive effects on the motivation for system use and the performance of ecological actions (Froehlich et al. 2010; Gifford 2011; Graml et al. 2011; Petkov et al. 2011). The use of game-like elements such as virtual rewards like badges, leaderboards, levels, etc. make the concept gamification a common mechanism to motivate people for participation and commitment in various application areas, e.g., health, education, work, commerce, and – as in this case – sustainability (Blohm and Leimeister 2013; Hamari et al. 2014). The used game elements are intended to trigger hedonic desire of a person (Codish and Ravid 2014).

H2a: Dialogue support has a positive impact on hedonic motivation

However, sometimes motivation and ability alone are not sufficient to change behavior (Fogg 2009a). A person might generally be motivated to perform ecological behavior and has the cognitive and materialistic capacities to do so – but does not; mostly the reasons are temporal (Fogg 2009a). Fogg (2009) proposes the use of different triggers to stimulate target behavior based on the level of motivation and ability to overcome this issue. These triggers act as a reminder for the user at the right time and place and suggest that environmental sustainable behavior might be realizable at that moment. In the section above the positive potential of personalized information is mentioned. Besides the particular information the visual design has an important part in user–system interaction and system acceptance; the look and feel as well as the adequacy for the user can influence user performance (Blom and Monk 2003).

H2b: Dialogue support has a positive impact on performance expectancy

Moreover, if a system can create a strong bond with the user and serve as a virtual representation of that person, similarity effects can occur between the user and the system leading to more liking of the system and higher potential for persuasion (Fogg 2003). Such a digital personal agent can help to overcome information overload and possible existing cognitive shortcomings, reducing potential complexities of proposed tasks (Maes 1994).

H2c: Dialogue support has a positive impact on facilitating conditions

System credibility design principles aim to make a system more credible to the user and thereby strengthen the effect of persuasion (Oinas-kukkonen and Harjumaa 2009). In a meta-analysis of UTAUT implementations Dwivedi et al. (2011) could already show that external variables such as trust, belief, and credibility can have a significant impact on performance expectancy. However, the results are mixed and vary for different scenarios. In the context of environmental sustainable behavior change trust often constitutes and important factor. People might mistrust institutions regarding the provided information of environmental impacts, and other people about their contribution and effort in sustainable actions (Flynn et al. 2009; Kollmuss and Agyeman 2002; Kurz 2002). Hence, when trust and credibility in society is corrupted concerning ecological matters, people are more unlikely to engage in sustainable behavior. Therefore, we expect a positive impact of system credibility on performance expectancy and social influence.

H3a: System credibility support has a positive impact on performance expectancy

H3b: System credibility support has a positive impact on social influence

Social aspects play a crucial role in sustainability activities (Gifford 2011; Siero et al. 1996; Stern et al. 1995). The opinions and actions of others can have positive and negative implications on one’s actions. Environmental sustainable behaviors of friends and family can serve as a positive example and lead to a change of mind of a person (Gifford 2011). Social interaction with people who think alike and have equal interests or personal goals can result in an increased person’s willingness to engage in tasks positively contributing to the environment (Ebermann and Brauer 2016; Lindenberg and Steg 2013). Thus, leading to higher performance regarding environmental sustainable behavior.

H4a: Social support has positive impact on performance expectancy

On the other hand, if social peers are reluctant to ecological topics these people can create pressure and prevent a person from engaging in sustainable actions because of the fear that these people will keep distance or even make fun of that person (Corral-Verdugo et al. 2014; Lindenberg and Steg 2013). Thus, a person could initially refrain from engagement in sustainable activities without even knowing the exact opinions of others, just out of fear. However, social activities and interactions can also enable and facilitate certain behavior. Studies in the area of environmental sustainable behavior change show that the interaction with society has an essential share in the readiness to engage in sustainable activities (Gifford 2011; Kollmuss and Agyeman 2002). This can happen for multiple reasons.

H4b: Social support has positive impact on social influence

Exemplarily, some people like being part of a community and are willing to adapt in order to be part of the community (Petkov et al. 2011). Others feel a motivation due to social processes and the pertinent use of appropriate mechanisms to support goal attainment (Lindenberg and Steg 2013). For example, the utilization of game-mechanisms helps to drive user-engagement through cooperation and competition functionalities (Law et al. 2011).

H4c: Social support has positive impact on hedonic motivation

Previous studies already show the significant impact of the constructs performance expectancy, effort expectancy, social influence, facilitating conditions, and hedonic motivation on behavioral intention within UTAUT (Chang et al. 2007; Chiu and Wang 2008; Curtis et al. 2010; Gupta et al. 2008; Wang and Shih 2009). Moreover, a meta-analysis of multiple studies utilizing UTAUT indicate a consistent relationship between constructs (Dwivedi et al. 2011). Thus, we propose positive impacts of the selected constructs on behavioral intention.

H5a: Performance expectancy has positive impact on behavioral intention of system use

H5b: Effort expectancy has positive impact on behavioral intention of system use

H5c: Social influence has positive impact on behavioral intention of system use

H5d: Facilitating conditions has positive impact on behavioral intention of system use

H5e: Hedonic motivation has positive impact on behavioral intention of system use

4 Research Methodology

4.1 Instrument Development and Measurement of Construct

The measurement constructs are based on persuasive design principles derived from Oinas-Kukkonen and Harjumaa (2009) and UTAUT2 constructs from Venkatesh et al. (2012). Persuasive design encompasses primary task support (PTS), dialog support (DS), system credibility support (SC), and social support (SS). The UTAUT2 model is composed of performance expectancy (PE), effort expectancy (EE), social influence (SI), facilitating conditions (FC), hedonic motivation (HM), and behavioral intention (BI).

In a prior study we performed an extensive analysis of available eco-apps in the google play store. We identified over 260 mobile applications with sustainability related goals (Brauer et al. 2016). However, because there could be no app identified covering all or at least a high share of the proposed design principles, we decided to use functions and characteristics of these apps matched with the persuasive design principles to describe the general idea of a comprehensive PESS for the design of a virtual artifact.

The measurement of the items is performed with a 7-point Likert scale ranging from 'I strongly disagree' to 'I strongly agree' to determine whether a participant considers a certain design principle as required for the acceptance of a PESS. The same applies for the measurement of the UTAUT2 constructs.

4.2 Data Collection Procedure and Sample Description

The data was collected with an online survey distributed through a variety of channels such as university websites, social media platforms, and online communities. Although online surveys are traditionally known to have shortcomings regarding the sample (Evans and Mathur 2005), we consider this to play a minor role in this case. First, the online community in social networks has become significantly broader in terms of age and technology savviness than a decade ago. Second, the examined case of mobile app-use primarily addresses people that are already familiar with technologies and are potential smartphone owners. Thus, the positive properties of online surveys such as higher return rate and more easily access to target audience (Evans and Mathur 2005) outweigh the alleged drawbacks of online surveys for this particular case.

Before the respondents answered the construct's questions they were asked to read a short introduction paragraph about the meaning and purpose of a PESS to provide them the required fundamental knowledge to properly answer the questions. The questionnaires items regarding the persuasive constructs are formulated according to the design principle's descriptions by Oinas-kukkonen and Harjumaa (2009) and extended with short descriptions of the design principle's function or characteristic to give the respondent an idea about the principle's purpose. The survey closes with the UTAUT2 questions.

The virtual PESS artifact has been designed based on existing theory in the domain of user-centric Green IS research (Brauer et al. 2016; Brauer and Kolbe 2016) and persuasive design principles (Oinas-kukkonen and Harjumaa 2009). The design of the PESS used in this study is the result of a first evaluation of the underlying theory and the feedback of test-subjects. The findings of this study are integrated in a future design phase; the implementation of a real IS artifact which will be further evaluated in a future study. The descriptions of the single functions covering the persuasive design principles, answered by the questionnaire's participants, were developed together with the test-subjects from the initial artifact draft design phase. Hereby, we assured to design the description of the virtual artifact as comprehensible and precise as possible.

The survey took place over a timespan of three weeks in spring 2016 and yields 210 responses of which 178 were complete and could be used for further evaluation. The questionnaire covers 48 items and was invoked 231 times by potential respondents resulting in a completion rate of 77%. The distribution of the gender shows predominantly female participants (61.3% to 38.7%). The age of the sample spans from 16 to 61 years with a mean of 27 years and a standard deviation (SD) of 6.9 years. Almost half of the participants (48.9%) have a university degree (bachelor or master), 2.8% have a doctoral degree, 29.6% have an associate degree, and 18.2% have a high school/college degree.

Table B-22. Sample Demographics

N = 178	**Min**	**Max**	**Mean**	**Std. Dev.**
Age	16	61	27	6,9
Gender	Female: 109 (61.3%)		Male: 69 (38.7%)	

5 Data Analysis and Results

5.1 Assessment of Measurement Model

SmartPLS version 3.2.3 was used to analyze the data gathered. The analysis was performed in two steps. First, we verified the reliability and validity of the measurement model. Second, the posited hypotheses are checked with structural equation modeling (SEM). Since the model consists of different type latent variables (LV), two approaches are conducted to report reliability and validity of the presented model (Wong 2013). Natively, the exogenous variables of UTAUT are reflective (Wu et al. 2007). Whereas the variables of the persuasive constructs are formative regarding their underlying items. This means that the direction of causality is from the indicator to the construct with the property that the collection of formative indicators jointly determine the empirical and conceptual meaning of the associated construct (Jarvis et al. 2003). Moreover, formative indicators may be mutually exclusive and need not to covary with each other (Hardin et al. 2008). The collection of indicators constitute the meaning of the proposed construct, thus, removing one of the indicators – as commonly done for reflective constructs – might change the meaning of the formative construct (Diamantopoulos and Winklhofer 2001; Jarvis et al. 2003) and should be well-considered (Hardin et al. 2008). Hence, different evaluations of measurement indicators are required (Wong 2013).

For the UTAUT2 LV's convergent item validity is given when each item loads significantly on their respective constructs. Items should have a loading of at least .70 to be considered as significant (Hulland 1999). In this study all UTAUT2 items have a loading higher than the threshold of .70 except one item of the LV facilitating conditions (.67). However, we refrained from dropping this particular item because of its high loading and the fact that the composite reliabilities of the construct is above .70 as for all other UTAUT2 constructs as well (Hulland 1999). Moreover, the average variance extracted (AVE) for each construct is greater than .50 (Bhattacherjee and Premkumar 2004). Hence, the exactness of the measurement can be supposed. The convergent validity (CV) describes the degree to which multiple measures of the underlying construct are in agreement (Bagozzi et al. 1991) and is examined by calculating individual indicator reliability, composite construct reliability (CR), and AVE (Fornell and Larcker 1981). All UTAUT2 items have a loading above the minimum of .60 regarding their respective construct implying an acceptable limit of indicator reliability (Chin 1998). Finally, discriminant validity (DV) is given as every item loads higher on its related construct than on any other model constructs (Chin 1998). This is further illustrated by the square root values of the AVE's as they are all greater than the corresponding construct correlations (Fornell and Larcker 1981). The results of reliability and validity check are shown in Table B-23.

Table B-23. Mean, Composite Reliability, Average Variance Extracted, and Correlation Matrix

	M	CR	AVE	PTS	DS	SC	SS	PE	EE	SI	FC	HM	BI
PTS	5.39	n/a*	n/a*	n/a*									
DS	4.97	n/a*	n/a*	n/a*	n/a*								
SC	6.03	n/a*	n/a*	n/a*	n/a*	n/a*							
SS	4.29	n/a*	n/a*	n/a*	n/a*	n/a*	n/a*						
PE	4.78	0.94	0.84	0.38	0.38	0.21	0.33	**0.92**					
EE	5.25	0.90	0.70	0.27	0.33	0.22	0.28	0.69	**0.84**				
SI	3.63	0.96	0.89	0.26	0.26	0.20	0.25	0.66	0.47	**0.95**			
FC	5.38	0.88	0.66	0.24	0.24	0.27	0.18	0.42	0.63	0.33	**0.81**		
HM	4.20	0.96	0.90	0.32	0.34	0.14	0.24	0.66	0.55	0.57	0.44	**0.95**	
BI	3.58	0.97	0.92	0.27	0.35	0.17	0.30	0.70	0.53	0.66	0.44	0.75	**0.96**

1. M: Mean, CR: Composite Reliability, AVE: Average Variance Extracted
2. PTS: Primary Task Support, DS: Dialog Support, SC: System Credibility Support, SS: Social Support
3. PE: Performance Expectancy, EE: Effort Expectancy, SI: Social Influence, FC: Facilitating Conditions, HM: Hedonic Motivation, BI: Behavioral Intention
4. **Bold** elements are square roots of the AVE

* values are not available (n/a) due to formative measurement

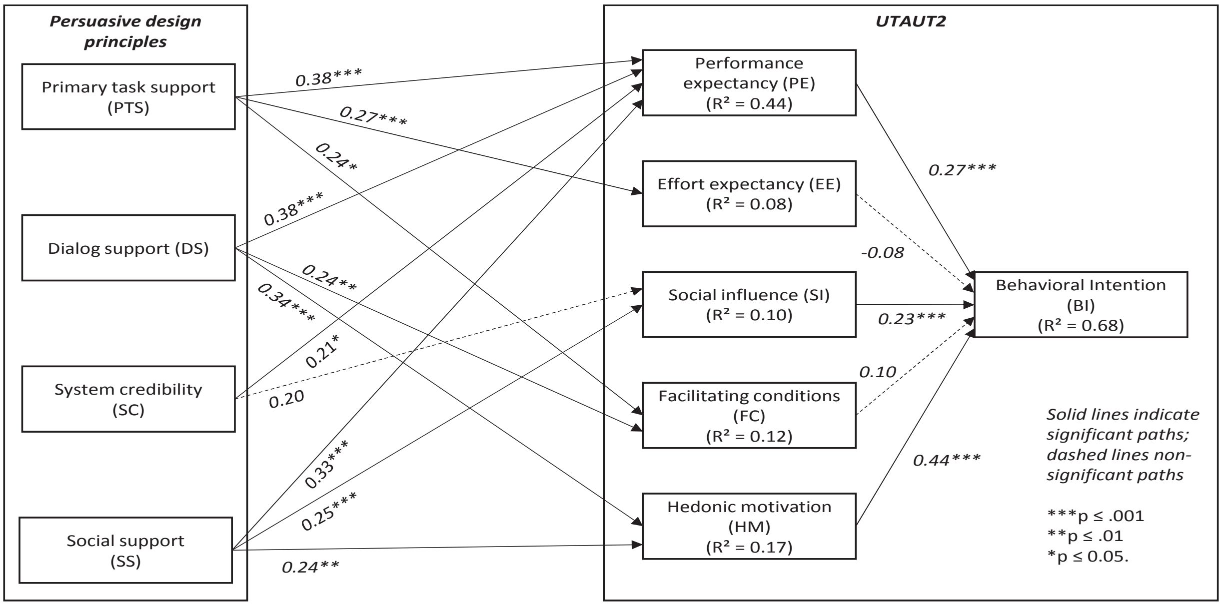
For formative constructs the determination of validity and reliability requires other measures for interpretation. Indicator contribution to a construct is measured by the indicator's weight to determine the relative contribution of this indicator to the proposed construct (Cenfetelli and Bassellier 2009; Hardin et al. 2008). Relative contribution describes the importance of a predictor compared to the other predictors attributed to this construct (Nunnally and Bernstein 1994). Thus, if the weight of an indicator is significant it can be considered to have a high relative contribution to its construct (Cenfetelli and Bassellier 2009). For this research model only the items DS1, DS4, and SC6 have significant weights regarding their assigned construct (see Appendix). Due to the nature of formative constructs the indicators compete being the relevant predictor of the construct, thus, low weights are not rare (Cenfetelli and Bassellier 2009). Moreover, for constructs with high numbers of indicators (here: 7), weights tend to be lower as well (Cenfetelli and Bassellier 2009). However, a common mistake made when interpreting indicators within formative constructs is removing indicators with non-significant weight (Hair et al. 2012a). If the indicator weight is low and non-significant the indicator loading should be considered to decide about retaining that indicator (Cenfetelli and Bassellier 2009). Indicator loadings interpret the absolute importance of a predictor independent of the other predictors and thus can still have a high explanatory potential for this construct (Cenfetelli and Bassellier 2009). Here, DS5, DS7, SC1, SC2, SC3, SC5, SS1, SS3, and SS5 are not significant regarding loading. Moreover, these are the only indicators that are not significant regarding loading and weight (see Appendix). Thus, for these indicators it could be considered removing these indicators from the model (Cenfetelli and Bassellier 2009). To calculate the significance of indicator weight and loading bootstrapping has been performed with n = 5,000 samples.

Another important approach for assessing formative indicators is the examination of multicollinearity among the indicators (Cenfetelli and Bassellier 2009; Hardin et al. 2008). Multicollinearity describes the correlation of two or more variables with each other, meaning that they describe the same phenomenon (Hair et al. 2012a). When collinearity issues occur it should be considered to eliminate or merge the affected indicators (Hair et al. 2012a). Multicollinearity is tested by assessing the variance inflation factor (VIF) for each indicator (Hair et al. 2012b). In our case all values for VIF are above the minimum of 1 and below the threshold of 5 (Rutkowski et al. 2013). Thus, multicollinearity does not apply.

5.2 Structural Model and Hypotheses Testing

The structural model is assessed based on the path coefficient between the independent and dependent variables, and R^2. The path coefficient indicates the strength of the relationship of the independent and dependent variable (Cenfetelli and Bassellier 2009). R^2 measures the predictive power of the model for the dependent variables (Chin 1998; Hair et al. 2012b). The significance of the path coefficients is calculated by the bootstrapping resampling method with n = 5,000 samples. For the relations between the persuasive design constructs and the UTAUT2 constructs nearly all path coefficients are significant up to the level of .05 – except for the path from system credibility support to social influence (SC → SI) which shows no significant interaction (see Figure B-7).

Figure B-7. Structural model



The inner UTAUT2-paths' effort expectancy to behavioral intention to use the PESS (EE → BI, β = -0.08) and facilitating conditions to behavioral intention (FC → BI, β = 0.10) show no significant relationship within the UTAUT2 model contrary to prior utilizations of the UTAUT (Dwivedi et al. 2011). The construct effort expectancy (EE) even turns out to have a negative influence on the behavioral intention of system use. Overall, the model indicates an above-average explained variance in behavioral intention of 68.0% (Chin 1998). Table B-24 illustrates the hypothesized relationships and their significance.

Table B-24. Results of the Hypotheses Tests

Hypothesis	Relationship	Path coefficient	p-value	t-value	Supported?
H1a	PTS → PE	0.38***	0.000	4.97	Yes
H1b	PTS → EE	0.27***	0.001	3.28	Yes
H1c	PTS → FC	0.24*	0.022	2.29	Yes
H2a	DS → HM	0.34***	0.000	5.39	Yes
H2b	DS → PE	0.38***	0.000	5.07	Yes
H2c	DS → FC	0.24**	0.003	2.97	Yes
H3a	SC → PE	0.21*	0.020	2.33	Yes
H3b	SC → SI	0.20	0.065	1.85	No
H4a	SS → PE	0.33***	0.000	4.31	Yes
H4b	SS → SI	0.25***	0.000	3.74	Yes
H4c	SS → HM	0.24**	0.003	2.93	Yes
H5a	PE → BI	0.27***	0.001	3.69	Yes
H5b	EE → BI	-0.08	0.303	1.03	No
H5c	SI → BI	0.23***	0.000	3.91	Yes
H5d	FC → BI	0.10	0.140	1.48	No
H5e	HM → BI	0.44***	0.000	6.13	Yes

***p ≤ .001, **p ≤ .01, *p ≤ 0.05.

6 Discussion

In this paper we assess the impact of persuasive design principles on the acceptance decision process regarding user-centric Green IS by utilizing UTAUT2 for acceptance analysis. The examined design principles are based on a comprehensive proposal of design principles pertaining to persuasive system design by Oinas-Kukkonen and Hajumaa (2009).

With *H1a-H1c* we predicted a positive impact of the persuasive construct primary task support (PTS) on performance expectancy (PE), effort expectancy (EE), and facilitating conditions (FC). None of the design principles proposed to support these relationships indicated a significant weight, meaning that none of the principles stand out to represent the sole contribution to the construct (Cenfetelli and Bassellier 2009). However, all indicators have significant loadings and thus show an absolute importance to their constructs (Cenfetelli and Bassellier 2009). In *H1a* a positive influence of PTS on PE is predicted and likely to support the system's user in the process of performing sustainable behavior (Venkatesh et al. 2012). The PTS items aim to support the user in breaking down complex behavior such as CO_2 reduction, resource conservation, or sustainable nutrition into single easy-executable tasks. Suitable processes are meant to be proposed to the user based on their personal interests. For example, not every user might be interested in changing mobility behavior in order to save CO_2 emissions, but on the other hand, may be open to suggestions for energy conservation. Thus, welcoming support offered by the system. In such cases the sustainable goal does not even need to be focused on by the system or user. The user might have a different goal by saving energy, such as reducing the energy bill (Lindenberg and Steg 2013). However, the support of appropriate tasks implicitly leads to the fulfilment of both goals. The results show that the participants value the proposed design principles as valuable measures in supporting their adjustment towards more sustainable behavior and system acceptance, confirming *H1a*. *H1b* aims at the effort associated with the use of a PESS (Venkatesh et al. 2012). Functionalities offered by the system are implemented to achieve dually, the ease of using the system for its sustainable purpose and the reduction of effort put in sustainable actions. Automated monitoring of behavior helps the user to track personal progress without spending additional work doing it manually, e.g., by keeping a journal. Thus, full cognitive and temporal capacity can be allocated to the processes for sustainable behavior. According to the analysis, the participants find that a PESS can reduce the overall efforts required to engage in environmental sustainable actions. With *H1c* we predicted positive influence of PTS on FC by addressing the participant’s perception of available resources and support in the pursuit of sustainable behavior (Venkatesh et al. 2012). Thus, it can be assumed that a PESS is expected to positively influence the perception of overcoming a lack of cognitive or materialistic resources (Fogg 2009a; Ham and Midden 2010). Compared to the other two relationships of PTS, the relationship between primary task support and facilitating conditions (PTS → FC) is significant at a level of .05, but still indicates a positive impact. For the PTS construct and the underlying indicators we can conclude that they pose a successful potential for PESS acceptance.

Hypothesis *H2a-H2c* are concerned with the effect of dialog oriented design features (DS) between system and user. Such design principles aim to interact with the user in terms of feedback about personal behavior and suggestions for suitable actions (Fogg 2009a; Oinas-kukkonen and Harjumaa 2009). Moreover, a clear and structured design, in terms of system usability, can affect the supporting capabilities of a system (Maes 1994). In Hypothesis *H2b* we predicted a positive effect of dialog support on performance expectancy (DS → PE), which could be confirmed by the analysis. This indicates that the proposed design features were perceived as supportive measures by the participants. Prior research on environmental sustainable behavior change demonstrates that motivation can have an effective influence on engagement in sustainable actions (Froehlich et al. 2010; Gifford 2011; Graml et al. 2011; Petkov et al. 2011). When considering the indicator loadings for the dialog support construct (see Appendix), these findings can be underlined by this study. The participants particularly value the features providing praise and rewards based on behavior conducted, as well as suggestions of proper processes for sustainable actions. Praise and rewards are also strongly connected to the concept of hedonic motivation, thus often considered in gamification design mechanisms by implementing competition or cooperation (Blohm and Leimeister 2013; Codish and Ravid 2014). This relationship is illustrated by the connection DS → HM (*H2a*), hypothesized with a positive effect which is additionally confirmed by the data. The connection of dialog support and facilitating conditions (DS → FC) also shows a positive effect (*H2c)*. This can be explained by the significant loadings of the indicators, thus proposing periodically reminders and 'visual appealing in terms of look and feel' of the systems. As Fogg (2009) states about the potentials of persuasive systems to address individual's shortcomings regarding temporal and cognitive limitations, reminders can support the user in the process of identifying the right moment to perform a certain behavior. Thus, such limitations are reduced by freeing temporal and cognitive resources. The usability aspect of system usage applies similarly (Maes 1994). If a system provides intuitive interaction with the user – less cognitive effort is required along the entire task-set associated with the process of sustainable behavior. However, when considering the indicator-weight, the design principles praise and 'suggest for proper behavior' constitute the most significant characteristic of the DS construct. The latter indicator is particularly interesting, because it demonstrates the fact that many people are unaware of how they could contribute to environmental sustainability, although they might be willing to do so (Gifford 2011). Thus, properly proposed sustainable actions suited for individual user interest yield huge potentials for engagement, along with increase of sustainable behavior and system acceptance. The design principles considering a virtual specialist supporting a user during system usage, and the provision of a digital self-representation show no significant effect. Overall, we can conclude a positive influence of dialog support on PESS acceptance.

For the effect of system credibility support (SC) design principles, we could only confirm one of the two hypotheses constructed. Only the connection of system credibility support on performance expectancy (SC → PE) in *H3a* shows a significant relationship in our research model. Hypothesis *H3b*, representing the influence of SC → SI has to be rejected. Again considering indicator weight and loading to further elaborate the construct's impact on the research model, we conclude that only the indicator 'participation and representation of well-known partners' within the system poses an important indicator to the participants. Thus, we cannot confirm the assumption that system credibility has an influence on the effect of persuasion, as stated by Oinas-Kukkonen and Harjumaa (2009). However, this needs to be relativized to the concrete application area of environmental sustainable behavior. It can be assumed that trust and reliability of information gains higher relevance in, e.g., the health sector.

Finally, notable significances can be identified for the construct social support (SS). Hence, participants find social design principles as helpful measures to support their performance in sustainable actions (*H4a*), and thus indicate a high impact on the acceptance of such systems. Moreover, negative social influences, often discussed in the context of social norms regarding environmental sustainable behavior (Corral-Verdugo et al. 2014; Lindenberg and Steg 2013), seem to be positively addressed by social support design principles (*H4b*). Carrying slightly lower significance, the relationship between social support and hedonic motivation (SC → PE) also indicates an important connection (*H4c*). This shows that implementations should emphasize the consideration of social mechanisms to improve persuasive effects of indicated systems. As already exemplified for DS design principles, some of the significant social support design principles exhibit mechanisms that are often implemented by the gamification concept (Blohm and Leimeister 2013; Hamari et al. 2014). Thus, deducting that gamification can have huge potentials for the design of environmental sustainable information systems. The results also show that the participants favor competition elements (SS2, SS4, and SS6) over cooperative tasks (SS3 and SS5).

The analysis reveals that the model explains 68% of the variance in terms of behavioral intention to use a PESS, which is above the average of explained variance in SEM (Chin 1998). Further explanation improvements could be achieved by removing indicators with non-significant loadings and weights from their respective construct. However, in this case the analysis has an explorative characteristic, incorporating the goal to reveal the adequacy of single design principles including their conceptual meaning on the acceptance of PESS. Thus, the goal is not the optimization of the research model by dropping non-significant indicators, but rather the explanation of persuasive design principles in relation to the acceptance decision process. Hence, removing indicators in this case is not necessarily desired. Regarding the behavioral intention (BI) of system acceptance/adoption, the analysis reveals that effort expectancy (*H5b*) and facilitating conditions (*H5d*) do not significantly affect the adoption decision towards PESS. In contrast, the participants value the contribution of the system to improve their performance (*H5a*), along with the hedonic components (*H5e*) which aims to make sustainable processes more fun, e.g., by introducing social aspects (*H5c*). The data shows that the proposed design principles for primary task support are perceived to reduce the effort for sustainable behavior by the participants, yet the perceived effort reduction does not contribute to the intention of system use. On the contrary, the negative path coefficient indicates an increase of effort due to system use. Therefore, other approaches are required to address the issue of effort as a psychological barrier for sustainable behavior change. However, the presented design principles of the different categories seem to positively affect performance expectancy, leading to an increased behavioral intention of system use.

6.1 Implications

Utilizing the analyzation of influence regarding persuasive design principles on the acceptance of information systems to support environmental sustainable behavior, we contribute to both theory and practice. For practice, the implications of our work help system designers in the design process of sustainable applications by providing indicators for relevant implementations. Thus, in terms of user acceptance, designers can focus on the implementation of first-order relevant functionalities required for successful sustainable applications. For theoretical purposes, we provide ground for discussion about the integration of persuasive design principles in acceptance/adoption research models. Moreover, we add an instance of the utilization of UTAUT2 in the consumer context and the research domain of user-centric Green IS to the body of literature. While the findings are generally transferable to other application areas, such as health or education, it should be noted that different areas might have divergent requirements as discussed for the system credibility support construct. Thus, for other application domains a dedicated assessment of indicator suitability is recommended.

6.2 Limitations and Future Research

Despite these implications, there are also some limitations associated with our research performed. First, the analyzed persuasive constructs and the underlying indicators are not necessarily complete. While they serve as a very good starting point as a well-derived set of design principles by Oinas-Kukkonen and Harjumnaa (2009) – there could be additional suitable dimensions and design features than the ones considered, e. g., more appropriate design principles to reduce the perceived effort for sustainable behavior. Second, we used a virtual artifact for our measurement of the research model. Thus, the participants had to evaluate a theoretical system based on a textual description. Although we aimed to construct the descriptions of the respective comprehensive design principles concisely within the survey, the aid of practical examples still come short to actual system use with a real artifact. Therefore, future studies should examine concrete implementations of PESS, utilizing the proposed research model to validate our findings while measuring actual use compared to behavior intention. The use of a real artifact can also help to further examine the intention–behavior gap in this context, as mentioned above. Moreover, future research should evaluate the single design principles in more detail to gain real, practical evidence of their contribution. Additionally, including why certain design principles were not considered as help- or useful, and aim to derive yet unconsidered design principles. For such analysis, we suggest to conduct qualitative studies to comprehensively gather information by direct interaction with the test-subjects through interviews and observation (Froehlich et al. 2007).

7 Conclusion

This study aimed to gain insight about the influence of persuasive design principles on the acceptance of persuasive environmental sustainable system (PESS) in the context of user-centric persuasive Green IS. The results could show that persuasive design principles can have a positive influence on the acceptance of information systems, helping people to pursue environmental sustainable behavior. Moreover, we provide an overview of different concrete persuasive design principles and their impact on the user's acceptance decision process. With this analysis we add knowledge to the body of literature for the application of the UTAUT in the area of Green IS research, while integrating the relatively young research field of persuasive system design. Furthermore, we contribute to the design of information systems in a voluntary setting to address environmental sustainable behavior change. The findings of this research can be introduced into further practical implementations of user oriented Green IS artifacts, thus providing contributions to create sustainable societies and the path towards a greener world.

8 Appendix: Measurement of Persuasive Design Items with Loadings and Weights

Table B-25. Persuasive Design Measurement Items with Loadings and Weights

ID	L	t	W	t	Statement
PTS1	0.72	3.86***	0.18	0.61	A PESS should be able to reduce complex behaviors into simple tasks.
PTS2	0.76	4.66***	0.19	0.56	A PESS should guide me towards the right decision and through the underlying processes.
PTS3	0.68	3.96***	0.05	0.12	A PESS should be tailored to my personal needs/interests to provide me the ideal information.
PTS4	0.54	2.65**	0.30	0.92	Personalized content and prioritization improves the effect of the PESS.
PTS5	0.59	2.93**	0.20	0.65	A PESS should track and monitor my behavior.
PTS6	0.74	5.13***	0.22	0.72	A PESS should allow to simulate the cause and effect of my behavior on the environment.
PTS7	0.74	4.11***	0.34	1.03	A PESS should allow me to rehearse my behavior.
DS1	0.79	9.13***	0.70	2.70**	A PESS should praise me based on my behavior.
DS2	0.58	5.56***	-0.15	0.57	A PESS should reward me for performing the target behavior.
DS3	0.63	3.81***	0.09	0.52	A PESS should periodically remind me to fulfill a target behavior.
DS4	0.63	3.65***	0.43	2.79**	A PESS should provide me proper suggestion for sustainable behavior.
DS5	0.31	1.70	-0.03	0.21	A PESS should provide an accurate digital representation of myself.
DS6	0.46	2.57**	0.13	0.90	A PESS should be visually appealing in terms of look and feel.
DS7	0.32	1.77	0.25	1.54	A PESS should have a virtual specialist to establish a personal relationship with me.
SC1	0.25	0.89	0.23	0.38	For me it is important that a PESS is truthful, fair, and unbiased.
SC2	0.26	1.20	0.00	0.00	The information given by a PESS should be up-to-date and from competent sources.
SC3	0.20	0.88	-0.08	0.28	The PESS should have a professional appearance.
SC4	0.48	2.44*	0.38	0.96	A PESS should be transparent regarding the provider and potential practical partners.
SC5	0.41	1.88	-0.02	0.07	The provider of a PESS should be a trusted authority.
SC6	0.94	3.24***	0.95	2.82**	Respected and well-known partners should be part of the PESS.
SC7	0.49	2.60**	-0.20	0.57	The information provided by the PESS should be documented with reliable sources.
SS1	0.47	1.89	-0.18	0.36	A PESS should allow me to observe actions and outcomes of other people.
SS2	0.69	3.57***	0.12	0.19	A PESS should allow to compare myself with others.

SS3	0.37	1.33	0.29	0.73	A PESS should allow to create interest groups.
SS4	0.68	3.87***	0.58	1.66	A PESS should show me who and to what extent other people perform sustainable behavior.
SS5	0.48	1.86	0.15	0.34	A PESS should provide an option to facilitate cooperation to reach a common sustainable goal.
SS6	0.95	7.52***	-0.04	0.08	A PESS should provide a game-like competition between the PESS users.
SS7	0.83	5.76***	0.27	0.85	A PESS should give me public recognition about my behavior.
***p ≤ .001, **p ≤ .01, *p ≤ 0.05.					
PTS: Primary Task Support, DS: Dialog Support, SC: System Credibility Support, SS: Social Support L: Loading, W: Weight, t: t-value					

C. Contributions

The final part of this cumulative thesis summarizes the central findings of the three building blocks in Part B. Part C is structured into three chapters. The first chapter (C.I) gives an overview about the findings of the studies conducted respective to their associated building block in Part B. These findings are subsequently synthesized with regard to the fulfillment of the overarching goal of this thesis. In the second chapter (C.II) the implications for theory and practice are outlined based on the respective findings. Part C closes with concluding remarks (C.III) about this research endeavor and recapitulates the process of answering the three research questions with respect to the overarching research goal. Moreover, limitations of this dissertation are presented and an outlook for future research opportunities is provided at the end of this thesis.

I. Findings for User-Centric Environmental Sustainable Information Systems

The findings of this cumulative thesis are summarized in the following three sections according to their respective building block (Status Quo, Theories and Mechanisms, and User Acceptance). This chapter closes with a synthesis of the three building blocks to convey the cohesive nature of the central findings, and to pinpoint the close relationship of the studies presented regarding the overarching goal of this thesis concerning the diffusion of user-centric Green IS in research and practice.

I.1 Findings Regarding the Status Quo

The first chapter of Part B answers the question how information systems contribute to environmental sustainability and what solutions exist to address user-centric approaches of Green IS. This research question is addressed by the first two studies (B.I.1 and B.I.2) of the first building block regarding the status quo of user-centric Green IS research. Study 1 takes on this research question from a scientific perspective by performing a literature analysis on how Green IS are utilized in the smart city context. As mentioned in section A.I.5 (Anticipated Contributions) cities and their citizens have a major share on environmental degradation (Lövehagen and Bondesson 2013). Moreover, smart city research constitutes a growing research field in the IS community regardless of the specific focus, i.e., Green IS. Therefore, it is reasonable to investigate this application area for Green IS in a first attempt to take Green IS research outside the organizational boundaries (vom Brocke et al. 2013b). The second study (2) of this building block explores the availability of mobile applications supporting people in improving their pro-environmental behavior. Thus, providing a practical perspective on this topic as the study investigates existing Green IS solutions available on the market. Both studies together draw a holistic picture of the status quo of Green IS solutions.

The findings of these first two studies are outlined in the following, starting with the central findings of Study 1. The details of this first study are summarized in Table C-1.

Table C-1: Summarized overview of Study 1

Summary of Study 1	
Title	The State of the Art in Smart City Research – A Literature Analysis on Green IS Solutions to Foster Environmental Sustainability
Main research question	What is the state of the art of Green IS in smart city research within the IS community and how do adjacent research domains address this topic?
Main contribution	Structured overview of the implementation of Green IS practices and solutions in the smart city domain, and the deduction of a research framework to identify and address existing research gaps in this research field.

Study 1 examines the state of the art of research about the use of Green IS in the smart city context. The structured overview of the findings is accomplished by conducting two distinct exhaustive literature reviews. The first literature review covers the contributions of the top eight IS journals[5] and thus highlights the approaches from the IS research perspective. The second review is conducted without any limitation to the research domains and aims to shed light on this topic in IS-foreign research fields. Therefore, this study gives holistic insights in the application of Green IS in the city context irrespective of contextual limitations in terms of research domains.

The study provides a research framework with three dimensions to answer the question how Green IS are currently applied in the smart city context. The three dimensions of the framework are: information systems (IS), environmental sustainability (ES), and cities. The articles identified in course of the literature analysis are classified according to these dimensions in order to characterize *how* (IS dimension) the presented Green IS solutions of these studies aim to contribute to environmental sustainability, *what* (ES dimension) their pro-environmental goals are, and *where* (city dimension) these solutions are applied. Thus, the main findings of this study reflect the three dimensions of the research framework regarding the (1) type of Green IS, the (2) processes and ecological goals the systems aim to support, and the (3) application area where the solutions are applied in terms of the domain (e.g., transportation, energy, etc.) and target group (e.g., private persons or city planners).

The results show that the focus of Green IS solutions in the city context is set on city planners in an attempt to support city officials in their decision-making processes. The two leading types of supportive information systems are Geographical Information Systems (GIS) exclusively considered in the non-IS research context, and Decision Support Systems (DSS) which are almost only given attention to within the IS community. Both systems are predominantly used as city planning tools, e.g., garbage collection planning, public transportation planning, or landside planning. Overall the use of GIS covers more than half of the systems discussed in the articles identified. Moreover, only 20% of all articles lie their focus on solutions that directly address citizens. The discussed user-centric approaches are targeted to help the user to reduce residential energy consumption or support the user in choosing more sustainable mobility alternatives. These systems are predominantly designed in form of feedback systems which directly provide information to the user based on actions performed, e.g., household energy use or CO_2 emission causation in an attempt to trigger behavior change.

Moreover, the findings indicate that the research field of Green IS in the smart city context gains raining importance as two-third of the articles identified have been published within the last four years (2012-2015). However, the low total number of publications also indicates that Green IS research outside the business sector is still limited. The final framework serves as a basis for future research endeavors by providing an overview of existing solutions in terms of their goals and processes, and thus serve as a roadmap and inspiration for both theoretical and practical approaches. Furthermore, the study reveals several research gaps with high potential for future Green IS research, especially concerning user-centric solutions. For example, no mobile applications are covered by any of the studies although such solutions

[5] Senior Scholars' Basket of Journals, Association for Information Systems (2017)

can have great influence on people's behavior due to their pervasive nature and persuasive abilities.

Study 2 addresses the question about the status quo of Green IS solutions from a practical perspective by exploring the market for mobile applications helping to develop people's pro-environmental behavior. This study takes on the findings of Study 1, and particularly addresses the research gap regarding the lack of user-centric Green IS solutions in form of mobile applications. The main research question of the study (see Table C-2) is further subdivided into three parts with distinct foci. First, the study reveals (1) suitable application domains for user-centric mobile Green IS, analogously to the approach in Study 1. However, in contrast to Study 1 the application domains identified in Study 2 are more detailed in terms of the underlying processes supported by the respective application. Second, the study elaborates the (2) role of the applications identified based on the common roles automate, informate, and transformate from the well-established organizational Green IS research context (Chen et al. 2008). This part of the study aims to clarify whether these roles are transferable to the user-centric context, and what the implications are for future development of user-centric Green IS solutions. Third, the study examines the (3) ecological goals pursued by the applications, and how these goals are congruent with the user's individuals goals in terms of motivation for pro-environmental behavior. This helps answering the question if and how existing solutions attempt to satisfy the user's affordances regarding their purpose (Seidel et al. 2013).

Table C-2: Summarized overview of Study 2

Summary of Study 2	
Title	Green by App: The Contribution of Mobile Applications to Environmental Sustainability
Main research question	How do existing mobile applications contribute to environmental sustainability?
Main contribution	Insights about the status quo of existing user oriented solutions on the market with the goal to foster and/or induce pro-environmental behavior change on an individual level, and the analysis of these existing solutions.

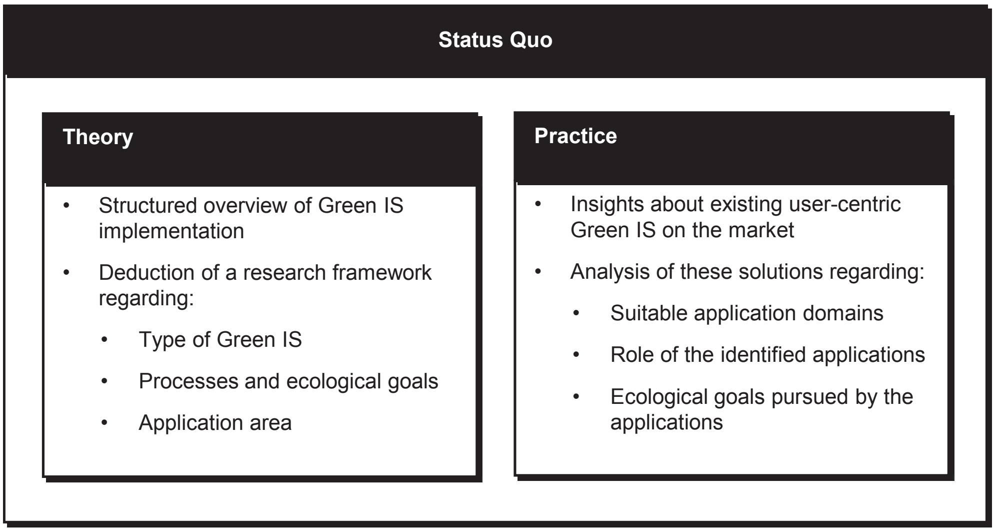
Study 2 examines 262 applications identified as Green IS solutions. The mobile applications are discovered in an exhaustive search of the Google Play Store with the help of 22 keywords. The keywords are derived in course of a text-analysis over 1200 articles on the topic of environmental sustainability throughout different research areas. This list of keywords helps to perform a thorough search process due to a strong specification of the keywords. The mobile applications revealed are then classified regarding their meta-characteristics: domain, role, and goal in order to address the above mentioned three parts of the study.

The results of Study 2 reveal 10 application domains over which the identified mobile applications are distributed, i.e., ecosystem, energy, food, lifestyle, mobility, pollution, recycling, waste, water, and wildlife. Each of these domains is addressed with various functionalities constituting the role of the respective Green IS. The attribution of the roles and functions is based on the three known roles of Green IS from the organizational context: automate, informate, transformate (Chen et al. 2008). The analysis shows that the roles informate and transformate are transferable to the user-centric Green IS context as various applications implement functions to support these roles, e.g., the control of smart household appliances helping to reduce energy consumption, or the access to more sustainable mobility alternatives as entities of the transformate role. In case of the informate role, several applications serve as feedback systems to support self-observation and the effect of personal behavior, e.g., self-monitoring of the personal ecological footprint in terms of CO_2 emissions caused. However, no application could be identified adopting the role of automation. Thus, breaking with the pattern from the organizational context. Moreover, three additional roles for user-centric Green IS could be identified based on the underlying functions of the mobile applications. Furthermore, the roles educate, collaborate, and gamify emerged from the analysis additionally to the predominant roles informate and transformate. Hence, the applications attributed to these novel roles aim to convey ecological behavior through learning applications, encouraging people to work together to achieve ecological goals, and by using gaming elements to motivate pro-environmental behavior or system use.

Finally, the study investigates the application's approach to comply with the user's affordances in terms of goal support. The analysis is performed with the inclusion of the goal framing theory. Thus, the applications identified are examined regarding the developer's attempt to support the normative goal of pro-environmental behavior with the activation of the additional hedonic or gain goal frame. The study shows that only few applications (16; 6%) consider the combination of two or more goal frames to increase the effect of the information system. The most used extension of the normative goal frame is the implementation of the hedonic goal frame in form of gamification elements, e.g., rankings, badges, rewards, etc.

Both studies together provide a holistic overview of the current state of the art of Green IS solutions with a user-centric focus outside the organizational boundaries. Moreover, the findings provide insights and suggestions for future user-centric Green IS solutions along various dimensions. The studies cover and elaborate roles, goals, processes, and suitable application areas for future system development.

Figure C-1: Integrated findings of Studies 1 and 2



I.2 Findings Regarding the Theories and Mechanisms

In the second chapter of Part B the assigned two studies take on the theoretical perspective of pro-environmental behavior change and the identification of suitable behavioral theories and functional mechanisms to support the process of pro-environmental behavior change. In this vein, Study 3 gives an overview about established behavioral theories examined in different research areas in context of pro-environmental behavior change. Furthermore, the study builds upon these theories and deduces potential technical and functional solutions for the implementation within Green IS. Finally, a research agenda for future studies on this topic is provided. A summary of the central research question and findings of Study 3 is illustrated in Table C-3. Study 4 selects a concrete theoretical approach identified in the course of Study 3 and conducts a field study to analyze this theory in a practical setting. The study examines the implementation of the goal framing theory in the context of a sustainable mobility initiative. Participants of the initiative used an information system with various functions supporting the three central goal frames of the theory: normative goals, gain goals, and hedonic goals. Table C-4 provides a summary of Study 4. The findings of both studies in Part B.II are outlined in the following.

As mentioned in the foundations section (Part A) research on user-centric Green IS is very scarce. Moreover, the existing literature is exclusively concerned with single concrete solutions and the analysis of particular elements or outputs of these solutions. However, no study provides a holistic view on the underlying theories and concepts, or attempts to structure existing knowledge for the proper design of user-centric Green IS. Hence, the central output of Study 3 is a framework for the development of user-centric Green IS. The framework constitutes a first attempt to identify and structure existing knowledge in this research field and offers a guideline for future practical and theoretical contributions.

Table C-3: Summarized overview of Study 3

Summary of Study 3	
Title	Towards IS-enabled Sustainable Communities – A Conceptual Framework and Research Agenda
Main research question	What behavioral theories exist and provide a best practice for pro-environmental behavior change and how can these theories be transitioned into Green IS?
Main contribution	Identification of prevailing problems and psychological barriers, possible counter measures, and the potential of information systems to support pro-environmental behavior change by the development of a conceptual framework.

The framework is based on an exhaustive analysis of prevailing theories and mechanisms to explain, predict, and support the complete process of pro-environmental behavior change. In a first step, the article (1) identifies common psychological barriers hindering a person from engaging in pro-environmental behavior change processes as well as personal factors that influence a person's decisions and the execution of the change process. Second, the article presents (2) common theories and influencing factors in the context of pro-environmental behavior change as counter measures to the prior identified barriers. Third, (3) environmental factors required for the implementation of Green IS based on the aforementioned barriers and counter measures are introduced. The structuring of the interaction of these components result in a well-arranged framework helping practitioners and researchers in the design process of future Green IS development, and to plan and conduct future studies in the field of user-centric Green IS. Additionally, the article provides a comprehensive research agenda for future studies based on the introduced components, their interactions, and their underlying concepts.

In Study 4 a field experiment was conducted in order to analyze the effect of the goal framing theory on the motivation of people to use a Green IS in the context of sustainable mobility as well as the effects of the goal frames on the concrete behavior. Three central questions are addressed in this study, helping to understand the effects of a practical implementation of the theory. Initially, it is of interest (1) which combination of the hedonic or gain goal frame with the normative goal frame shows the strongest positive effect. Answering this question will help to design future system and increase their performance (Steg et al. 2012, 2014). Respectively, it is important to (2) identify if users only use functions according to their personal goals, and if these functions are truly in accordance with their perceived functional affordances. These findings take on the explanation of the relationship between perceived functional affordances and actual use behavior, and helps to understand this phenomenon (Pozzi et al. 2014). Lastly, the study analyzes the (3) impact of function usage on the concrete normative goal of the initiative in terms of actual bike usage.

Table C-4: Summarized overview of Study 4

Summary of Study 4	
Title	The Role of Goal Frames Regarding the Impact of Gamified Persuasive Systems on Sustainable Mobility Behavior
Main research question	How does the implementation of the goal framing theory within a Green IS influence the motivational process to engage in pro-environmental behavior?
Main contribution	Function oriented analysis of motivational processes and user experience in the use of persuasive information systems to support environmental sustainable behavior.

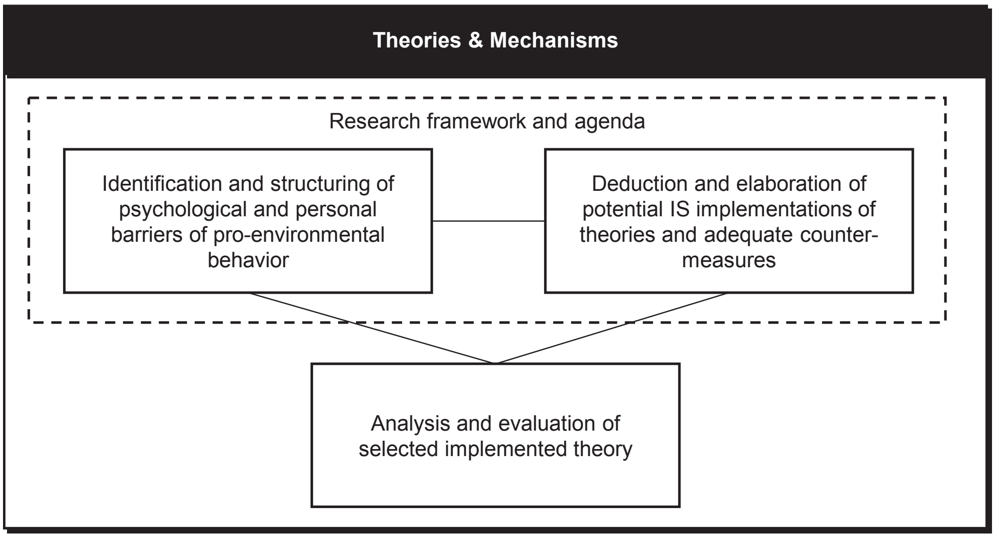
Regarding the first objective of this study the results show that the combination of the hedonic and normative goal frame with the respective implemented function result in the strongest interaction effect. Meaning that users engaging in a game-like competition (hedonic goal frame) and aiming to improve the climate by using the bike instead of the car (normative goal frame) travelled a greater distance by bike than users with any other combination of goal frames. This indicates that the concept of gamification can be an influencing factor for pro-environmental behavior change.

Concerning the second main question of this study regarding the perceived functional affordances of the IS, the data shows mixed results. While the use of functions representing the normative goal frame are as expected, the function usage for the hedonic and gain goal frame vary from the designated purpose of the system designers. This divergence of function usage and the personal goals pursued by the participants indicates an improper design and assignment of concrete functions within the system. This mismatch of the designer's anticipated usage and actual usage by the end-user leads to an impairment of the designer's and therefore the initiative's objectives due to an inadequate relationship between the implemented functions and the user's needs and goals (Blohm and Leimeister 2013; Gabbard et al. 1999). Thus, the study emphasizes the early integration of the end-user in the design and development phase of such persuasive systems. The user-centric characteristics of these systems require a strong involvement of the target group and their specific requirements as well as an elaborated analysis of their functional affordances.

This lack of proper matching between the user's personal goals and the designer's attribution and implementation of the respective functions is further illustrated in course of the third central question of the study. For instance, the ranking list feature implemented to satisfy the hedonic goal frame and its underlying participant's goals led to mixed results. People pursuing the hedonic goal frame and frequently using the ranking list travelled greater distances by bike when following the pivotal hedonic goal of competition. However, when pursuing the hedonic goal self-exploration the participants traveled lower distances. Moreover, gain goal oriented functions also lead to lower distances traveled. In summary, the study shows the importance of matching potential user's goal frames with proper customized functions. This user-centric approach needs to take place in the early stages of the system development process – ideally within the early design phase.

Both studies illustrate the complexity in the field of IS-driven pro-environmental behavior change. There are manifold theories and mechanisms helping to induce and support behavior change processes, however, to date there have only been few attempts to consolidate and structure existing knowledge about the potentials, requirements, and suggestions for the adequate design of user-centric Green IS. This gap is addressed in this part of this cumulative thesis.

Figure C-2: Integrated findings of Studies 3 and 4



I.3 Findings Regarding the User Acceptance

Study 5 in the third chapter of Part B builds upon the findings gained in the preceding two chapters. In this study a virtual user-centric Green IS is designed based on existing theory on pro-environmental behavior change and persuasive system design principles. The main research question in this study is concerned with the acceptance of user-centric Green IS. Hence, the goal of this study is to analyze the influence of appropriate functions to support pro-environmental behavior change processes on the acceptance decision of potential users to adopt such systems. This novel approach in the field of user-centric Green IS research addresses the lack of studies concerned with the identification of design recommendations for real-life use of user-centric Green IS.

Table C-5: Summarized overview of Study 5

Summary of Study 5	
Title	An Acceptance Model for User-Centric Persuasive Environmental Sustainable IS
Main research question	How do persuasive design principles influence the acceptance of user-centric Green IS?
Main contribution	Acceptance analysis of persuasive design principles for the development of user oriented environmental sustainable information systems and the effect on system adoption.

Although some studies about user-centric Green IS already exist (Flüchter and Wortmann 2014; Froehlich et al. 2009; Loock et al. 2013; Tulusan et al. 2012), their focus is always set on either the concrete output of these systems in terms of quantitative measurable metrics about the positive effect on the environment, e.g., amount of CO_2 reduction or resource consumption, or on the effect of single concrete mechanisms or functions, e.g., interface design, gamification features, and others. However, as these studies take place in a controlled environment and the use of the systems by the user is mandatory, these studies give little to no insight about whether the users would also consider using these systems in their private life. Hence, this study aims to shed light on the decision process of system use and what design elements influence the decision making process of user-centric Green IS adoption.

The results of this study indicate that functionalities supporting performance expectancy, social influence, and hedonic motivation have significant influence on the acceptance decision of a user-centric persuasive environmental sustainable system (PESS). Whereas functionalities concerning the effort expectancy (EE) and facilitating conditions (FC) do not influence the user's acceptance of such PESS.

Performance expectancy (PE) describes the expectations of a PESS user that the system is able to positively influence the user's pro-environmental behavior change process. Regarding the influence of persuasive design principles the data shows that functions attributed to primary task support (PTS), dialog support (DS), and social support (SS) have a significant link to performance expectancy. This illustrates that the implementation of functions that break down complex processes into confined simple tasks (PTS), a clear and tailored responsive interface (DS), and the integration of social media features (SS) have a significantly positive influence on the performance expectancy of a user. On the other hand, the credibility of the provided information has only little effect on the user's PE.

Similarly, social influence (SI) has a significant effect on the intention to use a PESS. The construct of social influence characterizes the impact of social factors on the user's decision to use the system. For example, the opinion of others, e.g., friends or family about usage of the system has an effect on an individual's decision making process. Persuasive design principles that allow social interaction within a PESS primarily cover two types of functionalities. The first set of functions enable social interaction via social media components, e.g., sharing personal interests, creating interest groups, or simple options for communication such as chats or instant messaging. The other set of social functions enable the concept of gamification by offering a platform for competition and cooperation. These types of functions allow the user to compare personal performances with others as well as public recognition about the actions performed by the user.

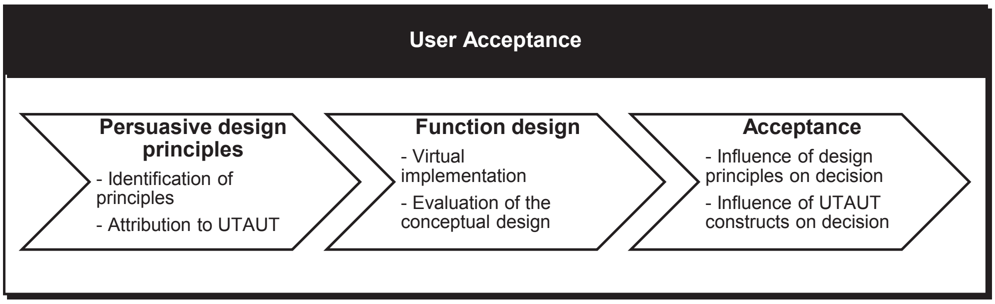
Lastly, hedonic motivation (HM) represents the third construct with significant influence on the system acceptance decision. Hedonic motivation aims to motivate a person to engage in activities which are either generally unsatisfying to the person or to give a final push for engagement in a task where the person inheres a level of uncertainty whether to act or not. Analogous to the construct of social influence gamification plays a key role for hedonic motivation. However, in contrast to SI the playfulness of the implemented functions are essential to the user rather than the social elements the gamification features can provide as well. Additionally, the direct and tailored feedback mechanisms about the personal performance as elements of the dialog support design principles play a key role as a hedonic motivating factor.

Contrary to the above mentioned three constructs with significant influence on the acceptance decision of PESS – the two constructs effort expectancy (EE) and facilitating conditions (FC) show no significant influence on that decision process. Although the data of the study indicates that the participants see high potential that PTS functions have a positive effect on effort expectancy – they do not believe that a PESS could actually reduce the effort necessary to induce pro-environmental behavior change. The same applies for the construct facilitating conditions and the assigned persuasive design principles PTS and DS.

Furthermore, the study contributes to IS acceptance research in general as the combination of persuasive design principles with the Unified Theory of Acceptance and Use of Technology (UTAUT) constitutes a novel approach in this research field. The design and evaluation of this new model paves the path for future acceptance studies with strong focus on the influence of persuasive design principles and system acceptance in various application areas beyond the field of Green IS.

The findings of this final chapter of Part B contribute to the research field of user-centric Green IS in two major areas. First, from the practical perspective, the results of the study in this chapter help designers of such systems to identify and plan the design of future applications. Second, the findings add to the theoretical base of acceptance research for both user-centric Green IS and the design of persuasive information systems in general.

Figure C-3: Integrated findings of Study 5



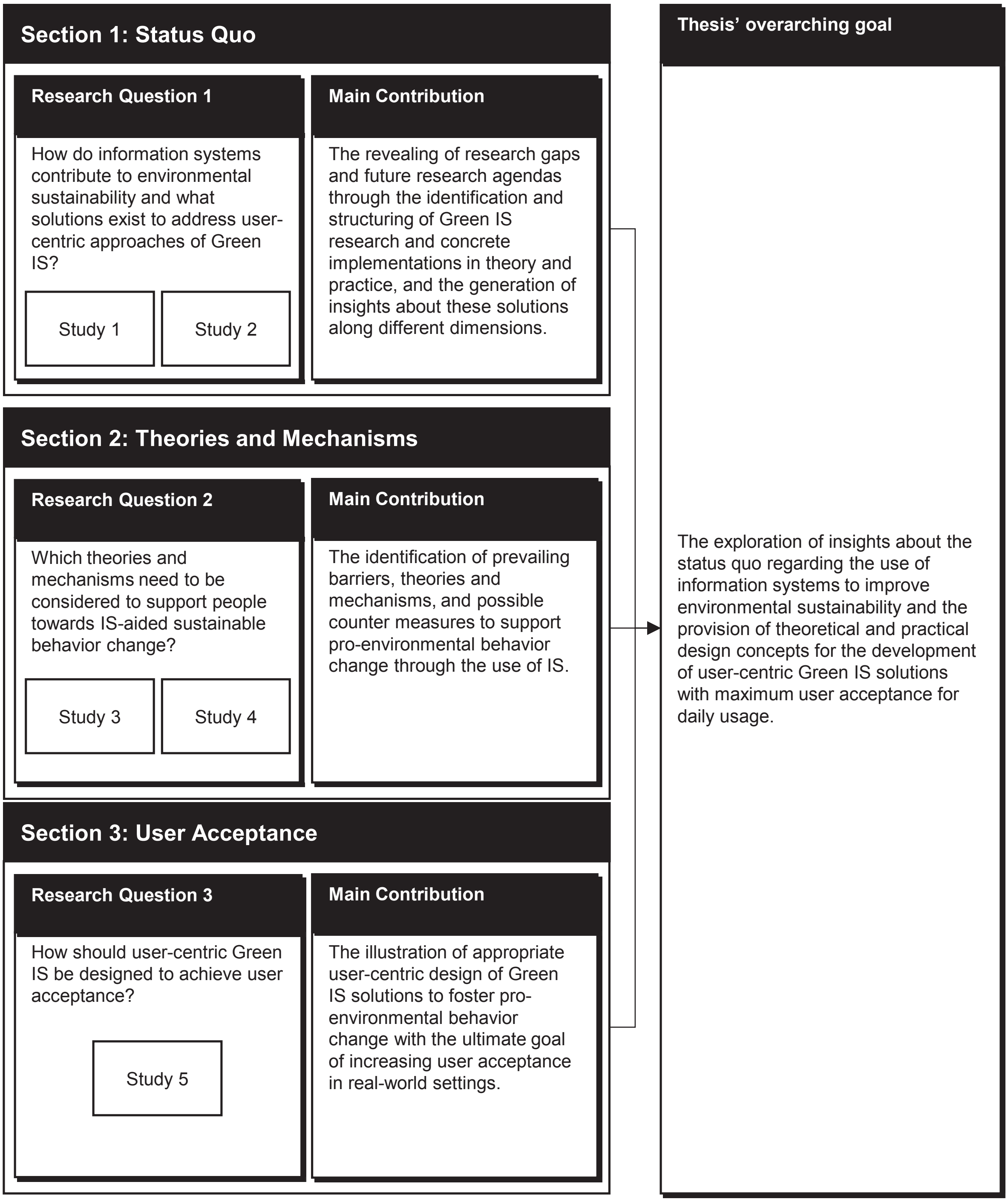
I.4 Synthesis: A Holistic View on User-Centric Environmental Sustainable IS

The main part in this cumulative thesis (Part B) is structured into three distinct building blocks (B.I-B.III) with a total of five studies. Each of the three building blocks with their respective assigned studies aims to answer one specific research question (*RQ1-RQ3*). However, the three individual research questions (see Section A.I.2) collectively contribute to the central goal of this thesis.

First, Chapter B.I gives an overview of the current attempts in theory and practice to approach user-centric Green IS and thus the individual's pro-environmental behavior change processes and practices with the aid of information systems. Second, in Chapter B.II a deep dive into individual's psychological and personal barriers preventing people's engagement in pro-environmental behavior change processes is performed. Furthermore, common theories and mechanisms are identified and examined upon their adequacy for potential implementation within user-centric Green IS. Lastly, the third section of Part B is concerned with the user's acceptance of such implemented user-centric Green IS (B.III). This building block sheds light on the concrete design of such systems in terms of suitable design principles, and analyzes their impact on the acceptance decision of user-centric Green IS. The main contributions of each chapter (B.I-B.III) as well as their contribution to the overarching goal of this cumulative thesis is illustrated in Figure C-4 below.

The versatility of the topics of the three building blocks allows to draw a comprehensive picture of the overarching scheme of user-centric Green IS in the Green IS research domain. This thesis aims to follow a thorough and structured approach to reflect the peculiarity and the state of Green IS research with focus on the individual and behavior change processes with the support of information technology. Thus, only the integration of the three perspectives examined enables a comprehensive and coherent disquisition of the topic.

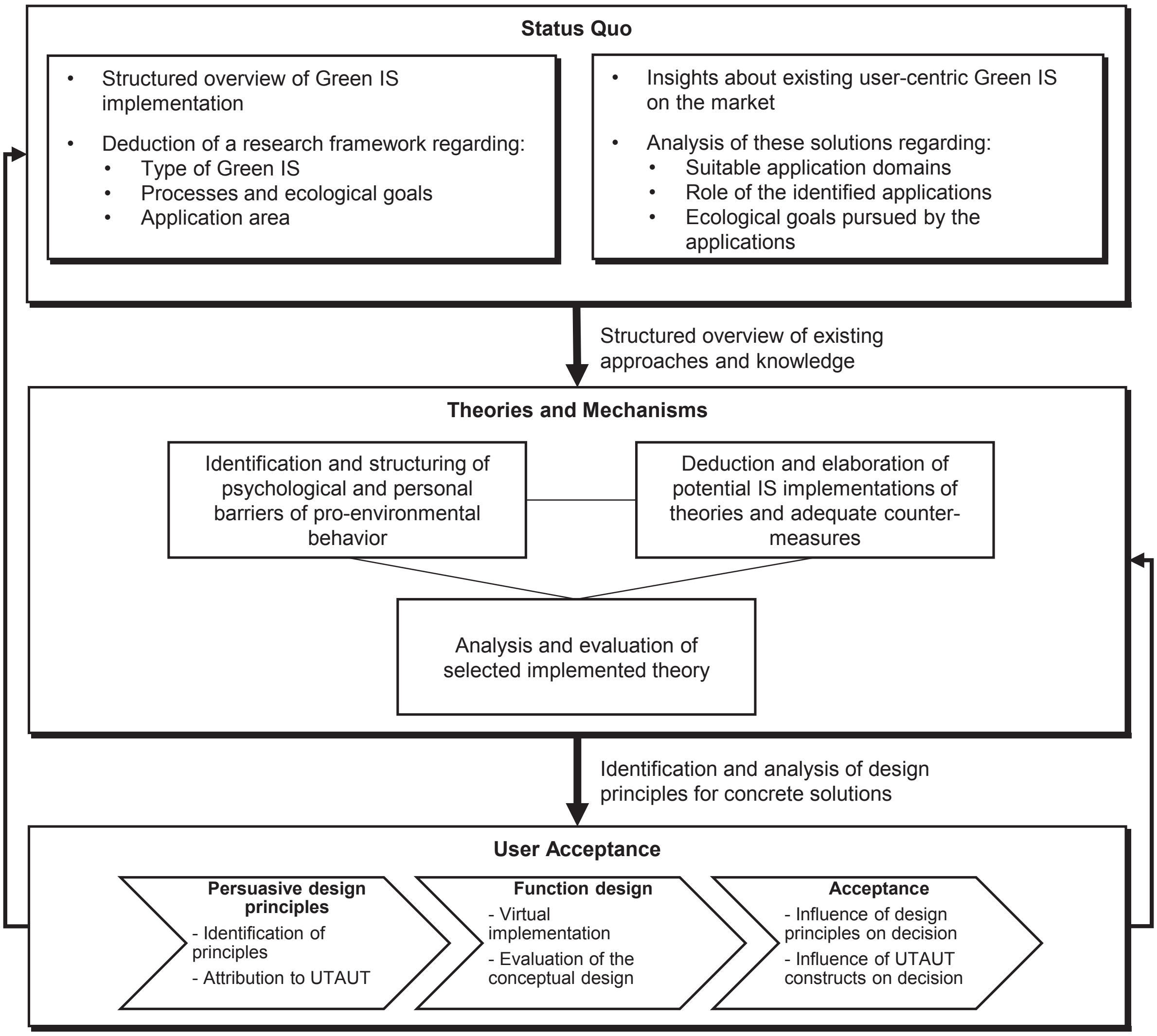
Figure C-4: Integrated contributions of all studies included in Part B



The overall findings of this cumulative thesis result in a comprehensive research framework to support future research approaches in the field of user-centric Green IS. The analysis of the status quo in research and practice yields an extensive overview of existing approaches and solutions in this field and reveals prevailing research gaps. This structured overview helps to build the basis for further deeper examination of prevailing theories and mechanisms with the potential of supporting IS driven pro-environmental behavior change practices. The cumulative results of both consecutive research approaches result in a theoretical proposition for the proper design for practical implementation of user-centric Green IS.

Moreover, the results of the ultimate building block add new knowledge to each preceding building block (Figure C-5).

Figure C-5: Integrated research framework of all studies in Part B



II. Implications

In this section the findings of this cumulative thesis are discussed regarding their theoretical and practical implications for the respective audience. On the one hand, the findings of this thesis are of great interest and potential for other researchers in the field of Green IS research but also to adjacent areas such as persuasive system design, IS user acceptance, and Green IS in general. On the other hand, this work also holds promising implications for practitioners. Primarily, the findings of this thesis help system designers and administrators to plan and design IS-driven pro-environmental initiatives. Furthermore, the findings derive implications for successful persuasive system design in terms of increased user acceptance. The implications for theory and practice are outlined in the following.

II.1 Implications for Research

This thesis answers the call of the IS community for further research in the field of Green IS (vom Brocke et al. 2013b). The potential of information systems as impactful contributors to the improvement of environmental sustainability is widely seconded among IS researchers (Boudreau et al. 2008; vom Brocke et al. 2013b; Chen et al. 2008; Dedrick 2010; Melville 2010). However, research on this matter is still underrepresented in the IS domain, and existing research only covers a fraction of potential and promising research streams. Besides the well-covered examination of Green IS in the organizational context studies about the use of Green IS outside the organizational boundaries are rare (El Idrissi and Corbett 2016). Only few studies with different application areas exist. However, upcoming research domains regarding the pervasiveness of IS, e.g., in smart cities or the internet of things (IoT) opened new perspectives for the use of IS in the everyday life of organizations but also for people. The pervasiveness and persuasive capabilities of information technology gradually intrudes people's lives and influences their behavior in many areas, e.g., health, education, budgeting, and more. These persuasive capabilities are also prospect for adjustment of daily behaviors towards increased pro-environmental attitudes. However, the link between personal behavior and the supportive use of information systems is scarcely investigated in IS research. Hence, this cumulative dissertation aims to address this lack of research by closing the gap between the promising use of information technology for environmental improvements and its adequacy and need for customized tailoring of these systems to appropriately support pro-environmental behavior change processes of individuals. The major theoretical implications of this cumulative thesis are outlined in the following and summarized in Table C-6.

Given that the research field of user-centric Green IS poses a novel area in information system research, this thesis foremost provides a comprehensive and structured overview of current theoretical and practical approaches in this area. The findings of this thesis allow Green IS and other environmental researches to gain insights about the status quo of user-centric Green IS research and also offers an agenda for future research endeavors. Hence, the call for more Green IS research (vom Brocke et al. 2013b) is answered by the provision of an extensive foundation for future studies with focus on individuals and their adaption of information systems for the improvement of environmental sustainability. The studies conducted demonstrate that there are versatile application areas outside the organizational context where the implementation and use of Green IS can lead to great environmental benefits. However, the studies also show that existing approaches do not unfold their full potential due to several reasons, e.g., the limited awareness of such solutions by the potential users or the improper design of Green IS artifacts and IS-driven initiatives.

Moreover, this thesis takes a deep dive into the theory behind pro-environmental behavior change processes and their link to Green IS design patterns and strategy. Prior studies already outline the complexity of human behavior change (Michie et al. 2013) and also in the particular case of pro-environmental behavior change (Gifford 2011). However, the studies in this thesis particularly take on the intertwinement of common general and pro-environmental behavior change theories and existing barriers with information systems. In the course of this, the thesis offers a framework for the integration and implementation of user-centric Green IS solutions based on the foundation of existing theories and mechanisms to influence people's behaviors. Particularly the practical implementation of motivational processes is examined in this thesis. Thus, providing insights into the effect and adequate design and implementation of motivational mechanisms in context of behavior change processes. The findings of the included studies not only contribute to the identification and transformation of theories and mechanisms in the Green IS context but also contributes to different adjacent research domains and fields with focus on human behavior and the integration of information technologies and systems with people, e.g., HCI or UX.

The aggregation of the studies and their findings on general Green IS approaches, and the immersion into pro-environmental behavior change theories, mechanisms, and processes offers insights into the characteristics and peculiarities of user-centric Green IS design and application. Thus, the findings presented in this cumulative thesis provide ground for the deduction, evaluation, and assessment of future theories and models to plan, organize, design, build, and measure innovative user-centric Green IS solutions. Moreover, the studies suggest and evaluate concrete design patterns and mechanisms for the instantiation of the presented integration of theoretical approaches into substantial Green IS with strong focus on individual's behavior change.

Furthermore, the thesis builds upon the above mentioned findings, contributions, and implications of the status quo and the deduction and analysis of theories and mechanisms for successful Green IS design. In a next step, the thesis takes on the design perspective from a different angle. While the above presented and discussed implications are concerned with the design and implementation of user-centric Green IS, here, the implications are concerned with the acceptance of potential users to adopt such implemented artifacts. Thus, this thesis offers a theoretical model to examine and evaluate persuasive design patterns for the creation of user-centric Green IS with regards to the acceptance and adoption decision of such systems by the end-user. The presented model not only contributes to the concrete research field of user-centric Green IS but also helps researchers in the area of persuasive system design in general to evaluate artifacts regarding the influence of variable persuasive design principles on the acceptance and adoption decision of users.

Table C-6: Major theoretical implications

Implication	Explanation
(1) Offering a holistic view on Green IS research outside the organizational context, and the identification of associated research gaps.	The identification and structuring of existing knowledge from the scientific perspective, and the analysis of existing practical implementations helps other researchers to design and conduct future studies in the novel field of user-centric Green IS research.
(2) Contributing to the understanding of challenges of pro-environmental behavior change processes and the deduction of suitable concepts as foundation for practical implementations and the extension of the theoretical basis for pro-environmental behavior change.	The identification and analysis of behavioral theories, existing behavioral barriers, and the entanglement with information technologies sheds light on the prevailing problems and potentials of user-centric Green IS implementations. The studies conducted and their findings create the basis for comprehensive future studies on this topic.
(3) Offering insights about existing user-centric Green IS solutions and future design prospects.	The assessment of behavioral theories, technical mechanisms, and the combination of both perspectives lead to a structured foundation for the theoretical and practical design of future artifacts. Future studies can build upon the theoretical framework for the design of user-centric Green IS.
(4) Offering insights on the acceptance decision of users regarding the use of Green IS solutions for behavioral change.	The analysis of the influence of concrete persuasive design principles on the acceptance and adoption decision for the user of user-centric Green IS allow a more accurate design of solutions in terms of user acceptance in a real-life setting. This applies for Green IS as well as for other domains with the use of persuasive systems.

II.2 Implications for Practice

In addition to the above discussed theoretical implications and the thesis' contribution to the user-centric Green IS, persuasive system design, and IS user acceptance research base, this thesis also offers substantial implications for practitioners in the realm of environmental improvements and IS design. As discussed above, the diffusion of Green IS solutions in the daily-life environment is very low. Thus, little is known about the practical use of such artifacts. Hence, besides the provision of theoretical implications, this thesis also aims to address this gap by outlining crucial implications for practitioners. These practical implications are presented in detail in the following, and summarized in Table C-7 below.

Alongside the theoretical contributions for proper application design in terms of the consideration of suitable theories and mechanisms, this thesis also offers elaborated suggestions for practical implementation of user-centric Green IS. Foremost, the focus of this thesis is set on the dissemination of Green IS practices outside the organizational boundaries. As mentioned above, Green IS research is primarily situated in the organizational context (Dedrick 2010; Hilty et al. 2011; Melville 2010). Thus, findings and implications of these studies are not one-to-one transferable to the daily life of people. For instance, application areas such as dietary, waste management, or life-style require different processes, e.g., motivational and technical, than other everyday-life situations such as mobility or energy management. The latter two are similar to what can be done in the work-environment and thus can capitalize on the findings from existing Green IS research taking place in the organizational context. However, when taking things outside the workplace, as for the particular exemplary cases in the above mentioned three application areas: dietary, waste management, and life-style, different processes are needed. Study 2 shows that the prevailing processes in the Green IS research domain (Chen et al. 2008) do not fit the requirements for user-centric solutions outside the organizational context. In course of this study more suitable processes are identified. These identified processes help practitioners to tailor the application design to the potential users and also the respective application area. Thus, leading to an increased efficiency of the applications developed in terms of the outcome, i.e., improved pro-environmental behavior by the people, and the acceptance and intention to use these applications in their daily life.

The contribution to the understanding of the user's acceptance of user-centric Green IS represents another crucial implication for practice. The majority of studies in Green IS research are concerned with the use of applications to influence or improve people's environmental behaviors, and primarily focus on the concrete outcome or the effect of particular implemented mechanisms. These studies are great contributions to the Green IS research domain in terms of their particular focus, e.g., the outcome or the evaluation of certain specific mechanisms. However, as these studies take place in controlled environments with a compulsory use of the applications examined, these studies cannot exhibit whether the test-subjects would also consider to use these applications in their daily life routine. Neither do system developers get insights on the workings and influence of certain design elements on this circumstances. Study 5 explicitly takes on this gap, and highlights the interaction of concrete design principles on the acceptance decision of potential users. Moreover, the study considers the implementation of persuasive design elements into behavioral changing information systems. Although research on the use of IS with the goal to influence behavior is not completely novel – the contemplation, implementation, and examination of concrete deduced persuasive design elements constitutes a young and up-coming domain in IS research (Langrial 2014).

In conclusion, the major practical implications of this cumulative thesis lie in its contribution to the guidance of system designers and developers in creating persuasive Green IS with the goal to influence people's behavior with particular focus on pro-environmental behavior. However, other application areas can also benefit from the findings presented, i.e., the health sector. The guideline provided covers infrastructural planning in terms of creating service platforms for pro-environmental user-centric Green IS, the identification and evaluation of proper processes and their technical implementation, and the suggestion of proper application design to increase user acceptance. The most substantial practical contribution, however, accords to raising awareness about the potential of user-centric Green IS to improve environmental sustainability. This thesis aims to convey this stance by convincing people to understand how IS can effectively contribute to achieve global ecological goals, and support environmental campaigners to utilize the potential of todays and future IS capabilities.

Table C-7: Major practical implications

Implication	Explanation
(1) Offering insights about potential application areas for Green IS solutions outside the organizational context.	The identification and discussion of possible application areas for user-centric Green IS outside the organizational boundaries helps application designers, and agents of pro-environmental campaigns to consider IS aided solutions for the improvements of ecological goals.
(2) Contributing to the understanding of the potential of user-centric Green IS solutions and the deduction of appropriate design concepts.	The analysis of application domains, behavioral theories, behavior change processes, and IS-based mechanisms and design principal facilitate the proper design of user-centric Green IS, especially regarding the tailoring of solutions to increase user acceptance.
(3) Raising awareness about the potential of user-centric Green IS on the global ecology.	The thesis aims to convey the potential of Green IS solutions with strong focus on individual's behaviors. This dissertation aims to raise awareness about the consequences of people's behaviors on the environment and how IS can contribute to ameliorate the aftermath of these behaviors.

III. Concluding Remarks

The goal of this cumulative thesis is the provision of insights regarding the use of information systems to induce pro-environmental behavior change. Hereby, the findings contribute to the improvement of the prevailing global ecological challenges and support the striving to ameliorate these problems. In order to achieve this overarching goal, the thesis is structured into three distinct building blocks (Chapter B.I-B.III) with three respective research questions (RQ1-RQ3). This subdivision helps to reduce the complexity of this topic and simplify the process of following the content of this work. The sequence of the research questions poses a successive approach to the topic and contributes to the understanding of this cumulative thesis.

In the first chapter of Part B (B.I Status Quo) the thesis aims to convey the status quo of user-centric Green IS (RQ1) from two perspectives. First, this section answers the question from the scientific angle by reviewing existing literature on the topic of IS as a contributor to environmental sustainability. The second part focuses on how information systems already approach pro-environmental behavior change of individuals. The findings of this first building block shows that only little research is concerned with the utilization of information systems to induce pro-environmental behavior change of individuals. Most studies conducted in the area of Green IS research focus on the utilization of information systems in the organizational context, e.g., supply chain management or clean production (Boudreau et al. 2008; Kurnia and Gloet 2012). From the practical perspective the thesis reveals that some applications which can be considered as user-centric Green IS already exist. However, these solutions are rarely recognized or lack proper design in terms of effectiveness or user acceptance. The findings of this first building block pave the way for future Green IS researchers to elaborate on this young research field. Moreover, the findings support system designers and developers, and environmental campaigners to utilize the capabilities of modern information technologies to solve ecological issues.

The second chapter of Part B (B.II Theories and Mechanisms) intertwines behavioral theories and the capabilities of information systems to construct effective user-centric Green IS. The goal of this second building block is the identification and especially the structuring of known behavioral theories, psychological barriers, and respective counter-measures relevant for successful pro-environmental behavior change initiatives. Particular focus is set on the workings of motivational processes and mechanisms supporting an individual in the engagement of pro-environmental behavior with the aid of information systems. Hence, this chapter of Part B addresses the overarching question which theories and mechanisms have to be considered for the design and development of user-centric Green IS (RQ2). The findings of this building block assists Green IS researchers and system designers in the design phase of the user-centric Green IS development process by suggesting a set of theories and mechanisms for concrete implementation.

Finally, the third chapter of Part B is concerned with the acceptance (B.III) of user-centric Green IS solutions. While the second chapter (B.II) focuses on the concrete processes of pro-environmental behavior change in terms of working mechanisms and their effectiveness for behavioral persuasion – the third chapter (B.III) takes on the acceptance of the user-centric Green IS. Thus, this building block is concerned with the question how these systems need to be designed so that people would consider using them in their daily life (RQ3). The findings indicate that certain implemented design principles have a stronger effect on the positive acceptance decision of user-centric Green IS than others. Hence, this building block contributes to the design and development process of such systems regarding the increase of the likelihood of system adoption. Moreover, this chapter contributes to the design of persuasive systems with the goal of behavioral change in general. Meaning, that the findings are also transferable to other application areas, e.g., the health or education sector.

In summary, this cumulative thesis follows a holistic approach on the topic of user-centric Green IS, and sheds light on a young but not less important research stream inside the Green IS research domain. This thesis aims to build a foundation for upcoming studies on this matter and shall help to guide researches and practitioners in the process of contributing to the improvement of our ecological environment.

III.1 Limitations

Besides the aforementioned theoretical and practical implications, this thesis also yields some crucial limitations which need to be considered. Foremost, it is essential to emphasize that the holistic research approach of this cumulative thesis only scratches the surface of the three presented building blocks of Part B. This entails that every chapter (B.I-B.III) is subject for further profound examination. The major prevailing limitations of the respective studies conducted in Part B and the cohesiveness of the central findings of this cumulative thesis are presented in the following.

With the first building block this thesis gives an overview of the status quo of user-centric Green IS from the research and practical perspective. However, the data presented, results, and implications is based on two studies conducted. Study 1 provides an overview about the state of research of Green IS outside the organizational context. However, two important restrictions take place. First, the focus of the study is set on Green IS applied or discussed in the smart city context. This constrained search process omits other possibly available articles on user-centric Green IS that are not attributed to the smart city domain. Second, the search for articles in the IS research domain is limited to top journals and conferences. Hence, additional relevant articles from other outlets can be overseen. Furthermore, from the practical perspective the search for existing user-centric Green IS (Study 2) is limited to the available applications of the Google Play Store. Other practical implementations, e.g., on other platforms such as the Apple App Store, or solutions used within possible existing ecological campaigns are not considered in this thesis.

The second building block of this cumulative thesis covers the identification of behavioral theories, psychological barriers for behavior change, and technological mechanisms helping to overcome prevailing issues of individuals during the behavior change process. Because behavior change is generally a very complex research area (Michie et al. 2013) not every theory could be considered. This thesis primarily considers theories which have been applied in either the larger corpus of IS literature and literature from other research areas with focus on pro-environmental behavior change (Study 3). The same applies for the presented technological mechanism. Thus, other theories and mechanisms that might be useful are not considered in this work. Moreover, the resulting theoretical framework for the design of user-centric Green IS based initiatives relies on these findings and is therefore uncomplete. Furthermore, the framework has not been applied to practice yet in order to verify its eligibility. Additionally, in Study 4 only one single theory for the motivation of user-centric Green IS is thoroughly examined within an extensive field study. The field study also only observes and analyzes system usage in a short-term timeframe. Hence, Long-term data and implications are not collected and examined. Moreover, the Green IS used in this study is an existing third-party application and the author of this thesis could not influence the system design or the sample composition.

Finally, the acceptance of user-centric Green IS constitutes the central research focus of the third and last building block. Study 5 yields two major limitations which need to be mentioned. The designed and analyzed user-centric Green IS artifact is of virtual nature. This means that the participants of the study evaluated a theoretical application based on comprehensible descriptions. No software is developed or used on real devices. Hence, no short- or long-term evaluation is performed with the described Green IS. Moreover, the derivation of the constructed functionalities of the Green IS grounds on the findings of the prior studies in this cumulative thesis. Therefore, prevailing limitations of these works also affect the execution and findings of this final study.

In conclusion, the studies conducted in this thesis offer a multitude of useful theoretical and practical implications for future endeavors on user-centric Green IS in research and practice. However, the findings of this thesis need to be viewed with caution due to the prevailing limitations of this work. Nevertheless, the findings and limitations create ground for more research on this interesting and important topic. The following section suggest prospect future research opportunities inspired by the findings and limitations of this thesis.

III.2 Further Research Opportunities

The overarching goal of this cumulative thesis is to create ground for future research endeavors on user-centric Green IS. This thesis is composed of three distinct building blocks in order to address important areas in the context of user-centric Green IS. As mentioned in the preceding section (C.III.1 Limitations) this approach yields some limitations besides its broad contributions to the topic. However, the findings presented and the prevailing limitations of this work offer great opportunities for further research projects in this young research domain. An outlook for future research opportunities on user-centric Green IS is given in the following.

The first building block of Part B (B.I Status Quo) indicates that there are various potential application areas where the support of people with Green IS solution can greatly contribute to the improvement of individual’s pro-environmental behavior. Future studies should focus on single particular application areas and derive required processes and particular demands regarding concrete design principles for system development. Accordingly, the thesis shows that there are already user-centric Green IS available. Future studies should analyze these existing solutions in detail in order to gain deeper insights in the pros and cons of these solutions. These findings can greatly contribute to theory and practice in form of theoretical frameworks for system design and development.

In the second building block this thesis takes on theories and mechanisms (B.II) that are important to trigger and support pro-environmental behavior change with the aid of information systems. The framework provided serves as a foundation for future theoretical and practical research projects. First, research should focus on single IS-aided implementations of theories and mechanisms, and analyze the concrete impact on pro-environmental behavior change processes. In a next step, the combination and interaction effects of these distinct implementations should be examined and evaluated. This also includes the effect of single design principles such as feedback mechanisms, social media integration, or other approaches presented in this thesis. This particularly pertains the compliance with people’s personal affordances regarding system usage (Seidel et al. 2013). Special attention should be set on motivational theories and mechanisms as well as the use of incentives to increase and improve the engagement of systems use in the context of pro-environmental behavior change. Second, future studies should use the framework provided for practical implementations of user-centric Green IS, and particularly consider the implementation and examination of service platforms. The utilization of service platforms enables additional benefits, e.g., business integration, and therefore the opportunity to develop business models for service provision by business partners.

Finally, the thesis encourages the implementation and analysis of concrete user-centric Green IS artifacts with regards to the examination of theories and mechanisms, as mentioned above, but especially to the analysis of user acceptance. In this thesis the analysis of user acceptance is performed on the basis of a virtual artifact (B.III User Acceptance). Future studies should implement systems based on this findings and conduct short- and long-term analysis on the effect of the deducted design principles in this thesis. Moreover, the design of the virtual artifact used in Study 5 bases on a set of persuasive design principles derived by Oinas-Kukkonen and Harjumaa (2009). Thus, other promising design principles should be derived, evaluated, and implemented in future studies.

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Appendix

Appendix A. Overview of the authors' contribution in the studies included in this thesis

No.	Section	Title	Authors	Authors' contribution
1	B.I	The State of the Art in Smart City Research – A Literature Analysis on Green IS Solutions to Foster Environmental Sustainability	**Benjamin Brauer**	**80**
			Matthias Eisel	15
			Lutz M. Kolbe	5
2	B.I	Green by App: The Contribution of Mobile Applications to Environmental Sustainability	**Benjamin Brauer**	**55**
			Carolin Ebermann	30
			Björn Hildebrandt	5
			Gerrit Remané	5
			Lutz M. Kolbe	5
3	B.II	Towards IS-enabled Sustainable Communities – A Conceptual Framework and Research Agenda	**Benjamin Brauer**	**95**
			Lutz M. Kolbe	5
4	B.II	The Role of Goal Frames Regarding the Impact of Gamified Persuasive Systems on Sustainable Mobility Behavior	Carolin Ebermann	60
			Benjamin Brauer	**40**
5	B.III	An Acceptance Model for User-Centric Persuasive Environmental Sustainable IS	**Benjamin Brauer**	**60**
			Carolin Ebermann	35
			Lutz M. Kolbe	5

Appendix B. Overview of the authors' published double blind reviewed articles as of December 2017

Authors and Publication	**Ranking**
Peer-reviewed conferences	
Ebermann, C.; Brauer, B.; Brendel, A. B.; Kolbe, L. (2017): Decoding the Motivational Black Box – The Case of Ranking, Self-Efficacy, and Subliminal Priming, Proceedings of European Conference on Information Systems (ECIS), Portugal.	B
Brauer, B.; Ebermann, C.; Kolbe, L.M. (2016): An Acceptance Model for User-Centric Persuasive Environmental Sustainable IS, 37th International Conference on Information Systems (ICIS). Dublin 2016.	A
Hildebrandt, B.; Remane, G.; Brauer, B.; Kolbe, L.M (2016): Facilitating E-Mobility Through Digital Technologies – Development and Evaluation of a Dynamic Battery-Leasing Business Model, 20th Pacific Asia Conference on Information Systems (PACIS). Chiayi, Taiwan.	C
Brauer, B.; Ebermann, C.; Hildebrandt, B.; Remané, G.; Kolbe, L. M. (2016): Green by App: The Contribution of Mobile Applications to Environmental Sustainability, 20th Pacific Asia Conference on Information Systems (PACIS). Taiwan.	C
Brauer, B.; Kolbe, L. M. (2016): Towards IS-enabled Sustainable Communities – A Conceptual Framework and Research Agenda, 22nd Americas Conference on Information Systems (AMCIS). San Diego.	D
Brendel, A. B.; Brauer, B.; Hildebrandt, B. (2016): Towards User-Based Relocation Information Systems in Station-Based One-Way Car Sharing, 22nd Americas Conference on Information Systems (AMCIS). San Diego.	D
Ebermann, C.; Brauer, B. (2016): The Role of Goal Frames Regarding the Impact of Gamified Persuasive Systems on Sustainable Mobility Behavior, 24th European Conference on Information Systems (ECIS). Istanbul.	B
Ebermann, C.; Piccinini, E.; Brauer, B.; Busse, S.; Kolbe, L. M. (2016): The Impact of Gamification-Induced Emotions on In-Car IS Adoption – The Difference between Digital Natives and Digital Immigrants. In: Hawaii International Conference on System Sciences (HICSS). Kauai.	C
Hanelt, A.; Hildebrandt, B.; Brauer, B.; Kolbe, L. M. (2015): Towards Sustainable Mobility – Digital Eco-Systems as Drivers of Disruptive Change, in: China Media Research, Vol. 11, No. 4, pp. 53-63.	n. a.
Brauer, B.; Eisel, M.; Kolbe, L. M. (2015): The State of the Art in Smart City Research – A Literature Analysis on Green IS Solutions to Foster Environmental Sustainability, 19th Pacific Asia Conference on Information Systems (PACIS). Singapore.	C
Hanelt, A.; Nastjuk, I.; Krüp, H.; Eisel, M.; Ebermann, C.; Brauer, B.; Piccinini, E.; Hildebrandt, B.; Kolbe, L. M. (2015): Disruption on the Way – The Role of Mobile Applications for Electric Vehicle Diffusion, Wirtschaftsinformatik Proceedings (WI), Osnabrück, Germany.	C

The study ranking was assessed according to VHB Jourqual 3.

Curriculum Vitae

Personal Details

Name	Brauer, Benjamin
Date of Birth	July 10th 1983
Place of Birth	Göttingen, Germany
Nationality	German

Academic Career

Since 2014	Research Associate, Chair of Information Management, University of Göttingen, Germany
2010 – 2013	Master of Science (M. Sc.) in Business Information Systems, University of Göttingen, Germany
2005 – 2010	Bachelor of Science (B. Sc.) in Business Information Systems, University of Göttingen, Germany

Relevant Working Experience

Since 2014	Freelance Consultant at Business Engineering Institute (BEI), St. Gallen, Switzerland
Since 2013	Research Associate, Chair of Information Management, University of Göttingen, Germany
2012 – 2013	Student Assistant, Mathematical Institute, University of Göttingen, Germany
2012 – 2013	Student Assistant, E-Assistants-Program, University of Göttingen, Germany
2010 – 2012	Student Assistant, Courant Research Centre “Higher Order Structures in Mathematics”, University of Göttingen, Germany
2007 – 2013	Student Assistant, Chair of Information Management, University of Göttingen, Germany

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