GREEN BY APP: THE CONTRIBUTION OF MOBILE APPLICATIONS TO ENVIRONMENTAL SUSTAINABILITY

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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 CO_2 *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, Loos, et al. 2013), 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, Loos, et al. 2013; 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 1, displaying the total occurrences of each keyword. An asterisk indicates the primary keyword in the combination in terms of the number of occurrences.

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

Table 1. Keyword list refining environmental sustainability.

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 1. 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 2 and Table 4), 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 1. 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 2.

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 2 and attributed to the respective roles and application domain.

Thus, the analysis of the Google Play store revealed 10 domains (Table 2, 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 4).

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 3). 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.

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	• **gamify** (*fuel efficiency competition, learning game to save fuel, CO_2 production competition*)

(45)	• **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)*

Table 2. Categorization of green apps with the underlying processes and functions.

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 3 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.

	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

Table 3. Average user ratings and mean installation numbers based on the underlying IS role.

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 4). 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 4).

Normative Goal	Goal Frame Activated	Compatibility Approach
animal protection	hedonic	donations
carbon footprint reduction	hedonic	collecting points, (team) rankings, donations
	gain	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	awards, rewards
	gain	saving energy costs
resource efficiency	hedonic	rankings and levels, badges and points, donations
	gain	saving money (fuel, energy)
resource protection	–	–

Table 4. Sustainability goals and interaction of goal frames.

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 2) 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.

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