When information systems address environmental sustainability challenges: The role of immersive technologies[1]

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Abstract:

As the world becomes increasingly interconnected, smart city movements bring together infrastructure and technology to improve citizens' quality of life, easing their interactions with the urban environment. However, although seen as a part of their missions, current smart city practices partly fail to achieve environmental sustainability. In this context, the Information Systems (IS) community is expected to demonstrate the applicability of technological and empirical solutions for triggering pro-environmental behaviors and improving environmental policies. One of the important roles of technology is to simplify and demonstrate the complex, often temporally and spatially distant environmental information, to increase their relevance and seriousness. Recent attention has been brought to immersive technologies, such as Augmented Reality (AR) and Virtual Reality (VR): by providing realistic virtual simulations of environmental threats, these tools could serve as Green IS for raising individuals' environmental engagement. We conducted a systematic literature survey covering Green IS and immersive technologies in the IS literature. Our results indicate that the field is still young, as there is a lack of AR/VR research for environmental sustainability in the leading IS journals. This paper aims to pave the way for IS community towards increased recognition of the potential use of AR/VR for improving environmental policies in smart cities. We provide theoretical arguments, built on the insights from behavioral literature, for the use of immersive technologies for environmental policy evaluation and implementation.

Keywords: Green IS, pro-environmental behavior, Augmented Reality (AR), Virtual Reality (VR), smart city policy

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1.Introduction

Cities are elements of huge global importance, not only for social and economic activities but also for their – mostly negative – environmental impact. Activities such as pollution and overexploitation of natural resources could lead to serious and irreversible consequences for humankind, wildlife, economies, and ecosystems all over the world (IPCC, 2014; Stern, 2007). Although a movement towards "smarter" cities promises sustainability outcomes, cities often fail to achieve this goal (Yigitcanlar et al., 2019). Therefore, there is a need for an effective smart city policy tool that would boost its citizens' pro-environmental behavior.

The Information Systems (IS) community is expected to respond to these global challenges by demonstrating the applicability of technological solutions for environmental sustainability (Elliot & Webster, 2017). Information systems, especially built with insights from behavioral economics, have the potential to influence fundamental behavioral and practical changes and impact decision-making (UNFCCC, 2016; Goes, 2013; Corbett & Mellouli, 2017).

This paper proposes the use of immersive technologies, such as Virtual Reality (VR) and Augmented Reality (AR) for improving the implementation of environmental policies in smart cities. Namely, direct experiences of environmental threats, such as floods or fire, are likely to enhance citizens' perception of risk and engagement around environmental issues (Akerlof et al., 2013; van der Linden et al., 2015). Since such experiences are complicated to provide in real settings, researchers have discovered that an alternative method – immersive virtual experiences – could also be effective in generating psychological mechanisms that lead to environmental behavior (Ahn et al., 2014). For example, people may be willing to donate money to an environmental agency after they dive deep under the sea in VR to experience the ocean acidification on the coral reefs (Nelson et al., 2020).

As a starting point of a large project, we examined leading academic IS literature aiming to find out *"What are the main IS studies addressing immersive technologies as Green IS?"* The answer to our research question relies on a meta-research (Rowe, 2014; Templier & Paré, 2015) resulting from a systematic literature review. Our results suggest that there is an absence of such studies in the worlds' leading IS journals. Aiming to position immersive technologies within the Green IS literature and to increase their recognition among the IS community, we discussed how to fill this gap by borrowing insights from behavioral literature.

This paper is organized as follows. In the next section, we provide some background about smart cities, Green IS, and immersive technologies, to clarify the relationship between these concepts and the potential of using such technologies for smart city policy. In section 3, we explain the methods used to conduct the study, present and discuss the results, and define the literature gap. In section 4, we suggest how to fill the gap by using insights from other disciplines. Finally, we conclude and highlight implications for smart city policy.

2.Background

2.1 Sustainable development challenges of smart cities

Due to the global trend of moving to urban regions, cities have become bigger, as well as their consumption of natural resources. This poses a great challenge for environmental sustainability

(Norman, 2018). In the last decade, we witness a global movement towards "smart cities" – cities in which advanced technology is applied to increase the quality of life for its citizens and communities (Albino et al., 2015).

The growing interest in smart city initiatives points to a promising shift in environmental conservation because sustainability is one of their goals. Some claim that cities cannot be truly smart without being sustainable (Yigitcanlar et al., 2019). However, it seems that current smart city policies and frameworks partially fail to achieve long-term sustainability goals (Ahvenniemi et al., 2017).

One of the criticisms of current smart city practices is their technocentric approach, that is, relying on technological solutions to ensure sustainable outcomes. Namely, technology alone will not turn a city into a smart one, unless there is no smartness in leaders, policy-makers, and citizens (Yigitcanlar et al., 2019). This brings on the surface the importance of motivating the pro-environmental behavior of smart citizens. Starting from a local scale, only together we can achieve long-term global sustainability goals. Hence, there is a need for innovative solutions to make smart city policies more effective in encouraging sustainable practices (Norman, 2018). One of the tools for improving smart city policies may be Green Information Systems.

2.2. Past research on Green IS

Along with researchers from various disciplines, IS scholars have the responsibility to tackle global environmental challenges. An urgent call for action has been issued several times to the IS community, to highlight the need for research on Green IS - technology designed to minimize the negative impact on the environment and leverage green awareness among its users (Murugesan, 2007; Elliot & Webster, 2017; Gholami et al., 2016; vom Brocke et al., 2013).

Technology plays a crucial role in shaping people's beliefs about the environment and improving eco-friendly performances (Melville, 2010). At the organizational level, Green IS implies the design and implementation of information systems that support businesses in their environmentally sustainable processes, while at the individual level it provides information and helps consumers in their effort to make green choices (Watson et al., 2008).

In 2010, Melville indicated the lack of research on Green IS, concluding the literature search with one single article on environmental sustainability within the leading IS literature (Melville, 2010). One year after, the state of the art did not change much; Elliot (2011) conducted a broad transdisciplinary review of existing literature on environmental sustainability, concluding with only five papers listed under the IS discipline (Elliot, 2011). After two years, the IS knowledge was richer by 14 articles dealing with environmental sustainability (Malhotra et al., 2013). Leading Green IS scholars converge in issuing an urgent call for action to the IS community (Elliot & Webster, 2017; vom Brocke et al., 2013).

2.2 Immersive technologies as Green IS?

The concept of experiencing one reality while living in another has always sparked curiosity among people. Today, it is easier than ever to unleash imagination in digitally created virtual

environments. Immersive technologies – under the umbrella term Mixed Reality (MR) – provide experiences of a fully or partially virtual environment. While VR is completely immersive with a virtual surrounding environment, AR merges real and virtual by supplementing 3D digital objects over the real environment in real-time (Azuma, 1997). These vivid simulations can create presence – the sense of "being there" – tricking the human mind to treat such experiences as real (Steuer, 1992). For such advanced features, we witness wide applications of immersive technologies in various contexts, including smart cities.

Technologies like AR or VR are of great potential for environmental sustainability purposes: they can directly benefit the environment by serving as a tool for education, monitoring, raising ecological awareness, and improving resource efficiency (Rambach et al., 2020; Bekaroo et al., 2018). In this article, we want to go beyond existing applications of immersive technologies in smart cities, such as smart retail or urban planning (Dacko, 2017; Jamei et al., 2017). Immersive technologies can serve as a practical and accessible policy tool for enhancing risk perception of environmental threats, by replacing real experiences of natural disasters with virtual ones.

Namely, environmental communication is tricky: people often lack direct experiences of environmental crises, which in turn leads to treating environmental problems as spatially, temporally, and socially distant risk (Trope & Liberman, 2010; van der Linden et al., 2015). With the help of AR and VR, today is easier than ever to experience events that are difficult or even impossible to conduct in reality because they are unpredictable, unsafe, costly, or impractical (for example, exposing somebody to a natural hazard such as a wildfire or floods).

Research has shown the potential of immersive technologies for rising engagement around environmental issues (Ahn et al., 2014; Chirico et al., 2020). By providing hypothetical virtual experiences of environmental degradation, these technologies can have emotional and cognitive effects on users, and consequently impact their behavior (Nelson et al., 2020). Moreover, environmental organizations have also recently used AR to engage people around environmental issues (Reuters, 2018; WWF, 2017). Because of their persuasive nature, immersive technologies could be used as a widely accessible Green IS for raising awareness of environmental issues, motivating pro-environmental behavior, and improving the implementation of environmental policies in smart cities.

3. Immersive technology at the service of environmental sustainability: survey in the leading IS literature

3.1 Methods

We conducted a systematic literature survey, to find out what are the main IS studies addressing immersive technologies as Green IS. The literature search was performed in November 2020 in the databases Scopus and Web of Science using keywords: (1) "Green IS" OR "environmental sustainability" OR "environment" OR "nature" OR "climate change" ;(2) "Augmented Reality" OR "Virtual Reality" OR "Mixed Reality" OR "Virtuality" OR "Immersive technologies".

The sample of this literature review covers the Association for Information Systems (AIS) basket of top eight IS journals, as they are globally accepted as holders of the leading scientific IS knowledge (EJIS, ISJ, ISR, JAIS, JIT, JMIS, JSIS, and MISQ). We are aware that our

journal selection may obtain some important articles of the trend, however, we wanted to ensure the credibility of the references.

Papers were downloaded, fully read, reviewed, and filtered based on inclusion/exclusion criteria: only peer-reviewed empirical and conceptual journal articles were included; only papers including high-immersive virtual environments were included; only papers in the English language were included; editorials were excluded. We didn't find any result that matched both criteria, so we did two separate searches.

3.2 Results

3.2.1. Green IS in the leading IS literature

Firstly, we present a summary and categorization of main papers in leading IS journals that deal with Green IS. We adopted the classification from Elliot (2011) who proposed six categories of research on environmental sustainability (Table 1).

Major Category	Description
Environmental	Identifies literature that establishes the nature of environmental challenges and the potential contribution of IT to their resolution
Societal	Identifies literature that addresses environmental issues specific to societies locally, nationally, and internationally at individual and collective levels
Governmental	Identifies literature that determines and evaluates policies and initiatives to achieve environmentally sustainable outcomes
Industrial and Alliances	Identifies literature to facilitate the implementation of business transformation for environmentally sustainable outcomes through industry and cross-industry groups and alliances
Organizational	Identifies literature on determining and implementing initiatives for business transformation by business and other organizations with a strategic focus on achieving environmental sustainability
Individuals and groups within organizations	Identifies literature on organizational initiatives and transformations influenced by individuals and groups within organizations with an interest in or responsibility for environmental sustainability

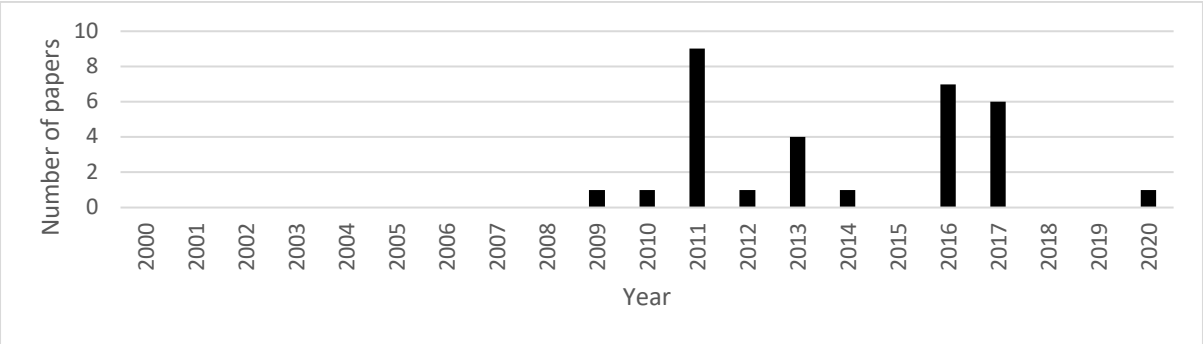
Table 1. Major categories of the literature on environmental sustainability (adopted from Elliot, 2011)

A total of 31 papers were included in this literature survey. The distribution of the papers within journals and categories is presented in the table below (Table 2).

		Categories of the literature on environmental sustainability							
		Environmental	**Societal**	**Governmental**	**Industrial & Alliances**	**Organizational**	**Individuals & groups within organizations**	**All categories**	**TOTAL**
Journal	**EJIS**					2	1		**3**
	ISJ	1	1	1		4			**7**
	ISR								**0**
	JAIS	1	1		1		1		**4**
	JIT		1						**1**
	JMIS					1			**1**
	JSIS	3	1	1		5			**10**
	MISQ		1			1	1	2	**5**
	TOTAL	**5**	**5**	**2**	**1**	**13**	**3**	**2**	**31**

Table 2. Number of papers on Green IS per journals per category of the literature on environmental sustainability

The graph below (Graph 1) demonstrates the distribution of papers on Green IS in leading IS journals over the last 20 years.



Graph 1. Trends of publishing papers on Green IS over the last 20 years in the leading IS literature

Although there is a growing tendency of publishing environment-oriented papers in leading IS journals, there was no paper found which proposed any type of immersive technology as IS for addressing environmental sustainability, which demonstrates that these technologies are still emerging and their applications for societal challenges are in the early days. The summary of leading papers on Green IS, their research questions, methodology, and the category is presented in Table 3 (see Appendix A for the list of references).

Reference	Research question	Methodology	Category
Elliot (2011)	What is meant by environmental sustainability? What are its major challenges? What is being done about these challenges? What needs to be done?	Conceptual (literature survey)	All
Melville (2010)	What is the research agenda on information systems innovation for environmental sustainability that demonstrates the critical role that IS can play in shaping beliefs about the environment, in enabling and transforming sustainable processes and practices in organizations, and in improving environmental and economic performance?	Conceptual (literature survey)	All
Hasan et al. (2016)	How IS researchers and practitioners can make a positive contribution to climate change adaptation by seeking to determine the potential of IS to impact, support, and transform the planning and execution of climate change adaptation activities?	Empirical (Canonical action research)	Environmental
Fridgen et al. (2016)	How can one quantify the monetary value of IS-enabled, short-term flexibility in consumer demand for electricity using real options analysis?	Conceptual (design science research)	Environmental
Zhang et al. (2011)	What is the framework to support the IT system design decision support based on the system's environmental impact?	Conceptual	Environmental
Pitt et al. (2011)	In which ways smartphones, both as green technologies and as integral parts of green information systems, are beginning to make serious contributions toward a sustainable environment?	Conceptual	Environmental
DesAutels & Berthon (2011)	What is the market price of "sustainable" notebooks?	Empirical (secondary)	Environmental
Corbett & Mellouli (2017)	How do IS support cities in their efforts to manage water quality and green space? What type of IS are needed by cities to achieve the SDGs by 2030?	Empirical (The grounded theory)	Governmental
Bengtsson & Agerfalk (2011)	How can IT serve as a change actant in sustainability innovation and what is the nature of its relation to other human and non-human actants?	Empirical (case study)	Governmntal
Chan & Ma (2017)	How different CEO compensation forms influence the execution of IT-based environmental strategies	Empirical (survey and archival data)	Individuals & groups within organizations

Corbett (2013)	Do personal CMS in organizations help to promote ecologically responsible behaviors by employees? Which, if any, of the persuasive system design principles are most relevant to personal CMS deployed within organizations? How does the persuasion context of environmental sustainability influence the design of personal CMS used in organizations?	Empirical (case study)	Individuals & groups within organizations
Marett et al. (2013)	How important are personal benefits and institutional pressures for current end users when deciding to continue using sustainable information systems?	Empirical (survey)	Individuals & groups within organizations
Nishant et al. (2017)	How much do green IT announcements affect a) market value and b) share trading volume? Do shareholders react differently to different types of green IT announcements? Do shareholders view green IT announcements by innovative and non-innovative firms differently?	Empirical (event study)	Industrial & Alliances
Seidel et al. (2017)	What are appropriate design principles for IS for sensemaking (i.e., sensemaking support systems) in environmental sustainability transformations?	Empirical (design science research)	Organizational
Benitez-Amado & Walczuch (2012)	Does IT capability have a positive effect on the capability of proactive environmental strategy? Does IT capability influence firm performance by means of the capability of proactive environmental strategy?	Empirical (secondary data)	Organizational
Loeser et al. (2017)	How environmental orientation and strategy influence Green IS initiatives and whether Green IS initiatives yield organizational benefits in general?	Empirical (survey)	Organizational
Cooper & Molla (2016)	What is IS-environmental absorptive capacity? What influences IS environmental absorptive capacity? What is the value of developing IS-environmental absorptive capacity?	Empirical (case study)	Organizational
Hanelt et al. (2016)	What is the impact of supporting IS on the organizational performance of eco-innovations? What are the mechanisms through which this impact occurs? How do organizational factors influence the use of supporting IS?	Empirical (case study)	Organizational
Hedman & Henningsson (2016)	How do Green IS initiatives and organizational sustainability process influence each other?	Empirical (case study)	Organizational
Hu et al. (2016)	How firms decide whether to practice green IT, as conducted by Chen et al. in a similar setting, using finegrained analyses and empirical testing at the organizational level?	Empirical (Survey)	Organizational
Butler (2011)	What features and functions of Green IS are required to support: (i) sense-making; (ii) decision making; and (iii) knowledge sharing/creating activities in response to signals from the institutional environment? How are the organizations studied using Green IS to support such activities?	Empirical (case study)	Organizational
Dao et al. (2011)	What is the role of IT resources and their integration with human and supply chain resources in helping firms develop sustainability capabilities that help firms deliver sustainable values and gain sustained competitive advantage?	Conceptual	Organizational
Bose & Luo (2011)	What framework can be used as a theoretical foundation for studying Green IT across different stages?	Conceptual	Organizational
Petrini & Pozzebon (2009)	How can the process of defining and monitoring socio-environmental indicators be integrated into the organizational strategy for sustainability?	Empirical (case study)	Organizational
Henfridsson & Lind (2014)	What is the process by which the micro-strategizing of actors from a variety of organizational sub-communities contribute to realize strategy contents as they use IS to implement a sustainability strategy?	Empirical (case study)	Organizational
Seidel et al. (2013)	How do information systems contribute to the implementation of sustainable work practices?	Empirical (case study)	Organizational
Tim et al. (2017)	How does the use of social media influence community-driven environmental sustainability?	Empirical (case study)	Societal
Han et al. (2020)	How do the three major actions in the knowledge reuse for innovation process affect the generativity of an innovation that addresses societal challenges?	Empirical (secondary data)	Societal
Rajão & Marcolino (2016)	How new users in developing countries use ICT to broadcast or render opaque particular self-images?	Empirical (interpretive methodology)	Societal
Watson et al. (2011)	How can four information drives (ubiquity, uniqueness, unison, and universality) be used to explain the tight coupling that is necessary between the physical and informational components of green projects to improve their usefulness?	Empirical (secondary data)	Societal
Loock et al. (2013)	To what extent goals and defaults lead to higher energy savings, implemented in the user interface of a web-based energy feedback platform?	Empirical (field experiment)	Societal

Table 3. Summary and categorization of main empirical and theoretical contributions to Green IS research in the leading IS literature

3.2.2 Immersive technologies in the leading IS literature

Secondly, we present the primary studies dealing with immersive technologies in the leading IS literature. Typology of virtual environments is adopted from Innocenti (2017), who classified them according to the degree of users' immersion: (1) LIVE, low-immersive virtual environments experienced on a computer screen and (2) HIVE, high-immersive virtual environments, experienced by specialized head-mounted display (HDM) equipment or by entering a CAVE (a cube-shaped room in which the virtual content is projected onto the walls) (Innocenti, 2017). Our survey focuses on high-immersive virtual environments (HIVE), because we introduce the concept of highly immersive technologies (AR and VR) as stimulators of environmental behavior.

		Journal							
		EJIS	**ISJ**	**ISR**	**JAIS**	**JIT**	**JMIS**	**MISQ**	**TOTAL**
AR/VR	**AR**						1		**1**
	VR			1	1		1		**3**
	AR&VR						1		**1**
	TOTAL			**1**	**1**		**3**		**5**

Table 4. Number of papers on AR/VR per journals per type of immersive technology

Table 4 presents the total of 5 papers addressing high immersive virtual environments (AR and/or VR) in the leading IS journals. Summary and categorization of main empirical and theoretical contributions to AR/VR (HIVE) research in IS literature are presented in the Table 5 (see Appendix B for the list of references).

Reference	AR/VR	Research question	Methodology	Sample	Domain of application
Pfeiffer et al. (2020)	VR	Can eye movements be used to classify two search motives: goaldirected and exploratory search?	2 eye-tracking experiments in virtual (CAVE) and physical reality	29 participants (VR); 20 participants (physical)	Commerce
Gleasure & Feller (2016)	VR	Oculus VR's changing relationship with their backers on Kickstarter from August 2012 to April 2014	Grounded theory	2,202 comments, 53 webpages, 1,156 responses, the public profile for Oculus VR, 9,522 members profiles	VR industry
Peukert et al. (2019)	VR	How immersion influences adoption of highly immersive shopping environments?	Laboratory experiment (in highly immersive VR and low immersive computer screen)	257 participants	Commerce
Steffen et al. (2019)	AR & VR	Do users adopt virtual and augmented reality because they afford activities that are impossible or advantageous when compared to the activities afforded by physical reality?	Multimethod: Quantitative: 2 experimental surveys including hands-on experience with AR and VR / Qualitative: open-ended interview	Quantitative: 263 students + 204 participants from Amazon's Mechanical Turk / Qualitative: 18 professionals from different fields	users' acceptance / adoption of VR and AR
Biocca et al. (2007)	AR	How can an AR system successfully manage and guide visual attention to places in the environment where critical information or objects are present, even when they are not within the visual field?	Within-subjects experiment	14 students	Decision support & task completion

Table 5. Summary and categorization of main empirical and theoretical contributions to AR/VR (HIVE) research in the leading IS literature

Besides HIVE, the second type of virtual environment is LIVE, which stands for low-immersive virtual environments experienced on a computer screen. Common examples are games and simulations such as the virtual world Second Life (Innocenti, 2017). Although this is not the focus of our research because immersive technologies fall into the HIVE category, we listed them and categorized based on the topic of the paper. Most of these papers are related to virtual worlds Second Life, massively multiplayer online games (MMOG), or virtual shopping environments (see Appendix C for details and references).

3.3 Discussion

The results from this systematic literature survey confirm our initial assumption that immersive technologies have not yet been researched or applied as a Green IS in the leading IS literature. In our sample, the interest for Green IS and immersive technologies have appeared over the past decade, but only as two separate topics. However, the total of 31 papers on Green IS and 5 papers on AR/VR is not an encouraging result. Considering that the AIS basket of top 8 IS journals should hold the world's leading IS knowledge, paradoxically there is a lack of research on Green IS, an absence of AR/VR applications for environmental sustainability, and only a few papers addressing environmental policy (Corbett & Mellouli, 2017; Bengtsson & Ågerfalk, 2011; Tim et al., 2017).

Environmental sustainability has become a topic of interest among IS community only in the last 10 years. However, the number of papers is not growing, there are rather certain trends in publishing. Several years have marked a growing interest in Green IS research – 2011, 2016, and 2017. These trends might indicate that IS community is reactive to important ecological events, such as Paris Agreement (UNFCCC, 2015). Also, it may be that systematic literature surveys on Green IS motivated other researchers to investigate IS applications for environmental sustainability (Melville, 2010).

As seen from Table 3, most of the research on Green IS has been conducted at the organizational level. For example, these studies investigated businesses' Green IS initiatives (Hedman & Henningsson; 2016; Seidel et al., 2013), their use of Green IS to support sensemaking and decision-making activities (Seidel et al., 2017; Butler, 2011), and their sustainability strategies (Petrini & Pozzebon, 2009). Green transformations within organizations, businesses, and governments are unquestionably important; their role has been recognized as relevant in tackling environmental challenges (Elliot, 2011).

However, our sample consists of only five studies conducted at the societal level (Table 3). Individuals should not be ignored – not only do their actions have an enormous impact on the environment, but they have the power to pressure suppliers and governments in reducing their negative practices (Watson et al., 2010). Information and communication technologies can do much more than just help businesses achieve their green practices. Green IS can help individuals understand and relate to environmental issues, and their specific design can motivate them to take sustainable actions (Tim et al., 2017; Loock et al., 2013).

Undoubtedly, IS has a major role as a promotor of public awareness and engagement around environmental issues. In this paper, we focus on under-researched phenomena – how IS could help individuals or groups in society in addressing environmental sustainability – and we highlight the need for more research on Green IS specific to societies locally, nationally, and internationally at individual and collective levels (Elliot, 2011). For their ability to generate

psychological mechanisms important for motivating pro-environmental behavior (discussed in section 4), we suggest immersive technologies as the basis for building persuasive Green IS.

Surprisingly, our literature search resulted in a total of only five papers dealing with HIVE among leading IS journals (Table 4), which demonstrates that knowledge of VR and AR in the IS discipline has been accumulated slowly. Four out of five papers were published in the last four years. This growing interest in immersive technologies among IS scholars could be due to the cost reduction of AR/VR equipment and its recent wide accessibility. Therefore, we expect that this trend will continue.

The dominant methodology in the papers on AR/VR in the leading IS literature is an experiment - researchers have recognized the potential immersive technologies could offer to improve laboratory experiments. However, supplementing quantitative with qualitative studies are recommended for such emerging concepts when their state of the art is still inconclusive (Venkatesh et al., 2013), as in the case of immersive technology in the context of environmental sustainability. Moreover, comparative research is suggested for the development of contextual theory in IS research (Avgerou, 2019). IS community should recognize the opportunity of this historical turn when immersive technologies have become widely accessible to the mass public, to investigate their potential in addressing societal challenges.

Since there is an absence of papers among leading IS literature addressing this issue, we discuss how to fill this gap by borrowing insights from other disciplines. Combining IS knowledge with behavioral science can improve research on environmental sustainability and provide practical solutions for incentivizing green behaviors. In the next section, we suggest how virtual experiences, built on behavioral insights, could serve for environmental policy evaluation and implementation in smart cities.

4. Filling the gap with immersive virtual experiences built on the insights from the behavioral literature

4.1 Behavioral concepts integrated into virtual experiences for policy implementation

Motivating environmental behavior is not an easy task. Insights from behavioral literature can improve IS research in building more efficient "behavioral information systems" (Goes, 2013), that could be used to improve smart city policy aiming for environmental sustainability. These insights, if integrated into virtual experiences provided by immersive technologies, could serve as a policy tool that could boost citizens' environmental behavior and policy implementation. This approach could enhance environmental policy implementation for several reasons discussed below.

Virtual experiences reduce the psychological distance. By providing direct and rich sensory experiences, AR or VR might be effective in raising engagement around environmental issues that are spatially or temporally distant, such as pollution or ocean acidification (Fox et al., 2019; Ahn et al., 2016). Virtual experiences can improve the presentation of information (Steffen et al., 2019), past or future experiences can become present, and far-away places can become closer. In other words, virtual experiences can reduce the psychological distance (Trope & Liberman, 2010).

Presence influences risk perception. In addition to psychological distance, some studies reveal that presence can be manipulated through virtual experiences. The sensation of "being there" is an important psychological factor that can influence risk perception of environmental threats, such as forest fire or flood. Consequently, it can impact an individual's coping responses (Treuer et al., 2018; Zaalberg & Midden, 2013; Fiore et al., 2009). In traditional environmental campaigns, governments can supplement visual communication with immersive AR experiences, letting citizens "live" the consequences of any environmental threat through the lens of their smartphone camera.

AR campaigns could activate social norms. AR has recently been getting significant attention on social networks – digital platforms with the potential for encouraging green behavior (Malhotra et al., 2013). For its vivid and entertaining nature, AR campaigns on social networks could become viral, reducing the cost of fundraising campaigns and raising collective awareness by the means of social norms – a powerful lever that can influence behavior change (van der Linden et al., 2015). Therefore, mobile AR could serve as a powerful smart city policy tool for raising awareness of environmental issues and encouraging pro-environmental behavior.

4.2 Virtual experiences for policy evaluation in controlled settings

By bringing the field in the lab, immersive technologies could improve scientific research where human behavior is being investigated. Virtual environments could raise the internal validity of experiments by providing context and field cues needed for examining real decision-making (Innocenti, 2017). This is useful for policy testing, as a replacement for artefactual cues (textual and pictorial presentation) that are usually used in environmental valuations.

Virtual environments could provide citizens with realistic scenarios needed to understand and properly evaluate policy choices, lowering the choice error variance, left-right bias, and asymmetry between willingness to pay (WTP) and willingness to accept (WTA) (Fiore et al., 2009; Olschewski et al., 2012; Matthews et al., 2017; Bateman et al., 2009). For example, governments can expose citizens to virtual simulations of environmental disaster such as forest fires, to test their willingness to pay for prevention policies (Fiore et al., 2009).

6. Conclusion and future directions

Smart city movements promise to improve environmental sustainability in urban regions. However, motivating citizens' environmental behavior remains a challenge. In this paper, we explained how immersive technologies can be used as a Green IS to enhance smart city policy implementation and evaluation. Immersive technologies could provide virtual experiences of environmental threats, as an alternative to direct experiences that are proven to be effective in raising awareness and risk perception of environmental issues. Such experiences can cause emotional and cognitive reactions that lead to green behavior, because "*experiencing is believing"*. Moreover, virtual environments provide the context and field cues to lab, which is useful for experiments investigating real decision-making and testing environmental policies in controlled settings. In order to find out the current state of the art, we systematically presented the leading IS knowledge dealing with immersive technologies as Green IS. Our results indicate that the field is still embryonic and emerging technologies such as AR and VR have not yet been scientifically investigated for such purposes in the leading IS literature. We

proposed to fill this gap by borrowing insights from behavioral literature. Future studies should extend the limited sample of this study with relevant papers outside of the AIS basket of 8 leading IS journals. Also, it would be interesting to test the early acceptance of such mode of environental communication among end users, and to test the real impact of such immersive experiences on execution of pro-environmental behavior. This paper paves the way for researchers and practitioners involved with smart city policy issues and encourages them to keep exploring the potential of immersive virtual experiences for encouraging citizens' sustainable practices.

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Appendices

Appendix A. References from Table 3. Summary and categorization of main empirical and theoretical contributions to Green IS research

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Appendix C. IS papers dealing with LIVE and their categorization

Reference	Topic
Animesh et al. (2011)	Business aspect of virtual environments
Berente et al. (2011)	Business aspect of virtual environments
Goh & Ping (2014)	Business aspect of virtual environments
Goode et al. (2014)	Business aspect of virtual environments
Nah et al. (2011)	Business aspect of virtual environments
Yang et al., (2012)	Business aspect of virtual environments
Chaturvedi et al. (2011)	Design and creation of virtual worlds and 3D objects
Kohler et al. (2011)	Design and creation of virtual worlds and 3D objects
Seymour et al. (2018)	Design and creation of virtual worlds and 3D objects
Suh et al. (2011)	Design and creation of virtual worlds and 3D objects
Saunders et al. (2011)	Design and creation of virtual worlds and 3D objects / Usage/acceptance of virtual worlds
Jiang & Benbasat (2004)	E-commerce
Suh & Lee (2005)	E-commerce
Yang & Xiong (2019)	E-commerce
Zahedi et al. (2016)	E-health
Bhagwatwar et al. (2018)	Learning and collaborating in virtual worlds
Davis et al. (2009)	Learning and collaborating in virtual worlds
Mueller et al. (2010)	Learning and collaborating in virtual worlds
Nardon & Aten (2012)	Learning and collaborating in virtual worlds
Srivastava & Chandra (2018)	Learning and collaborating in virtual worlds
Roquilly (2011)	Legal aspects of virtual worlds
Schultze (2010)	Presence in virtual worlds
Goel et al. (2011)	Usage/acceptance of virtual worlds
Goel et al. (2012)	Usage/acceptance of virtual worlds
Junglas et al. (2013)	Usage/acceptance of virtual worlds
Lee & Chen (2011)	Usage/acceptance of virtual worlds
Nevo et al. (2011)	Usage/acceptance of virtual worlds
Schwarz et al. (2012)	Usage/acceptance of virtual worlds
Zhou et al. (2015)	Usage/acceptance of virtual worlds
Featherman et al. (2006)	Users' behavior in virtual worlds
Hinz & Spann (2008)	Users' behavior in virtual worlds
Hinz et al. (2015)	Users' behavior in virtual worlds
McKenna (2019)	Users' behavior in virtual worlds
Schultze (2012)	Users' behavior in virtual worlds
Schultze & Brooks (2018)	Users' behavior in virtual worlds
Schultze & Mason (2012)	Users' behavior in virtual worlds
Ketter et al. (2015)	Virtual environments for addressing environmental sustainability
Ketter et al. (2016)	Virtual environments for addressing environmental sustainability
Greenhill & Fletcher (2013)	Virtual games
Putzke et al. (2010)	Virtual games

Table 6. Categorization of IS papers dealing with LIVE

References from Table 6. Categorization of IS papers dealing with LIVE

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