Green Information Systems Research:
A Decade in Review and Future Agenda

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Abstract   It has been two decades since Green Information System attracted scholars in information systems research. The surge of sustainability issues over the world naturally made Information Systems scholars to turn their attention to understanding how the use of Information Systems is making impact to our society and environments. This paper reviews studies on Green Information Systems(Green ISs) to evaluate efforts made in the last decade. Based on a systematic approach, 64 articles published in peer-reviewed international journals in Information Systems and Business & Management disciplines are analyzed to identify research gaps and propose future research agenda in Green ISs that include the application of psychological theory in the design of Green ISs, energy efficient IT/IS to respond to accelerated virtualization, and contribution of Green ISs to biodiversity.

Keywords : green information systems, systematic literature review, sustainability, biodiversity, IS values.

그린 정보시스템 연구: 과거 10년간 연구 동향 분석 및 향후 과제

이 하 빈*

요 약   그린 정보 시스템 컨셉이 등장한지 20여년이 되어 가고 있다.지속가능성에 대한 관심은 정보시스템 연구자들 또한 정보시스템이 지구의 지속가능성에 기여할 수 있는 방안에 대하여 그린 정보 시스템이라는 주제하에 연구하는 계기를 마련하였다.이 연구는 지난 10여년간 이루어진 그린 정보 시스템 관련 연구들을 리뷰하고 향후 연구 과제들을 제시하는데 목적을 둔다.시스템적인 관련 연구 기법을 적용하여 2010년에서 2020년까지 정보시스템 및 경영학 분야 저널에 게재된 그린 시스템 논문들을 탐색하고 이들의 연구주제들을 6가지 분야(그린 정보 시스템도입,효과,역량,설계,의견, 리뷰) 로 구분하여 분석한다.각 분야별 사용된 이론적인 프레임워크 및 주된 연구분야들을 정리하고 이에 따라 앞으로 더 연구가 이루어져야 하는 주제들을 제시한다.

주제어 : 그린 정보 시스템, 시스템적인 관련 연구리뷰, 지속 가능성, 생체적 다양성, 정보시스템 성과

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Ⅰ. Introduction

As climate change is intensified all over the globe, the sustainability is main agenda across all industries. As human activities are blamed for increased Green-House-Gas (GhG) emissions, the organizational activities take large responsibility. While Information systems have been quoted important facilitator to transform organizations into sustainable and green entities, there is lack of assessment on how Green Information Systems (Green ISs) are playing a role in the transformation processes. This paper reviews studies on Green ISs during the last decade to assess their contributions and gaps for future research directions.

The importance of Green ISs has been noted by scholars since early 2000s. Initially, the efforts were initiated in industry organizations as a part of corporate social responsibility to respond to social pressure on climate changes (Watson et al 2010; Esty and Winston 2006). This new type of ISs was expected to help organizational managers understand, change and redesign organizational business processes to be more eco-friendly and ensure long-term sustainability (Watson et al. 2010).

Information Systems scholars have been working on how ISs are helping organizations achieve productivity improvements for a long time. While traditional IS scholars were focused on the economic and societal values of ISs, Green IS scholars are more interested in environmental values of ISs. Those values have inevitably trade-off relationships between them. Maximizing economic values could reduce the environmental values and vice-versa. The studies on Green ISs are more challenging as the measurement of environmental values are much difficult than economic values. The organizational managers are much more interested in the latter than the former. Sometimes, Green initiatives are more symbolic to respond to social corporate responsibility. Those factors are barriers and also opportunities for future Green IS studies and it is time to review existing Green IS studies to identify the gaps and future research directions.

Singh and Sahu(2020) define Green IS as "*the effective and efficient IT/S expertise and set of practices focused on plummeting GHGs emission, carbon footprints and ensuing environment sustainability in the society.*" The definition includes two aspects of Green ISs: developing and maintaining Information systems minimizing impacts on environments; and using Information Systems to develop and maintain organizational practices in an environmentally friendly way.

In the beginning, scholars do not clearly distinguish between Green IT and Green IS but Watson, et al.(2013) define Green IS as broader concept to include "*a greater variety of possible initiatives to support sustainable business processes*" therefore superset of Green IT which is more focused on the technology aspect of Green IS. Green IS scholars are working on the development, use, and evolution of ISs in relation with sustainability of organizations.

Existing studies on the Green IS are more focused on the first and second order effects of ISs. Seidel, et al.(2013) proposes a framework to understand how ISs contribute to the creation of environmentally sustainable organizations and the design of ISs to create required functional affordances. Gholami, et al.(2018) recently reports

how a local business community is using its website to facilitate trading eco-friendly goods and services in West Midlands region of the UK. Seidel, et al.(2017) reviews the initiative of Green IS and argue that Green IS needs to be integrated into IS research as a core research agenda to improve the sustainability of organizations. The paper also proposes future research agenda through integration with practitioners and different cultures.

On the other hand, Green ITs have been one of the popular topics in Engineering discipline including computer science, building design, and energy engineering. Scholars in the disciplines actively worked on manufacturing energy efficient computer systems, energy efficient building design, and renewable energy supply among others. Those studies are mainly based on design science approach which aims at providing novel solutions for managerial or engineering problems. Energy efficient computing(Brown & Reams, 2010) is a discipline in computer engineering for the design of energy efficient computing servers and software. The design of computing chips that consume less energy and development of system software that requires less processing power are examples. On the other hand, Green ISs are taking the broader perspective including human and organizational contexts as well as ITs. For example, the effect of Green ISs, understanding human and organizational issues for adopting Green ITs, the energy efficient use(operations) of legacy Information Systems, cost-benefit analysis of replacing legacy ISs with Green ISs among others. In spite of the importance of the new initiative, the literature has very biased efforts focused on Green ITs and, relatively small

number of studies are investigating human and organizational issues of Green ISs. This paper aims at reviewing studies on Green ISs in the last decade in which the studies have been most active since the concept appeared in early 2000s. While the concept of Green IT/IS was discussed before 2010, diverse issues of Green ISs have been addressed in 2010s. Reviewing the studies between 2010 and 2020 can help scholars understand areas covered by studies so far and identify uncovered issues of Green ISs that need to be investigated in 2020s.

The organization of this paper is as follows. Section II provides the method used for the systematic literature review. Section III provides the summary of findings from the literature review. Section VI discusses future research agenda and concludes the paper.

II. Method

We conducted a systematic search of related studies on 6 databases that cover business & management and computer science discipline including Emerald, Science Direct, ACM Digital Library, IEEE, JSTOR, Sage and Wiley.

We applied a keyword search using "Green" and "Information Systems" on the texts in the abstracts and titles of target peer-reviewed journal articles. The initial search returned total 91 articles in business & management discipline. We filtered articles published in Information Systems and Operations Management related journals and finally selected 64 articles for further analysis. The number of academic journals is 34 including major IS journals like

〈표 1〉 그린 정보 시스템분야에서 다루어진 주제들의 년별 빈도표
〈Table 1〉 Topics addressed in the Green IS literature

| Year	Total	Value	Capability	Adoption	Design	Opinion	Review
2010	6	1	0	1	0	4	0
2011	8	0	3	1	0	3	1
2012	1	0	0	0	0	1	0
2013	11	5	1	2	3	1	0
2014	4	0	3	1	0	0	0
2015	1	0	0	1	0	0	0
2016	5	1	2	1	0	0	0
2017	12	5	1	1	3	2	1
2018	9	3	1	4	1	0	0
2019	4	1	0	2	1	0	0
2020	3	0	0	1	0	1	1
Total	64	16	11	15	8	11	3

MIS Quarterly, Journal of AIS, Journal of MIS, European Journal of IS, Australian Journal of IS, IS Journal, IS Management, Journal of Business Research, IS Frontiers, Communications of the AIS, and Journal of Strategic ISs, among others. Appendix A shows the list of the journals and the number of articles used in this study.

We reviewed each article to classify it into broader topic categories based on their findings: Green IS values, capability, adoption, design, opinion and literature review. The acceptance and adoption of Green IS are focused on identifying factors that affect the adoption of Green ISs in organizations. Evaluating economic, environmental and social benefits of Green ISs is another popular topic. Number of articles are addressing how organizations can strengthen their capability of operating Green ISs to maximize positive impacts. Also, identifying design principles and novel design architecture of Green ISs have also

been proposed by a group of scholars. There are meaningful number of opinion articles that encourage IS scholars to put more efforts on sustainability issues and provide future research agenda in the discipline. Finally, there are two literature review articles that summarize existing efforts and provides research directions.

Table 1 summarizes the number of articles in each category between 2010 and 2020 and Fig. 1 shows the portion of each topic in thelast decade. Also, it is interesting to see that 25% of the total articles are opinion articles.Those opinion articles are mainly for facilitating IS scholars to put more efforts on the sustainability issues of IS research and providing future research directions.

As can be seen in Fig. 2, Green IS studies show a steep-slope linear growth line. It does not take an exponential curve, and this represents a lack of attention of IS scholars in this field. The
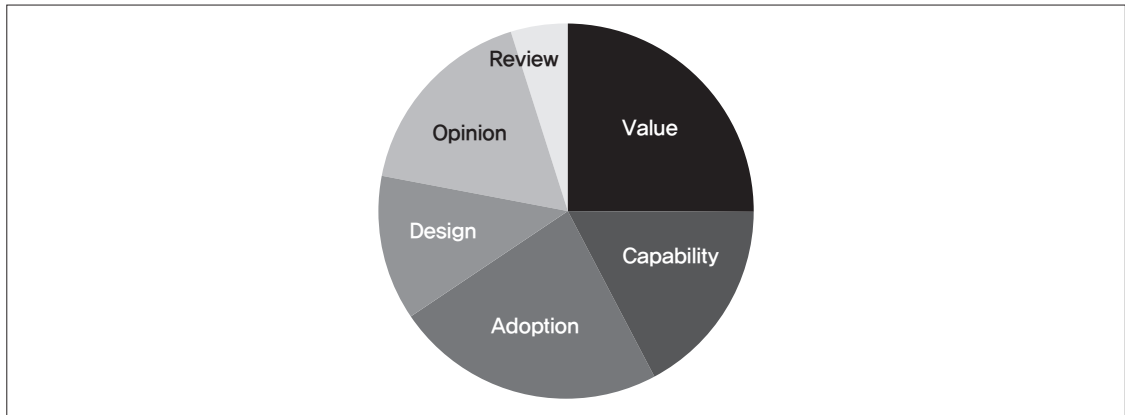
〈그림 1〉 2010–2020 그린 정보 시스템 연구 주제별 분포도
〈Fig. 1〉 Topic distribution of Green IS studies, 2010–2020
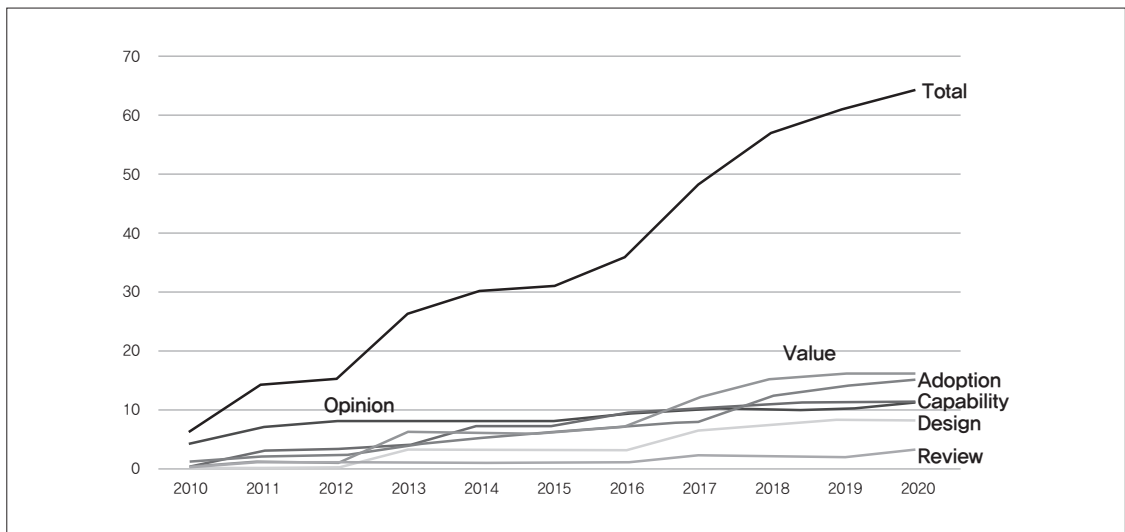
〈그림 2〉 2010 – 2020 사이 그린 정보 시스템 주제별 성장곡선
〈Fig. 2〉 The growth of Green IS topics between 2010 – 2020

growth of opinion articles is a bit flat. Those opinion articles have been mainly published early 2010s when the sustainability issue started attracting attention of IS scholars and its portion decreases as time evolves. Considering the slow growth curve of the total articles, we can expect more opinion articles in the future. Studies on the value and adoption of Green ISs have been steadily increased during the period. This trend is expected to continue in next decade as the sustainability issue is becoming more important as time goes. Studies on organizational capability

of running Green ISs have attracted a good amount of attention of scholars in the early but its growth became slow after that. Design science studies gained momentum only after 2015 and is growing in good shape. We were able to find only three literature review articles during the period. They are balanced in 2011, 2017 and 2020. The review studies are mainly focused on the adoption of Green ISs.

Ⅲ. Findings

1. Theoretical frameworks and methods

The most popular theoretical framework used in the studies is Resource based View(RBV) that indicates that Green IT/ISs influence other organizational resources and processes to improve organizational performance. RBV has been applied to explain wide Green IS related phenomena including the adoption, value and capability of Green ISs.

Belief-action-outcome(BAO) framework (Melville, 2010) is another one that were used in multiple studies. It asserts that organizational and individual behaviors are the result of belief and action on the micro and macro level(Melville, 2010). This theoretical framework has been applied mainly to explain the adoption and values of Green ISs.

On the other hand, institutional theory has mainly been applied to explain how and why organizations adopt Green IT/ISs in organizational level. The theory particularly highlights the importance of external and internal factors including social, political and institutional forces that create pressure for organizations to adopt Green ISs and improve corporate social responsibility(CSR).

On the other hand, Norm Activation Model (Schwartz, 1977) is concerned about altruism of actors to elicit pro-social behavior. Three antecedents of the pro-social behavior include awareness of consequences, ascription of responsibility, and personal norms. A person considers consequences of his/her behavior in terms of negative impact to environment and society therefore affect decision on what actions to be selected in a given circumstance. Ascription of responsibility indicates that a person thinks about potential negative impact of note doing pro-social behavior. Personal norms enforce a person to make action which is in line with his/her value system.

IS evaluation framework is also used for evaluating values of Green IS adoption and operations(Jongsaguan & Ghoneim, 2017).

Majority of the studies take quantitative methods in developing theories. Structural equation modeling (SEM: Hair, 2016) to test hypotheses based on large scale survey data is the most popular. Exploratory Factor Analysis(EFA) is also frequently used in developing measurement instruments.

For qualitative methods, single or multiple case studies are the most popular. Content analysis is also used to evaluate the capabilities of Green ISs. Q methodology(McKeown & Thomas, 1988) is a qualitative method for explorative studies to induce theoretical concepts and their relationships from small or medium size of qualitative data.

2. Value of Green IS

The largest number of articles are investigating

〈표 2〉 그린 정보 시스템 분야에서 사용된 이론적인 프레임워크
〈Table 2〉 Theoretical frameworks used in Green IS studies

Framework	Description	Studies
Institutional theory	Organizations activities are influenced by institutional forces.	Carberry, et al.(2019); Hu, et al.(2016); Vykoukal, et al.(2010);
BAO(Melville, 2010)	Green behaviors are the result of belief and action on the micro and macro level	Anthony(2019); Baggia, et al.(2019); Molla, et al.(2014); Khuntia, et al.(2018); Loeser, et al.(2017);
Resource based view	Green ISs influence other resources or processes of the organizations to improve performances	Chen, et al.(2011); Dao & Carbo (2011); Elliot(2011); Nishant, et al.(2017); Nanath & Pillai(2017); Ryoo & Koo(2013); Benitez-Amado & Walczuch(2016); Chuang & Huang(2018)
Norm Activation Model (Schwartz, 1977)	Awareness of consequence, ascription of responsibility, and personal norms are antecedents of Green IS behavior	Asadi, et al.(2018); Dalvi-Esfahani, et al.(2018); Dalvi-Esfahani, et al.(2017); Loock, et al.(2013)
IS Evaluation Model		Jongsaguan & Ghoneim(2017); Anthony, et al.(2018)

the impact of Green ISs. The studies investigate how environmental, economic and societal values are created by using Green ISs. Table 3 summarizes studies that investigate major factors that affect Green IS performances. The identified factors are mainly classified based on theoretical frameworks selected in the studies. Studies that takes Resource based view(RBV) identify organizational resources, practices and processes as major factors that create organizational performances. Nanath and Pillai, (2017) identify Green IS implementation as the determinant of green innovation performance which in turn affects the competitive advantages of organizations. In their study, green innovation performance plays a mediator role between Green IS implementation and its economic value. Nishant, et al.(2017) on the other hand takes econometric method to verify positive relationship

between green innovation announcements made by organizations and their organizational performances including abnormal market returns and share trading volume. Ryoo and Koo(2013) also report that green practice and its IS alignment influences environmental performance, and coordination mediates the relationship.

Finally, Benitez-Amado and Walczuch(2016) argue that IT capability and proactive corporate environmental strategy make positive influence on firm performance. Similarly, Chuang and Huang(2018) take Green IT capital and electronic corporate social responsibility as the determinants of environmental performance and business competitiveness.

On the other hand, Belief-Action-Outcome (BAO) framework(Melville, 2010) is another popular theoretical framework to investigate

〈표 3〉 그린 정보 시스템 성과에 영향을 미치는 요인들

〈Table 3〉 Factors affecting Green ISs performances

Author	Theory	Method	Factors	Performance Variables
Anthony(2019)	BAO	SEM	IT professionals and executives' behavior	Environmental performance
Chuang & Huang(2018)	GIT capital	SEM	Green IT capital, electronic CSR	Environmental & competitiveness
Khuntia, et al. (2018)	BAO	Econometrics	Green IT investment & implementation	energy conservation and profit
Jongsaguan & Ghoneim(2017)	IS Evaluation	Case study	external and internal organizational factors	Green IT/IS indirect cost factors
Loeser, et al. (2017)	BAO	SEM	environmental orientation, Green IT/IS practices, Green IS strategies	cost reduction, corporate reputation, green innovation capabilities
Nishant, et al. (2017)	Natural-resourced view	Event study	Green innovation announcement	abnormal market returns, share trading volume
Nanath & Pillai(2017)	Resource based theory	SEM	Green IS implementation, Green innovation performance	competitive advantage
Corbett(2013)	Inf. processing theory	Econometrics	smart grid IS	energy efficiency of Utility corporates
Hasan & Meloche(2013)	Activity theory	Q methodology	Green IT activities (virtual team, production and manipulation of data, visualization of information)	green performance
Meacham(2013)		SEM	information sharing, green IS	Environmental performance
Ryoo & Koo (2013)	Resource based view (RBV)	SEM	green practice, IS alignment, coordination	Environmental performance
Seidel, et al. (2013)	Socio-Technical Systems (STS) theory	Case study	reflective disclosure, information democratization, output management, delocalization	sustainability transformation
Schmidt, et al. (2010)	Integ. Infor. Management model	EFA	Green IT	operational efficiency, reputation, market competitiveness
Benitez-Amado & Walczuch(2016)	Resource based theory	SEM	IT capability, proactive corporate environmental strategy	firm performance

the values of Green ISs. Anthony(2019) finds that IT professionals and IT executives' pro-environmental behavior positively influences environmental performance. He and his colleagues also develop a Decision Support System(DSS) to evaluate performances of Green ITs as well as performance nomenclatures for Green ITs including green design, production, procurement, operation, and disposal(Anthony, et al., 2018). Khuntia, et al.(2018) Green IT investment and implementation improve energy conservation and profit. Loeser, et al.(2017) takes the BAO theory to identify environmental orientation and Green IT/IS practices as the determinants of Green IS strategies which in turn affects performance including cost reduction, corporate reputation, and green innovation capabilities.

Apart from RBV and BAO, scholars take other theoretical frameworks to identify factors that affect Green IS values. Hasan and Meloche(2013) adopt activity theory and use Q-methodology to identify main organizational activities that affect green performance. They include Green IT activities including virtual team, production and manipulation of data, and visualization of information. Seidel, et al.(2010) use socio-technical systems(STS) theory to identify reflective disclosure, information democratization, output management and delocalization as the antecedents of the sustainability transformation of organizations.

3. Adoption of Green IS

The acceptance and adoption of new ISs in organizations poses challenges due to cultural, political, and organizational challenges. ISs scholars have been working on this issue since 1980 and there are still large number of articles addressing the issue are published on IS journals. One of the shared understandings on IS acceptance is that the acceptance of a new IS requires considering the type of the IS and organizational context therefore every new IS needs to take different approaches for different organizations.

As shown in Table 4, Scholars identified organizational, individual, and institutional factors that facilitate the adoption of Green ISs in organizations and their acceptance by organizational members during the last decade. Institutional theory and norm activation theory are two most popular theoretical framework to explain the adoption of Green ISs in organizational and individual level respectively.

Based on institutional theory, Carberry, et al.(2019) test that social movement activism, manager commitment and regulative pressure are determinants of the adoption of Green ISs using survey data collected from US. Hu, et al.(2016) on the other hand collect data from Taiwan and report that institutional factors including environment awareness, industry norms, customer and equity stake holders' attitude, and internal readiness make positive influences on the adoption of Green ISs. Vykoukal, et al.(2010) also report that external pressure affects grid assimilation as Green IT strategy in energy sector in Germany.

On the other hand, norm activation model is also a popular theoretical framework to explain individual level acceptance of Green ISs. Scholars adopting the model report that awareness of

〈표 4〉 그린 정보 시스템 도입에 영향을 미치는 요인들
〈Table 4〉 Factors affecting Green ISs Adoption

Author	Theory	Method	Adoption Factors
Centobelli, et al.(2020)	WH2 Framework	Content analysis	Sustainability leaders, green practice adopters, IS adopters and sustainability followers
Carberry, et al.(2019)	Institutional theory	SEM	Social movement activism, manager commitment, regulative pressure
Asadi, et al.(2018)	TPB, Norm Activation model	SEM	Awareness of consequence, ascription of responsibility, and personal norms
Brooks, et al.(2018)	CSR	Case study	employee attitude
Dalvi-Esfahani, et al. (2018)	Norm activation theory	SEM	Awareness of consequence, ascription of responsibility, and personal norms
Gholami, et al.(2018)	Theory of uses and gratification of media use	SEM	Content, social and performance gratification and environmental concern
Dalvi-Esfahani, et al. (2017)	Norm activation theory, Schwartz's values system	SEM	Awareness of consequence, ascription of responsibility, and personal norms
Hu, et al.(2016)	Institutional theory	SEM	environment awareness, industry norms, customer and equity holders' attitude, internal readiness
Lekakos, et al.(2014)	Needs theory, TAM, psychological distance theory	SEM	company social responsibility
Cai, et al.(2013)	Stakeholder theory	SEM	political and economic (cost reduction and differentiation) factors
Marett, et al.(2013)	Self-determination theory	SEM	economic benefits and industry pressure
Chen, et al.(2011)	Natural-resourced view	SEM	mimetic and coercive pressures
Vykoukal, et al.(2010)	Institutional theory	SEM	external pressure
Baggia, et al.(2019)	BAO	SEM	stake pressure and employee's environmental sustainability attitude

consequence, ascription of responsibility, and personal norms as influencing individuals' acceptance of Green ISs in Malaysia (Asadi, et al., 2018; Dalvi-Esfahani, et al., 2018; Dalvi-Esfahani, et al., 2017).

4. Green IS Capability

As summarized in Table 5, this group of studies are investigating organizational and human capabilities to develop and maintain long-term green performances. Four types of organizational capabilities are reported in the literature. Task technology fit is an organizational capability with regards to alignment between Green IT/ISs and organizational processes and tasks. Yang, et al.(2018), for example, assert that operational fits between Green ISs and green supply chain management as the result of functional deployment has long-term impact on environmental and social performances of Chinese companies. Hedman and Henningsson(2016),

〈표 5〉 그린 정보 시스템 운영을 위한 역량요인들
〈Table 5〉 Organizational Capabilities for Green ISs

Capability	Studies	Findings
task technology fit	Yang, et al.(2018)	Capability to have operational fits between GIS and GSCM as the result of functional deployment has long-term impact on environmental and social performances
	Hedman & Henningsson (2016)	Green IS initiatives become part of a firm's overall strategy and part of the organizational sustainability process
	Ajamieh, et al.(2016)	Green Supplychain (capability) mediates IT infra/competitive aggressiveness and firm performance relationship
Green IT assimilation	Cooper & Molla(2014)	Organizational context and IT absorptive capacity influence Green IT assimilation in organizations
	Molla, et al.(2014)	Green IT belief, attitudes, information acquisition capability, and organizational fields influence green IT behaviour
Green IS operation	Parker, et al.(2014)	Three themes (location, presentation and specificity) to form a theoretically informed framework to explain how SME websites present green contents
	Gawin & Marcikowski (2017)	The capability of exploring business intelligence facilitate energy efficiency of facility management retailers.
organizational readiness	Molla(2013)	17 eSITP(environmentally sustainable IT performance) instruments to explain IT firms' environmental sustainability performance
	Bose & Luo(2011)	integrated framework to assess firms' readiness to go green via IT-enable virtualization

on the other hand, argues that Green IS initiatives needs to be part of a firm's overall strategy and part of the organizational sustainability process to ensure long-term performances.

Ajamieh, et al.(2016) also reports that a firm's IT infrastructure and competitive aggressiveness affect firm performance when they improve green supply chain capability.

Green IT/IS assimilation is an organizational capability to assimilate Green IT/ISs seamlessly within organizations to support tasks and processes. Cooper and Molla(2014) argue that Organizational context and IT absorptive capacity influences Green ITs assimilation in organizations Molla, et al.(2014) also assert that Green IT belief, attitudes, information acquisition capability, and organizational fields influence green IT behavior of organizational members.

On the other hand, Parker, et al.(2014) and Gawin and Marcikowski(2017) reports organizational capability to operate Green ISs. Parker, et al.(2014) propose a theoretical framework for the design

of green web content including three themes of webpage design: location, presentation and specificity. Gawin and Marcikowski(2017) on the other hand, argue that the capability to exploit business intelligence in facility management is crucial for green initiatives and develops benchmarking scenarios for applying business intelligence in managing energy efficiency in facility management industries.

Finally, organizational readiness to implement sustainability agenda is another important capability. Molla(2013) propose 17 environmentally sustainable IT performances instruments which can be used to measure organization's readiness to implement Green ISs. Bose and Luo(2011) propose an integrated framework to asses firm's readiness to go green via IT-enable virtualization.

5. Green IS Design

Meaningful number of studies focused on novel design of Green ISs. Novel design of Green IT/ISs have long been studied in Engineering disciplines including Computer Science(Brown & Reams, 2010), Energy(Henning, 1997), and Environment Engineering(Turon, et al. 2007).

This paper focus on studies taking IS perspective therefore limited the search on the articles published on the Management journals. In Management discipline, Operations Research scholars have been developing optimization models and algorithms to save energy consumption in logistics (Lee, et al., 2017; Aydin, et al., 2017), manufacturing (Gahm, et al., 2006), and Building Energy System(Hu, et al., 2012) among others. We excluded those articles from our analysis.

Table 6 summarizes selected studies that takes design science approaches for Green ISs. The studies can be classified into two categories according to their design artefacts. The first group of studies propose novel design of Green ISs to solve sustainability issues of organizations.

〈표 6〉 그린 정보 시스템 분야에서의 Design Science 연구들
〈Table 6〉 Design Science Studies in Green ISs

Artefact	Study	Description
Novel designs	Guerlain, et al.(2019)	A DSS for sustainable logistics for construction industry
	Anthony, et al.(2018)	An agent-based green IS assessment tool
	Piel, et al.(2017)	A model for the quantification of location-based investment incentives in RE support mechanisms
	Shokouhyar, et al.(2017)	Green IS assessment tool based on Fuzzy Analytic Hierarchy Process and Fuzzy Screening Procedure
	Hilbert & Kranz(2013)	A Green IS artifact for GhG emission tracking in logistics
Design principles	Seidel, et al.(2017)	Design principles for IS to support organizational sensemaking in environmental sustainability transformations
	Corbett(2013)	developing design principles for persuasive GISs
	Loock, et al.(2013)	Goal setting make positive impact on energy conservation behavior

Guerlain, et al.(2019) design and validate a Decision Support System(DSS) to improve sustainability of logistics of construction companies. Anthony, et al.(2018) adopts a multi-agent system approach to design a tool to assess the maturity of Green ISs. Shokouhyar, et al.(2017), on the other hand, adopts Fuzzy Analytic Hierarchy Process and Fuzzy Screening to develop a decision support system to assess Green ISs. Piel, et al.(2017) develop a model for the quantification of location-based investment incentives in renewable energy support mechanisms to foster spatially diversified capacity deployment. Finally, Hilbert and Kranz(2013) develop a Green IS artifact for GhG emission tracking in logistics.

The second group of studies aim at proposing design principles of Green ISs. Seidel, et al.(2017) propose and validate design principles for ISs that support organizational sensemaking in environmental sustainability transformations. Corbett(2013) also develops design principles for persuasive Green ISs that facilitate pro-social behavior of organizational members. Loock, et al.(2013)conduct an experiment to confirm that goal setting makes positive impact on energy conservation behavior of organizational members.

6. Opinions on Green IS Research

Opinion articles are mostly distributed in the early 2010s when the issue of sustainability started attracting attentions of IS scholars. Watson, et al.(2010) proposes a new research agenda focused on energy informatics for IS scholars to foster changes that reduce environmental impact. Carter-

Steel and Tan(2010) highlights the importance of sustainability awareness by IT Service Management sector CIOs and IT Service Managers. Dedrick(2010) notes the role of Green IT/ISs to enhance carbon productivity as the former can increase the energy efficiency of building, logistics and supply chains operations. Melville(2010) based on BAO framework develops research agenda of Green ISs. On the other hand, Elliot(2011) adopts resource-based view to define holistic, transdisciplinary and integrative framework for business transformation using Green IT/ISs. Pitt, et al.(2010) develop research agenda focused on the use of smartphone for sustainable environment. Loos, et al.(2011) identifies challenges for environmental management information system(EMIS), green informatics and green business process management, and propose future research directions. Chowdhury(2012) define the concept of Green information retrieval and proposes research agenda in the area. Gholami, et al.(2016) argues that too few IS scholars are engaged in impactful Green IS studies and summarizes barriers including incentive misalignment, the low status of practice science, data analysis poverty, identification of the proper research scope, research methods. Seidel, et al.(2017) report panel discussion on Green ISs and shed a light on how IS scholars can accumulate knowledge and promotion of Green IS studies. Finally, Lee, et al.(2020) recently argues that the trend of virtualization due to COVID19 further highlights the importance of Green IT/ISs as more energy consumption is expected by IT infrastructure. In particular,

more studies on data centers to minimize energy consumption.

Ⅳ. Discussion and Future Research Agenda.

There are three existing studies that review Green IS papers in the literature. Singh and Sahu(2020) classify existing studies on Green ISs into five categories including understanding, adoption, impact, measures and policies, and global context. Understanding category includes studies on definition, evolution, and dimensions of Green ISs. Adoption category includes studies on critical success factors and technologies of Green ISs. Impact studies are classified according to industry, government and society level. Measures and policies category is concerned with the performance measures, policies and regulatory compliances. Finally, global context is about studies in different countries including developed, developing and under developed countries. Asadi, et al.(2017) on the other hand classify existing Green IS studies between 2007 and 2016 into four categories including adoption, initiation, approaches and strategy, and benefits. Jenkin, et al.(2011b) develops a multilevel research framework for future research directions for Green IT studies. They review studies on Green ISs from more broad perspective including management, environmental psychology, and social marketing.

Compared with those studies, this study focused on managerial aspects of Green ISs by targeting peer-reviewed articles published in Information Systems and Management journals. Also, this paper review theoretical frameworks

applied in Green IS literature and shed a light for future research directions by identifying theoretical gaps. Also, this study reviews studies taking design science approach.

Based on the review, following research gaps are identified therefore provide scholars with future research directions.

Firstly, the literature requires more studies that apply psychological theories in the design of Green ISs to change human behavior toward pro-environmental behavior. Corbett(2013)'s study is an example that apply persuasive system design principles for carbon management system to persuade employees to conduct ecologically responsible behaviors. Psychology theories like Elaboration Likelihood Model(Petty & Cacioppo, 1986) has been widely used in Advertising(Dotson & Hyatt, 2000). ELM indicates that persuasive messages change receivers' attitude through two routes: central and peripheral routes. A central route persuasion is made when message receiver has time and interest in the message and put enough elaboration on the message contents. The argument quality of the message activates central route persuasion. If message receivers do not meet the conditions for the central route persuasion then peripheral cues can be activated. For example, a message comes from credible source(celebrity is advertising a product or service on TV), the receiver tends to put more elaboration regardless of the argument quality of the message contents. On the other hand, ELM has also been applied in other disciplines including Information Systems. Lee, et al.(2017b) apply it to derive design principles for persuasive mobile participation system that use citizens contexts including current

locations to present them with context relevant policy issues for their participation. Scholars need to investigate more psychology theories to be applied in the design of Green ISs to induce pro-environmental behavior from citizens. Cialdini(2000)'s six types of peripheral cues for persuasion is another example of such theories.

Secondly, the energy efficiency of IT/ISs will be more important and more efforts to make IT/ISs are required. Recent lockdowns due to COVID19 pandemic are changing the way we work, socialize, and educate based on virtualization technologies based on online(video) conferencing systems. This inevitably increases the Internet traffic dramatically. Our reliance on IT/ISs will be aggravated after COVID19 and the energy consumption of IT facilities will increase exponentially. Developing energy efficient computing systems have been actively sought by scholars in Computer Science and Electronic Engineering. Their focus is on the design of computing systems and the outcomes of such studies are new generation of energy efficient hardware and software. However, replacing legacy systems with energy efficient new systems can cause significant cost and sometimes, it makes sense to operate legacy systems in an energy efficient way. Lee, et al.(2020) provides few examples of saving energy consumption by data centers by optimizing the operation of cooling devices which consumes around 50% of total energy consumption of data centers. Scholars can further investigate motivational factors of data center managers to adopt and implement strategies for energy efficient system operations. In data centers context, managers

are putting the higher priority on ensuring the maximum level of service usability which inevitably results in unnecessary cooling of data center rooms. More scientific analysis of the trade-off relationships between service quality and energy efficiency is needed to convince IT/IS practitioners.

Thirdly, biodiversity has been another critical issue in sustainability discipline. Green IS studies are mostly focused on energy efficient IT/ISs and IS support for business processes to minimize environmental impacts by reducing CO_2 or Green-house-gas emissions. Green IS scholars need to take attention on the negative impact of IT/ISs and business processes on biodiversity. Measuring impacts of business processes of organizations on biodiversity is one research issue and understanding the values of Green ISs in terms of biodiversity is another one.

Fourthly, the number of studies that develop design principles of effective Green ISs is relatively small and further efforts on this area are required in the future. There are only two papers that propose design principles of Green ISs in this review and it needs more. The design principles for Green ISs are expected to be different for different applications including logistics & supply chain, smart grid, and IT facility management among others.

Acknowledgement

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〈Appendix A〉 The number of Articles selected from Target Journals

Journal	No	Journal	No	Journal	No	Journal	No
MISQ	6	CAIS	2	Inf Tec & Pep	1	Benchmarking	1
JMIS	2	JSIS	2	Ethic Inf Tech	1	Sustainability	2
JAIS	3	BISE	1	Elect Jr of IS Eval	1	IJIM	1
ISF	5	Inf & Org	2	JEIM	1	Biz Str & Env	1
ISM	3	Biz & Soc	1	Tel & Inf	1	IJBIS	1
EJIS	2	Inf Proc Mgt	1	Ind. Mgt&Dat Sys	1	Jr Case on IT	1
AJIS	7	Mgt Res Rev	1	POM	1	IJITM	1
ISJ	3	EJIM	1	Jr Biz Ethics	1		
JBR	1	IJPE	1	Jr Dec Sys	1		

MISQ: MIS Quarterly
JMIS: Journal of MIS
JAIS: Journal of AIS
ISF: Information Systems Frontier
ISM: Information Systems Management
EJIS: European Journal of Information Systems
AJIS: Australian Journal of Information Systems
ISJ: Information Systems Journal
JBR: Journal of Business Research
CAIS: Communications of the AIS
JSIS: Journal of Strategic Information Systems
BISE: Business and Information Systems Engineering
Inf & Org: Information and Organizations
Biz & Soc: Business and Society
Inf Proc Mgt: Information Processing Management
Mgt Res Rev: Management Research Review
EJIM: European Journal of Innovation Management
IJPE: International Journal of Production Economics
Inf Tec & Pep: Information Technology & People
Ethic Inf Tech: Ethics in Information Technology
Elect Jr of IS Eval: Electronic Journal of Information Systems Evaluation
JEIM: Journal of Enterprise Information Management
Tel & Inf: Telematics and Informatics
Ind. Mgt & Dat Sys: Industrial Management and Data Systems
POM: Production Operations Management
Jr Biz Ethics: Journal of Business Ethics
Jr Dec Sys: Journal of Decision Systems
Benchmarking: Benchmarking, An International Journal
IJIM: International Journal of Information Management
Biz Str & Env: Business Strategies and Environment
IJBIS: International Journal of Business Information Systems
Jr Case on IT: Journal of Case on Information Technology
IJITM: International Journal of Information Technology Management