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Integrative framework for assessing firms' potential to undertake Green IT initiatives via virtualization – A theoretical perspective

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ABSTRACT

Green IT (information technology) has recently emerged into an active research area in the information systems (IS) discipline. A major gap that exists in the Green IT research literature today is the absence of a theoretical framework that can be used to assist organizations in assessing their potential for undertaking Green IT initiatives and implementing them via modern technological means such as virtualization. This study attempts to bridge this gap by developing and proposing an integrative framework which focuses on identifying and examining the factors that contribute to the assessment of a firm's readiness to go green via IT-enabled virtualization. The framework is firmly grounded using three well-established IS theories: (a) technology-organization-environment, (b) process-virtualization, and (c) diffusion of innovation. It integrates these three theoretical lenses to utilize the strengths of each for assessing the potential for undertaking Green IT initiatives and the stages of Green IT implementation at the organizational level. The implications of the outcome of this study, both for the IS researchers and for the practicing managers are discussed. The plan for empirical testing and validation of our propositions is presented, as well as suggestions for future extensions of this study.

1. Introduction

The current global financial and energy crisis, coupled with the growing sense of urgency by the citizens, have galvanized businesses, governments, and nonprofits around the world to contemplate incorporating greener practices in all areas of the society. This nascent phenomenon has become the catalyst for the emergence of Green IT (information technology), which has piqued increasing interest among information systems (IS) researchers, business practitioners, and politicians in recent years. Originating from environmentally friendly movement towards more effective and efficient organizational and national strategies and policies worldwide, Green IT refers to the using of IT resources in an energy-efficient and cost-effective manner. It is expected to be the most important strategic technology in the imminent future, as there lies a IT value paradox (Thatcher and Pingry, 2007) where IS has become not only an inseparable strategic weapon augmenting organizations' business sustainability and also inevitably ushers social, economical, and ecological significances with its demand for ever-increasing energy consumption. With energy costs increasingly soaring, there is a growing demand for solutions that can reduce the need for IT-driven energy and make more efficient use of existing resources for organizations. In addition, it is also expected that the Green IT service market will reach nearly $5 billion by 2013 (Mines, 2009). Organizations are now actively pursuing Green IT solutions for a multitude of reason and benefits, including reduce power consumption, lower

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costs, lower carbon emissions and environmental impact, improved systems performance and use, increased collaboration and interaction amid constituents, space savings, and an agile workforce.

Esty and Winston (2006) revealed how companies generate lasting value – cutting costs, reducing risks, increasing revenues, and creating strong brands – by building environmental thinking into their business strategies. They explored what every executive must know to manage the environmental challenges facing society and business. According to a 2009 Green IT report surveying 426 companies in North America and a total of 1052 worldwide, 86% of companies stated that it is somewhat/significantly important that their IT organization implement Green IT initiatives. The report also found that 97% of companies are at least discussing a Green IT strategy (Symantec, 2009). In addition, a recent CIO magazine survey of IT executives revealed that *cost-cutting* and *social responsibilities* are the two main factors driving Green IT initiatives (CIO, 2008). UN's agenda 21 program, for sustainable development, provides a comprehensive blueprint of action to be taken globally, nationally, and locally by organizations of the United Nations, governments, and others to preserve the environment. In 2009, the European Commission called on the IT industry to step up efforts to cut emission by 15% by 2020. Their new action plan aims to establish common energy-efficiency metrics and industry-wide emission targets. At the same time, CIOs are considering how to best undertake Green IT initiatives, especially in time of shrinking IT budgets and increasing environmental compliance requirements in terms of ensuring socially responsible, environmentally friendly, and fiscally sound IT investments and practices. Given the above mentioned practical advantages for Green IT, many organizations are keen to understand how to accept and initialize Green IT schemes and further harness them toward competitive advantages (Esty and Winston, 2006; Velte et al., 2008; Watson et al., 2010). As such, there is a compelling and timely need to understand the salient facilitators that are important for assessing organizations' potential vis-à-vis possible Green IT approaches.

The Green IT strategy, design, and practice initiatives within organizations have recently emerged into an active research area in the IS discipline. However, the extant Green IT literature is heavily based on case studies, anecdotes, and survey of current practices thus quite fragmented and scattered. A major gap that exists in the literature today is the absence of a theoretical framework that can be used to assist organizations in assessing their potential for undertaking Green IT initiatives and then implementing them via modern technological means such as virtualization. To advance this line of research, this study attempts to bridge that gap by developing and proposing an integrative framework which focuses on identifying and examining the factors that contribute to the assessment of a firm's readiness to go green via IT-enabled virtualization. This study is targeted to both Green IT researchers and practitioners. The proposed framework is intended to provide a roadmap for future Green IT research and development. The comprehensive review of the current Green IT literature and practice that is provided herewith is intended to assist managers – who are currently or contemplating practicing Green IT in their organizations – by keeping them abreast with current practices and by helping them identify areas of practice where their organizations can have immediate impact on energy conservation.

The paucity of scientific investigations in the literature limits our understanding of the process of virtualization for achieving Green IT. Most competitive organizations today are seeking to create a dynamic infrastructure that converge business and IT infrastructure to work in concert to achieve high levels of productivity and business value. At present, the key facilitator to building a dynamic infrastructure is the virtualization process. As an organizational design practice that results in flattened organizational structures, larger spans of control, and extensive geographically dispersed work, virtualization allows IT to respond more quickly to changing business demands (Liu et al., 2008). Consolidating resources through virtualization increases the efficiency of organizational resource utilization. Advances in the technology, along with higher degrees of automation, offer more opportunities for consolidation than ever before. IT virtualization reduces costs for hardware, improves software testing and deployment, reduces energy and physical space use, and increases the flexibility of hardware investments. Similarly, automation of business processes through virtualization (e.g., online electronic commerce) enables increased utilization of business resources, time and space flexibility for the participants and operations of the process along with reduction in cost and improved service delivery to customers. As such, we posit that virtualization is one of the possible means that today's organizations can employ to respond to the requirement for "Reduce, Reuse, Recycle", the global green mantra (Velte et al., 2008). In this paper, we argue that virtualization is the primary force for organizations to integrate environmental sustainability into business and IT practices and therefore treat it as the underpinning of this study. One general research question drove this study: What framework can be used as a theoretical foundation for studying Green IT across different stages?

Our approach diverges from the majority of prior research because we posit that virtualization, which can provide most of the business drivers to make Green IT happen, needs to be holistically viewed and investigated. Drawing on the technology-organization-environment (TOE) framework (Tornatzky and Fleischer, 1990) and the process-virtualization-theory (PVT) framework (Overby, 2008), this paper breaks new ground by presenting an integrative research model that incorporates these theoretical lenses to synergistically achieve the strengths of each for assessing the potential for undertaking Green IT initiatives and the stages of Green IT implementation at the organizational level. Grounded in the innovation diffusion literature (Fichman, 2000; Rogers, 1995), the model defines Green IT implementation as a series of stages from a firm's initial evaluation of Green IT at the pre-adoption stage (i.e., initialization), to its formal adoption (i.e., integration), and finally to its full-scale deployment at the post-adoption stage in which Green IT becomes an integral part of a firm's value chain activities (i.e., maturation).

In an effort to contribute to the literature of Green IT, the model that we propose links technological, organizational, and environmental factors to the potential for undertaking Green IT initiatives. In essence, the main constructs and underlying theories of the PVT framework are applied to the technological factors to assess the *virtualizability* of the Green IT initiatives.

In addition to extending previous research on Green IT, the study proposes that sensory readiness, relationship readiness, synchronism readiness, identification and control readiness, champion support, resource commitment, firm size, regulatory support and competition intensity are important antecedents of undertaking Green IT initiatives via virtualization. Based on this research model a series of propositions are developed. We expect that the outcome of this study will provide business managers with the knowledge and guidance regarding the development and implementation of Green IT initiatives in their organizations. Actions can be devised regarding appropriate management/leadership and technical approaches. In other words, the integrative theoretical framework presented in this study will help inform Green IT practice in organizations. At present, there is a dearth of empirical research in the area of Green IT. Additionally we expect that this study will help the IS research community: to empirically test and validate the propositions made in our research model, and to articulate a future research agenda for this emerging and important field.

The rest of the paper is organized as follows. An overview of Green IT is provided in Section 2. The three frameworks – TOE, PVT, and Innovation Diffusion – are summarized in Section 3 to set up the theoretical foundation of our study. Section 4 describes our proposed research model and the propositions based on this model. Section 5 discusses the implications of this research from the perspectives of both: research and practice of Green IT. Methodological implications and validation approaches are also presented to set the stage for future research on Green IT to further refine and validate the framework. The concluding remarks are provided in Section 6 as well as the limitations of this research and plans for future research.

2. Overview of Green IT

In the face of ever-increasing energy costs, researchers, practitioners, and governments are now seeking effectively initiatives to regulate inefficient energy use by global business enterprises. For example, the UK government aims at decreasing greenhouse gas by 20% before 2020 (Capra and Merlo, 2009). IT now plays a crucially important role in the environmental and energy issues related to Green IT, because Green IT may refer to three primary research areas: (1) energy efficiency of IT, (2) eco-compatible management of the lifecycle of IT, and (3) IT as an enabler of green governance (Capra and Merlo, 2009). In essence, IT enhances organizational efficiency via substitution for more costly labor and regular capital, and enables new processes and services (Chwelos et al., 2010). Having been conceptualized in several ways, Green IT, in general, focuses on designing, manufacturing, using and disposing of computer, servers and associated subsystems efficiently and effectively with minimal or no impact on the environment (Dedrick, 2010). Organizations today are conscientious about being "green," but they are not sure how to go about it. The emergence of Green IT as an important strategic issue has been triggered by the recognition that environmental sustainability, which was once little more than a moral incentive for companies, has now become an imperative to doing business and hence an imperative for IT (Esty and Winston, 2006; Murugesan, 2008; Velte et al., 2008; Watson et al., 2010). Prior studies have stated that, via an input-production-output chain, IT capital is an element in a production function through which inputs are transformed to outputs via a production process. As shown in Fig. 1, information systems can influence the greening process and the ability to sustain economic growth as IT capital is an input into this process and is also the energy required to use IT.

Consequently the breadth and depth of the knowledge on the greening process are steadily evolving and are being increasingly studied by organizations to help them develop their Green IT strategy. Due to this evolutionary stage of Green IT, today being "green" means different things to different organizations – that is, there is still a lack of a universal understanding (Velte et al., 2008). Organization, by definition, is a collective, with individuals and larger units in different roles that involve different perspectives and values (March and Simon, 1993). Furthermore, the literature of organizational learning has suggested that, in regard to the different perceptions of greenness, learning-curve heterogeneity across organizations in terms of learning rates, industry environment, direction (i.e., dimension) as well as goal orientation influences the direction of learning (Balasubramanian and Lieberman, 2010). Their explanation of the meaning of being "green" depends on their preference for the path ranging from e-waste management to electrical power control they would like to pursue. Thus, for some organizations, it might mean buying technology that is more energy-efficient than what they have. Whereas others might suggest that it is an issue of reducing the amount of electricity their datacenter consumes. For some others, it might mean buying hardware that is made of environmentally friendly components. Yet for others they might look at the end of hardware life and suggest that Green IT means proper disposal of them. Green IT is definitely a combination of all of the

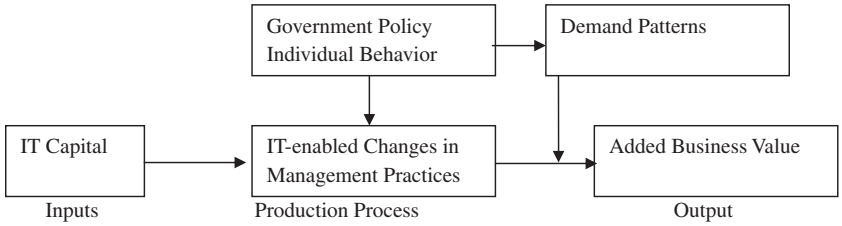

Fig. 1. Green IT process (adapted from (Dedrick, 2010)).

Table 1
Opportunities and challenges of Green IT (Source: Molla et al., 2009).

Opportunities/drivers of Green IT	Challenges/barriers of Green IT
Reducing cost of IT (80%)	Cost of Green IT solutions (71%)
Corporate strategy (79%)	Unclear business value of greening IT (48%)
Environmental consideration (77%)	Lack of government incentives (44%)
Social acceptance (71%)	Lack of business leadership on Green IT (43%)
Maturity of Green IT industry (64%)	The extent of IT sophistication (41%)
Government regulations (57%)	Inadequate skills and training (36%)
Government incentives (54%)	The extent of Green IT adoption in the industry (34%)
Clients'/consumers' pressure (48%)	Absence of enforceable government regulations (33%)
Industry associations (29%)	
Competitors' actions (20%)	
IT vendors' pressure (14%)	
Green IT uptake by more organizations (46%)	

aforementioned issues and beyond. Nevertheless, each of the above organizations, irrespective of their conceptualization of what being "green" means, is making positive contributions to themselves and to the environment.

The current literature on Green IT research and practice suggest that there exist factors beyond the control of IT which help create a sense of urgency in Green IT. Businesses are increasingly beginning to comprehend that "greening" is possible while making a solid return on the investment. The three primary drivers of Green IT initiatives according to the literature are: (1) reducing costs due to budget cuts, (2) reducing consumption due to resource restrictions, and (3) complying with the local law. Additionally, a study based on a survey of 143 organizations from USA, Australia, and New Zealand (Molla et al., 2009b) reported the current drivers and inhibitors of Green IT adoption, which are summarized in Table 1. The number inside the parentheses represents the percentage of respondents who agree.

In extant IS literature, the heightened importance of ecological sustainability has generated an array of research on Green IT/IS (Watson et al., 2010). As such, a number of methodological approaches have been devoted to understanding: (1) conceptualization of Greenness (Ijab et al., 2010), (2) the intersection of environmental responsibility and global IT outsourcing (Babin and Nicholson, 2009), (3) organizational adoption of Green IS and IT, (4) develop and justify energy conservation measures for Green IT (Corbett et al., 2010), (5) identify a set of software complexity and quality metrics that can be used to estimate energy consumption and to compare specific software applications (Capra and Merlo, 2009), and (6) define and measure green-readiness (Molla et al., 2009a). There is now a consensus about the direct and negative effects of the IT industry and the IT artifacts on the environment. In essence, such theories as transaction cost theory, institutional theory, and organizational-capability-based theory have already been employed to explain why one type of organizational structure (i.e., go green) is adopted over others. Transaction cost theory posits that organizations decide on a specific governance structure based on its ability to economize on the cost of doing business. As such, reduced cost is a major factor in adopting virtual work environment by managerial decision-makers (Liu et al., 2008). As a complementary explanation to transaction cost theory, organizational-capability-based theory holds that the capabilities of an organization define its boundaries and structure (Ghoshal and Morgan, 1996). It has been found that novel structures are adopted by the organization when they help the organization utilize its capabilities to realize business value. Therefore, such innovation as virtualization may aid in implementing capabilities accessible to potential adopters. In addition, institutional theory provides a useful theoretical lens to study the organizational response to environmental issues from mimetic pressures, mimetic coercive, and coercive pressures. It posits that organizations are subject to external influences, such as institutional pressures and promotion, which cause them to become homogeneous. IS studies have recognized the significance of institutional forces as important predictors of the adoption and diffusion of IS products and practices (Chen et al., 2009; Liang et al., 2007).

In recent years the concept of process virtualization has been playing a major role in designing and implementing a dynamic business environment. The capabilities and availability of the virtualization technologies and the current economic climate are the main drivers toward this movement. Process virtualization includes both the virtualization of the IT infrastructure of an organization as well as the virtualization of its business processes. It is conceptualized as the application of intelligent, network-enabled (Applegate, 2003), automation within and across the organizational boundaries to leverage its people, capital, technology, and knowledge resources to achieve significant improvements in productivity, value, and competitiveness. Examples include e-business capabilities from business process point of view as well as server virtualization in the datacenters from IT infrastructure point of view.

Despite the fact that a downside to virtualization is that its complexity requires frequent maintenance and support tools (Ruth, 2009), process virtualization is the main driver of Green IT implementation in organizations building environmental thinking into their business strategies (Harris, 2008). While virtualization ushers complexity and difficulty for system administrators to visualize and the problems may persist before the proper tools are employed, the downside risks are overwhelmed by the benefits. In general, the primary reasons being: (1) virtualization helps consolidate resources – both IT-based and non-IT-based resources – which help increase the efficiency of organizational resource utilization; and (2) virtualization adds flexibility in terms of time and space to efficiently conduct business processes which help contribute to cost savings and to improving the overall process effectiveness. Process virtualization's aim is to improve efficiency and reduce

overhead. We envision that the application of powerful computer platforms, combined with enabling software and high-capacity networks, to provide the fabric with which the virtual business infrastructure for Green IT initiative implementation will be created. Thus, process virtualization would involve the application of these technologies in the context of a single individual, a team, a department, a business unit or the entire company to improve efficiency and reduce overhead. From a managerial perspective, virtualization increases IT's agility because managers can help their organizations convert shorter time to market into market share and top-line revenue growth (Willoughby, 2010). For an organizational end-user, a purpose-built or on-demand application can be dynamically delivered to any end-user device with the settings and services required by the individual user. Thus, this process of decoupling all key components of the user environment from the underlying system may significantly simplify system control and management in terms of network configuration and policy specification. For the aforementioned reasons we contend that process virtualization is the primary force for organizations to integrate and implement environmental sustainability into their business and IT practices.

The current literature on Green IT research and practice additionally suggest that businesses can become involved in shaping Green IT policies and reducing their organization's carbon footprint in three critical areas: (1) asset management, (2) energy efficiency, and (3) enabling green practices through the utilization of IT (Murugesan, 2008; Schreck and Dines, 2009). Asset management includes the design, procurement, operations, and end-of-life management of IT equipments or products with the goal to reduce the burdens that these products have on the environment (McKinsey, 2009). IT products have a significant impact on the environment. They contain chemicals known to be threat to human health and the environment – lead, mercury, cadmium and brominated flame retardants among them. They create e-waste at the end of their lifecycle.

Achieving the highest return on IT assets is a balancing act. Asset managers have to find an optimal solution juggling four key variables/constraints: (a) achieving highest levels of reliability, (b) at the lowest cost, (c) within a compliance framework, and (d) with limited resource. Asset management thus aims to maximize the value of critical assets over their lifecycle. Optimizing the energy efficiency of the business and IT infrastructure is critical to demonstrate the value of green. The optimization functions to be used are firm-specific and are determined based on their IT readiness and infrastructure. Desktop and enterprise computer equipment require significant energy to operate, leading to increased greenhouse gas emissions. Today, large consolidated data centers alone use more than 5% of all electricity consumed in the United States. The Green Grid, an industry consortium dedicated to improving energy efficiency within data centers and business computing systems, is responsible for defining and promoting the most effective energy efficiency practices in data center operations, construction and design in order to help solve the problems related to power consumption, power conversion and energy efficiency that are plaguing data centers worldwide. Energy efficient IT infrastructures can consequently reduce costs, resolve space, power and cooling constraints that impact growth, improve flexibility and responsiveness, and achieve Green strategy objectives.

Many businesses are considering a new computing paradigm, called cloud computing, to optimize utilization and minimize cost of their IT infrastructure. Referring to both the applications delivered as services over the Internet and the hardware and systems software in the data centers that provide those services, cloud computing leverages shared infrastructure to deploy and balance IT resources to cater to the computing needs in real-time (Armbrust et al., 2010). As a catalyst for creating a paradigm shift and a wave of innovation and change in the globe (Greengard, 2010), cloud computing can help organizations of all sizes go green by providing a shared and on-demand infrastructure with virtualization capabilities (Durkee, 2010; Vouk, 2008). Thus, organizations can access services and infrastructure on an as-needed basis, and promote the ability to maintain distributed workforces. Virtualization is an energy-efficient consolidation technology found in cloud computing centers today. Virtualization helps reduce energy consumption and costs by increasing utilization and decreasing the number of servers and physical floor space in the data center (Kumar and Mieritz, 2007). It has been reported that virtualization has been shown to reduce floor space by 80% and energy consumption in data centers by 40%.

To address the corporate commuting and office space issues, and to offer flexibilities to both employees and employers, Telework has become an important contributor to green practices (Ruth, 2009), as companies such as IBM, Sun Microsystems, and Cisco have been using telecommuting for half their workforce for more than a decade. This environmentally friendly practice provides a multitude of benefits that include increased productivity, lower cost due to reduction in office space requirement, reduced business travel, and enables a virtual collaborative work environment (Butler et al., 2007; Westfall, 2004). IT's environmental impact can be significantly reduced by: (a) behavioral changes – by acting in an environmentally responsible manner and by developing and enforcing organizational policies aligned with the Green IT strategy undertaken by an organization; and (b) technology changes – by improving IT and business infrastructures to make them environment friendly. Table 2 summarizes the technological and behavioral changes needed to make Green IT happen. It focuses on increasing material and energy efficiency of an enterprise's IT infrastructure, business activities, and its IT-related product and services choices to reduce environmental impact.

This study is focused on developing an integrative theoretical framework that: (1) is grounded on IS research theories and findings, and (2) can be used to assess a firm's readiness to undertake Green IT initiatives through the virtualization process. Hence our research shares certain theoretical backgrounds that belong to the domain of Strategic IS research and development.

According to the strategic IS literature, IT-dependent strategic initiatives consist of identifiable competitive moves that depend on the use of IT to be enacted, and are designed to lead to sustained improvements in a firm's competitive position (Piccoli and Ives, 2005). Examples of such initiatives include ERP-enabled business integration, customer relationship management, and e-business among others. Our focus on IT-dependent strategic initiative in this study is rooted in a perspective

Table 2
Changes required for enabling enterprise actions toward a Green IT.

Technology changes	Behavioral changes
Increase material and energy efficiency of an enterprise's IT infrastructure	
• Dynamic IT infrastructure with cloud computing • Server virtualization and consolidation • Storage consolidation • Desktop virtualization and thin clients	• Develop policies for virtualization and consolidation of data processing and storage • Manage, measure, and regulate how your technologies consume energy • Server room upgrades, new buildings
Increase material and energy efficiency of an enterprise's business activities	
• Remote conferencing and collaboration • Telecommuting • Printer consolidation • PC power management	• Develop policy for reducing desktop printers and the amount of material that is printed • Develop policy for powering down equipment when not in use
Enterprise makes IT-related product and service choices that reduce environmental impact	
• Moving from CRTs to LCDs • New IT purchases conform to functionality standards • Asset disposal to include IT equipment recycling	• Develop policy for disposing IT equipment in a sound and environmentally friendly manner • Make energy conservation an acquisition objective for how you evaluate and procure technologies

that views strategy as consisting of the configuration of an activity system, dependent on IT at its core, that fosters the creation and appropriation of economic value (Brandenburger and Stuart, 1996).We term the implementation of Green IT initiatives as IT-dependent strategic initiative to highlight the fact that it could not be feasibly executed without the enabling technology foundation.

Aligning with the strategic IS concepts, we assume that the IT assets available to a firm include hardware (which includes network) components and platforms, software applications and environments, and data repositories. IT infrastructure of a firm is understood as "the base foundation of the IT portfolio (including both technical and human assets), shared through the firm in the form of reliable services" (Broadbent et al., 1999). The IT infrastructure provides the foundation for the delivery of business applications and services. The IT infrastructure varies from firm to firm in reach (the extent of the connectivity both within and outside of the firm), and range (the scope of services that it can support). As reach and range increase, the resources made available by the IT infrastructure, and its ability to support a wide range of strategic initiatives, increase as well (Broadbent et al., 1999).

Furthermore, a firm's ability to successfully carry out an IT-dependent strategic initiative depends on the availability of a set of resources and capabilities (Ross, 2003). The success of such an initiative is also critically dependent on carrying out effective Strategic Information Systems Planning (SISP) by the firm (Galliers, 1991). As the process whereby an organization determines a portfolio of computer-based applications to help it achieve its business objectives (Galliers, 1993; Lederer and Sethi, 1988), SISP focuses on aligning investment in IS with business goals, exploring IT for competitive advantage, directing efficient and effective management of IS resources, and developing technology policies and architectures (Chan and Reich, 2007; Dohertya et al., 1999; Min et al., 1999; Newkirka et al., 2003; Teubner, 2007). Effective SISP will help support innovations in a firm's IT-dependent strategic initiative (Galliers et al., 1998, 1995), such as the implementation of Green IT initiatives. For example, to support innovations in a firm's ecosystems – that is, their business partnerships with customers, suppliers, and other specialist firms (such as governmental agencies).

The assessment of a firm's innovation capability such as to undertake Green IT initiatives via virtualization is an important strategic activity. If a firm is found to have the innovation capability, the degree to which the characteristics and results of the innovation are discernible to others is linked to the rate of diffusion of the innovation (Moore and Benbasat, 1991). The implementation of the innovation in the firm over the years is studied using the Stages of Growth Model (Nolan, 1979). This stages theory is based on the premise that the organizations pass through a number of identifiable growth phases in utilizing and managing IT. These 'stages of growth' are then used to identify the organization's level of maturity in this context, with a view to identifying key issues associated with further IT development. Since the inception three decades ago, the initial 4-stage model has undergone several revisions and been further applied by the IS community. Galliers and Sutherland (1991) subsequently developed a revised 'stages of growth' model to take into account the socio-technical view of IS planning and also take account of the company's culture, staff, skills and organization structure necessary to implement the chosen strategy. Thus this model focused on internal alignment. While there has been some criticisms of these models in the IS research literature, many researchers however view the model as being useful in designating the maturity (in IT terms) of organizations. The main criticisms of the 'stages of growth' models have been the lack of substantiation based on empirical evidence, the overly simplistic assumptions on which it is based, and the limited focus of the original concept. Although the stages theory may be empirically elusive, it is acknowledged by both the academic community and the professional as one of the most popular models to outline the progression of the IS/IT within an organizations. Weick (1990) has pointed out that the 'stages of growth' models are not meant to be prescriptive but more of a sense-making device for studying adoption of new technologies in organizations. Furthermore, a number of studies have been conducted to produce empirical support for the theory (Drury, 1983).

Drawing from the above theory and upon the innovation diffusion literature (Fichman, 2000; Zhu et al., 2006), this study defines the assessment of a firm's innovation capability such as the decision to implement its Green IT initiatives via

virtualization as a series of stages. Beginning from the firm's initial assessment of its readiness to implement Green IT via virtualization which is the pre-adoption stage (Stage I – Initialization), to its formal adoption stage (Stage II – Integration), and finally to its full-scale deployment at the post-adoption stage (Stage III – Maturation) in which Green IT becomes an integral part of the value chain activities. While many of the existing research is focused on a single stage, such as one-shot adoption decisions, literature review by Fichman (2000) and Zhu et al. (2006) suggests that the post-initiation (i.e., post-initialization) stages of the undertaking of technological innovation are especially worthy of a focused study.

The IS literature (Armstrong and Sambamurthy, 1999; Sethi and King, 1994) suggests that the potential of IT to enhance a firm's performance in value chain activities (Porter and Millar, 1985) is a significant motivation for the firm to adopt IT. Applying this view to Green IT, we define *Green IT initialization* – the first stage, as evaluating and experiencing the benefits of Green IT to improve a firm's performance in value chain activities such as cost and energy consumption reduction. During the initial period organizations concentrate on learning the capabilities of virtualization for Green IT undertaking and gain confidence in its reliability. The focus is on proving its value to the organization. Following initialization is the stage of integration. Consistent with the technology adoption literature (Chau and Tam, 1997; Rogers, 1995; Zhu et al., 2006), we define *Green IT integration* – the second stage, as a shift from the acclimation with the fundamental concepts, benefits and tools of Green IT undertaking via virtualization to the strategic consolidation of Green IT undertaking via virtualization. This is possible due to the firm having reached a level of comfort with the virtualization concept and tools and their stability of use based on the experience and knowledge gained during the time period since initialization. After a new IT innovation adoption is integrated, it needs to be fully adapted, routinized, and institutionalized into the firm. *Green IT maturation* – the third stage, is defined as the stage in which Green IT via virtualization is widely and routinely used as an integral part in a firm's value chain activities. Additionally, it is used to take the operational efficiency of the firm to the next performance level through process improvement. In the information systems (IS) literature, routinization has been proposed as a significant dimension of IS success (DeLone and McLean, 1992). Thus, routinization itself is an important research construct for further study.

3. Theoretical foundation

In this study we posit that the *virtualization* process along with its supporting technologies is the main driver to make Green IT happen in organizations. Therefore, we attempt to holistically view and investigate virtualization within the context of organizational Green IT initiatives. The integrative framework that we develop is theoretically grounded using three well-established IS theories: (a) technology-organization-environment theory, (b) process-virtualization-theory, and (c) diffusion of innovation theory. The integrative model incorporates the above three theoretical lenses to synergistically achieve the strengths of each for assessing the potential for undertaking Green IT initiatives and the stages of Green IT implementation at the organizational level. A brief description of each of these theories is presented below.

3.1. Technology-organization-environment (TOE) theory

We provide the foundation to our integrative model by adopting the technology–organization–environment (TOE) theory developed by Depietro et al. (1990). According to this theory, the organizational adoption and implementation of technological innovations is influenced by three elements. First, the *technological context* refers to characteristics of the technologies which are available for possible adoption by the organization, and the current state of technology in the organization. This current state of technology can be expressed in both material (*e.g.*, equipment owned by the organization) and immaterial (*e.g.*, methods currently in use). Second, the *organizational context* consists of the organizational structure, the presence of innovation–enabling processes such as informal communication and strategic behavior of top management, and the size and slack resources of the organization. Third, the *environmental context* combines elements such as market structure and characteristics, the external support available for adopting new technologies and government regulations. These three elements are posited to interact with each other and to influence technology adoption decisions (Depietro et al., 1990).

Although the TOE theory has primarily been used to study the adoption of innovations, it does not provide concrete model describing the factors that influence the organizational adoption decision; it rather provides a taxonomy for classifying adoption factors in their respective context. The TOE theory has been used by a large number of studies to investigate the adoption of, for example, Electronic Data Interchange (EDI) (Kuan and Chau, 2001), open systems (Chau and Tam, 1997), and e-business (Zhu and Kraemer, 2005). The main contribution of TOE is that it encourages the researcher to take the broader context into account in which innovation takes place.

3.2. Process-virtualization-theory (PVT)

We adopt the process-virtualization-theory (PVT) developed by Overby (2008) to provide theoretical foundation for investigating the question: What factors affect the virtualizability of the Green IT implementation process in organizations? Process-virtualization-theory is designed to explain and predict whether a process is amenable or resistant to being conducted virtually. Process virtualization occurs when a physically-based process is migrated to a virtual environment. This characterizes a significant trend in recent IS developments such as the migration of social interaction to online communities

and virtual worlds, the migration of shopping to the Internet, and the migration of education to distance learning environments.

The dependent variable, process virtualizability, helps describe how amenable a process is to being conducted without physical interaction between people or between people and objects. The four main independent variables of the virtualization process include: (a) Sensory requirements – process participants to be able to enjoy a full sensory experience of the process, (b) Relationship requirements – process participants to be able to interact with one another, (c) Synchronism requirements – the degree to which the activities in a process to occur quickly with minimal delay, and (d) Identification and control requirements – the degree to which the process requires unique identification of process participants and the ability to exert control/influence the behavior. According to the PVT, these requirements are posited to have a negative relation to process virtualizability. However, there are three moderating constructs that are IT enabled, which aid the four aforementioned representations to positively influence the virtualizability of the process. These moderating factors are: (a) Representation – IT's capacity to present information relevant to a process, (b) Reach – IT's capacity to allow process participation across both time and space, and (c) Monitoring capability – IT's capacity to authenticate process participants and track activity. Since in this study we assume that the Green IT implementation will be IT driven, our model therefore assumes that the three aforementioned moderating factors will always influence positively to the virtualizability of the greening process.

3.3. Diffusion of innovation (DoI) theory

Diffusion of innovation (DoI) theory (Rogers, 1995) offers rich explanations of how new innovations are adopted, and how adoption decisions are affected by perceptions of the technology itself as well as the characteristics of the adopting organization and its environment. According to the DoI theory, a technological innovation passes through five stages: (a) knowledge – exposure to its existence, and understanding of its functions; (b) persuasion – the forming of a favorable attitude to it; (c) decision – commitment to its adoption; (d) implementation – putting it to use; and (e) confirmation – reinforcement based on positive outcomes from it. Despite the popularity of the DoI theory, researchers have criticized for its bias towards the technological component of the adoption process. The argument offered by these scholars is that other relevant, contingent factors, beyond the technical features of an innovation should be considered for deeper understanding to emerge (Fichman and Kemerer, 1997; Newell et al., 2001). Calls have been made to further extend and apply the theory to technology transition and other contexts.

We chose DoI theory because the theoretical foundation for most technology adoption research such as (Cooper and Zmud, 1990; Tornatzky and Fleischer, 1990) among others, is based on studying the process of technology diffusion and the factors influencing technology adoption decisions. Although in our proposed framework the factors influencing the determination of the readiness of implementing Green IT initiatives through the virtualization process are modeled and analyzed through the integration of TOE and PVT theories, the DoI theory allows us to take a process view that moves us from the decision to go Green via virtualization to the three stages of its implementation: (a) initialization, (b) integration, and (c) maturation.

DoI theory is a powerful descriptive tool, less strong in its explanatory power, and less useful still in predicting outcomes and providing guidance as to how to accelerate the rate of adoption. Nonetheless, it provides a valuable 'hook' on which IS research and practice has been hung (Zhu et al., 2006). In our framework the innovation-decision (that is, a firm is assessed to be ready for implementing Green IT initiatives via virtualization) is made through and integrated TOE and PVT analysis, and the stages of implementation is guided by the DoI analysis. When a firm has been determined to go Green, it is considered to have entered the pre-adoption stage or initialization stage. In this stage, we consider that, the firm will preserve the existing IT infrastructure and policies and incorporates simple measures to achieve their moderate green goals such as reducing energy consumption. These measures could include adopting policies and practices such as energy management. These kinds of simple measures should be easy to implement without much cost.

Over time, as the firm becomes more knowledgeable and learn from the experiences gained through the initialization stage to reap the benefits of the innovation effectively through the application of technologies, they enter the next stage which is the adoption or the integration stage. In this stage, we consider that, the firm will develop a strategic plan and build its IT infrastructure and its use from an environmental perspective, develop a comprehensive plan addressing broader aspects of greening its IT, and implement distinctive new initiatives. For example, the firm may deploy new energy-efficient, environmentally friendly datacenters and computing systems, or it may develop and implement new policies on procurement, operation, and/or disposal of computing resources. While the primary rationale will still be cost savings from operational efficiency and a reduced carbon footprint, it will also considers other factors such as branding, image creation, and marketing to be make itself more competitive or to sustain its competitive position with respect to its competitors.

The final stage, post-adoption or maturation, is reached once integration is complete and full-scale deployment of Green IT across the firm's value chain activities is assured. In this stage, we consider that, the firm will adopt additional measures such as implementing a carbon offset policy to neutralize greenhouse gas emissions which may include planting trees, buying carbon credits from one of many carbon exchanges, or using green power generated from solar or wind energy. An enterprise may also encourage its employees to go green outside the enterprise and offer incentives for doing so.

Consistent with the three aforementioned Green IT adoption stages – initialization, integration and maturation, firms would go through stages of virtualization administration maturity that would yield greater efficiencies at each level of experience. The key to passing from one stage to the next is not only technology but operational improvements that take greater

Table 3
Summary of the theoretical foundation of the proposed framework.

IS theory	Dependent variable	Independent variables	Short description
Technology-organization-environment (TOE)	A process by which a firm sees the need for, searches for, and adopts technological innovation	Technological context	Includes internal and external technologies of a firm. Includes equipment and processes
		Organizational context	Characteristics and resources of a firm. Includes size, communication processes
		Environmental context	Size and structure of the industry, the competitors and regulatory environment
Process virtualization theory (PVT)	A process by which a firm explains and predicts whether a process is amenable or resistant to being conducted virtually	Sensory requirements	Participants' ability to enjoy a full sensory experience of the process
		Relationship requirements	Process participants' ability to interact with one another
		Synchronism requirements	The degree to which the activities in a process to occur quickly with minimal delay
		Identification and control requirements	The degree to which he process requires unique identification of participants and the ability to exert control
Diffusion of innovation (DoI)	A process by which a firm's new technological innovation, artifact or technique migrates from creation to use	Knowledge stage	Exposure to its existence and understanding of its functions
		Persuasion stage	The forming of a favorable attitude to it
		Decision stage	Commitment to its adoption
		Implementation stage	Putting it to use
		Confirmation stage	Reinforcement based on positive outcomes from it

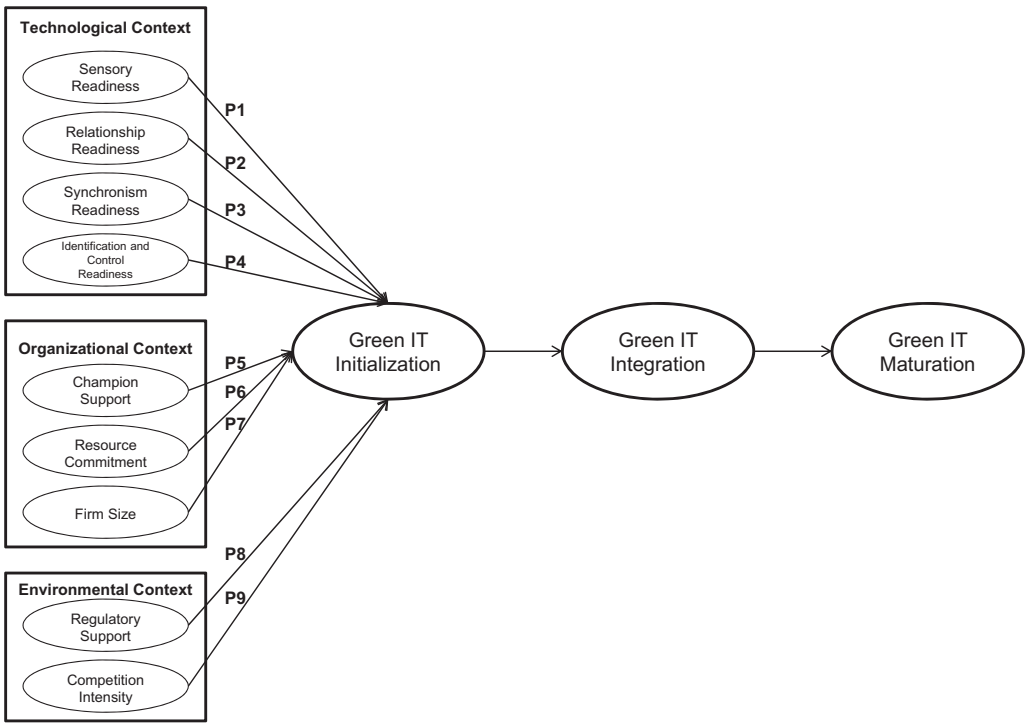

Fig. 2. The conceptual Model.

advantage of the unique features of the virtual environment, adapt existing practices to new capabilities, and create new processes that virtualization makes possible. Organizations, for all practical purposes, could take years to move from one stage to the next, as proficiency in each stage of the progression is required to ascend to the following stage.

Table 3 summarizes the purpose and constructs of each of the three IS theories discussed above that have been integrated to develop our research model.

4. Theoretical framework and propositions

Synergizing the process-virtualization-theory and the TOE theoretical framework as well as diffusion of innovation theory, we developed a conceptual model to capture these salient factors from organizational, technological and environmental perspectives and assess the organization's potential readiness for undertaking Green IT initiatives (i.e., Green IT initialization). Fig. 2 displays the theoretical framework graphically.

4.1. Technological context

Within the technological context, the first construct proposed to affect organizations' determination to go green via virtualization is *sensory readiness* which we define as the degree to which virtualization process participants are able to enjoy a full sensory experience of the process. We posit that, based on the literature, IT (i.e., virtualization) can be employed to simulate the sensory elements of the physical world. According to Overby (2008), the senses of sight and sounds have already been widely incorporated within IT-based virtual processes. These technological advancements have facilitated the virtualization of such business processes as shopping and information dissimilation. For instance, the sensory aspects associated with shopping can be represented via IT, such as a virtual model displaying a variety of colors, sizes, and articles of clothing or footwear and a virtual vehicle comprehensively demonstrating every single mechanical function of the vehicle through a virtual 360-degree interface. Therefore, we propose:

Proposition 1. *Sensory readiness will positively influence Green IT initialization.*

The next proposed technological construct influencing organizations' decision to go green is *relationship readiness* which we define as the need for process participants to interact with one another in a professional context. The literature has suggested that such interaction can trigger knowledge acquisition, trust, and friendship development. Prior studies (Hitsch et al., 2006) have found that, similar to physical interaction, IT-enabled virtual interaction can transmit communication cues which help establish relationship development. For example, virtual website such as Linkedin and FaceBook can help match participants with similar of complementary interests and help them build professional relationships with others. According to PVT, IT-based virtual processes such as e-commerce and online distance learning can facilitate the virtualization of processes with high relationship requirements. In essence, IT-based virtualization can enable process constituents to potentially reach other participants who share similar interests in a professional context.

Proposition 2. *Relationship readiness will positively influence Green IT initialization.*

In the technological context, synchronous participation is another important issue. We define *synchronism readiness* as the degree to which the activities that make up a process need to occur quickly with minimum delay. While physical processes can be highly synchronous because physical process participants can interact with others with little delay because they are all located in the same physical setting, IT-enabled virtualization can also enable multiple participants, regardless of where they are, to participate in a process on a synchronous basis. Existing technologies such as instant messaging which is featured by such characteristics as presence awareness, immediate closed loop communication, multi-party collaboration, and event notification can facilitate a live, multiple-way connection to a virtual process where participants can respond to and seek communication from one another in different locations in real-time.

Proposition 3. *Synchronism readiness will positively influence Green IT initialization.*

Within the technological context of the TOE framework, *identification and control readiness* is defined as the degree to which the process requires unique identification of process participants and the ability to exert control over/influence their behavior. Research on relationship development has argued that it is important to know the identity of the other party when developing a relationship (Dombrowski et al., 2004). With the virtualization of relationship development processes, it is possible that people can hide their identity and it may be difficult to identify the other process participants. In fact, due to the technological advancements in the domain of access control, it is increasingly feasible that participants in IT-based virtual processes can be authenticated via sophisticated technical means such as password-protected log-ins and biometrics. As such, this permits the virtualization process participants to be properly identified. Furthermore, IT-based tracking and monitoring applications can enable these participants' behavior to be tracked and analyzed in an automated and systematic manner.

Proposition 4. *Identification and control readiness will positively influence Green IT initialization.*

4.2. Organizational context

Green IT initiatives require organizations to transform traditional IT and business processes to those that rely on virtualization. This transformation presents challenges and requires organizations to smoothly adapt to it. The literature of IT sourcing offers instrumental insight in regard to top management's commitment and support being a critical factor of

ultimate project success. For instance, Lacity and Willcocks (1999) found that the IT and non-IT senior management involvement plays an effective and positive role on the decision-making on cost savings. Similarly, Koh et al. (2004) conducted a qualitative study and stated that overall outsourcing success is significantly related to management. A comprehensive literature review by Lacity et al. (2009) implies that, at the organizational level, top management support in IT outsourcing initiatives can impact the overall project success. In the same vain, prior studies have found that lack of managerial support for change management leads to unsuccessful organizational adaptations (Chatterjee et al., 2002; Roberts et al., 2003). Lacity et al. (2009) and Dong et al. (2009) suggested that top managerial support is important to orchestrate the organizational adaptations in technology, strategy, and business processes. Further, Zhu et al. (2006) found that managerial support is positively related to e-business initiation, adoption, and routinization. Within the Green IT context, we posit that the implementation or acceptance of Green IT initiatives requires support from the organization's top management – a champion – which refers to a management-level person (e.g., CEO) who recognizes the usefulness of an idea to the organization and leads authority and resources for innovation throughout its development and implementation (Meyer, 2000). Beath (1991) found that champion support can facilitate the adoption of a new technology by providing the necessary drive and effort to initiate the adoption. Echoing this finding, Crum et al. (1996) stated that the support of a champion is a significant factor in successful adoption and implementation of IS and telecommunications systems. According to the literature, we suppose that champion support can also help overcome possible resistance in adopting new technologies when organizations confront challenges in making organizational changes, redesigning processes, and acquiring new expertise. At the organizational level, prior studies such as Grover and Goslar (1993) and Teo and Ranganathan (2004) found that the support of champion was a significant discriminating factor between adopters and non-adopters for emerging business and/or technological processes.

Proposition 5. *Organizations with greater champion support are more likely to initiate Green IT.*

The next proposed construct affecting Green IT initialization is resource commitment. Following what Zhu and Kraemer (2005) have suggested, we mainly focus on the financial aspect of commitment which refers to the commitment of financial resources to Green IT as a proportion of total organizational resources. In the particular context of Green IT, we tend to adopt and tailor such measurable indicators as Green IT operating budget as percent of total revenue and Green IT spending as percent of total revenue as recommended by Zhu and Kraemer (2005) to denote the degree to which the financial aspect of commitment represents overall organizational resources. The literature of IS adoption and innovation has indicated that financial resources is another important antecedent to IS diffusion (Iacovou et al., 1995; Ramamurthy et al., 1999; Zhu and Kraemer, 2005). In this study, we posit that the implementation of Green IT initiatives requires additional financial investment in hardware, software, employee hiring and training, and system maintenance and redesign which are necessary for the organizations to initiate the virtualization process for their Green IT projects. In short term, the investment warrants sufficient financial resources dedicated to the initialization of Green IT. Similar to Zhu and Kraemer's contention with regard to successful e-business use, this study proposes that organizations with greater financial commitment are more likely to achieve successful virtualization process implementation toward Green IT.

Proposition 6. *Organizations with greater resource commitment are more likely to initiate Green IT.*

Another factor in the organizational context is firm size, which is defined by the number of employees in the organization. Firm size is another important organizational attribute for innovation diffusion and probably one of the most commonly studies organizational factors in the innovation literature. Firm size has been considered as a double-sided sword because, on one hand, large-size organizations which possess ample resources can facilitate innovation initiation (i.e., Green IT). The literature has defined SMEs as firms with the size of employees fewer than 500. Small firms are generally those with fewer than 50 employees. Therefore, large organizations would mean those with more than 500 employees. Rogers (1995) contented that firm size which could mirror several dimensions that are crucial for organizations to implement innovation: total resources, slack resources, and technical expertise of employees. Following the contention that Zhu et al. (2006) have made toward e-business innovation and adoption, we believe that the implementation and initiation of Green IT initiatives require resources from various aspects including technology, management, and finance. Based on prior empirical evidence presented by Zhu et al. (2006) who found that large-size organizations were more likely to invest in e-business, we further suppose that large-size organizations which have comparatively sufficient technical, managerial, and financial resources are more likely to initiate the Green IT project.

Proposition 7. *Organizations in larger size are more likely to initiate Green IT.*

4.3. Environmental context

In studies of organizational learning, it has been suggested that an appropriate balance between exploration for refinement and extension of existing technologies and exploitation for new opportunities is affected by the context of distributed costs and benefits and ecological interaction (March, 1991). Based on a theory of organizational ambidexterity, Tushman and

O'Reilly III (1996) and O'Reilly III and Tushman (2004) further claimed that ambidextrous organizations maintain a variety of innovation efforts through launching breakthrough products or services for growth while exploiting existing capabilities for better profit and lower cost without hampering its traditional business. In the context of Green IT, it is believed that the ecological interaction in terms of regulatory support may be instructive to help organizations reform to seek ambidexterity toward organizational sustainability. Accordingly, Rothaermel and Alexandre (2009) contended, from a perspective of technology sourcing, that the need for organizations to achieve ambidexterity is positively correlated with the dynamism of the respective environment. Within the environmental context, regulatory support has been recognized as a crucial component affecting innovation diffusion (Zhu and Kraemer, 2005; Zhu et al., 2003; Zhu et al. 2006). We believe that regulatory support in terms of supportive government or state policies and/or legislation (e.g., National Computer Recycling Act, Restriction of Hazardous Substances, European Waste Electrical and Electronic Equipment) on the state-wide or national level can help organizations achieve their Green IT aims with regard to redesigning IT and business processes through virtualization and minimizing environmental impacts and how they contribute to sustainable development. Further, we suppose that regulatory support by means of relevant legislation and regulation as well as incentives for greening IT (e.g., law, technical support, and funding or tax relief) can aid organizations in more effectively managing their IT and business processes and expanding market opportunities for environmental conscious businesses. Our contention is in line with Zhu and Kraemer (2005) and Zhu et al. (2006) who found from prior study by Umanath and Campbell (1994) and Dasgupta et al. (1999) that regulatory support could affect innovation diffusion.

Proposition 8. *Organizations with greater regulatory support are more likely to initiate Green IT.*

Competition intensity is defined as the degree that the company is affected by competitors in the market (Zhu et al., 2006). It is also known as competition pressure which refers to the degree of pressure that the organization feels from competitors within the industry (Zhu and Kraemer, 2005). In addition to regulatory support, competition intensity also plays an important role in pushing organizations toward initializing Green IT. According to the literature of diffusion, competition could drive organizations to initiate and adopt innovations to maintain a competitive edge. Further, as Porter and Millar (1985) and Zhu et al. (2006) noted, organizations once have initiated innovative information systems can then alter the rules of competition, affect the industry structure, and leverage new ways to outperform other competitors. Applying these scientific artifacts into the context of Green IT, we believe that organizations are able to use their green production programs to get ahead of the regulatory curve to such a degree that they can preempt future legislation altogether (Darnall, 2008). In the instance of Green IT, companies initiating Green IT through virtualization could avoid the risk of more stringent environmental protection regulation because their impact on the environment is so low that additional regulatory controls would have little effect on their operating procedures and many environmental regulations would no longer be relevant to them.

Proposition 9. *Organizations facing higher competition intensity are more likely to initiate Green IT.*

5. Discussion

In light of contributions to research and practice, we offer implications for Green IT literature and provide prescriptive guidelines for Green IT practices.

5.1. Implications for research

Successful initiation and implementation of Green IT in all its forms and stages will be an important issue for the coming decade. How do organizations assess their potential to initiate technological and strategic reforms to commence Green IT projects? Given recent surveyed statistics in Green IT and the prominence of social, economical, and ecological significances triggered by Green IT, this becomes a particularly relevant question. Drawing upon conceptualization in PVT, TOE, and DoI theories, our study presents an integrative framework in an effort to synergistically achieve the strengths of each theoretical lens for assessing the potential for undertaking Green IT initiatives and the stages of Green IT implementation at the organizational level. We discussed how Green IT might be implemented via the lens of process virtualization to further enhance business efficiency and effectiveness in general. Further, we provided arguments linking Green IT initialization to four different conceptualizations of process virtualization: sensory readiness, relationship readiness, synchronism readiness, and identification and control readiness. Given differences in the business industry in general, we theorize that champion support, resource commitment, and firm size in the organizational context and regulatory support and competition intensity in the environmental context also exert influence on the initialization of Green IT. This is one of the first studies in the Green IT literature that explores the evolutionary stages of Green IT diffusion process through virtualization (i.e., initialization, integration, and maturation). This theory-based study is also one of the first attempts to theorize the mechanisms linking process virtualization to technology-organization-environment model, as we endeavored to further adapt these four conceptualizations of virtual process to technological context.

In essence, this study makes several contributions to the academic literature on Green IT. First, we sought to propose a theoretical framework to help understand business and IT phenomena that cannot be explained by existing theories in the IS

literature. Our model suggests that the degree to which organizations decide to initiate Green IT approaches are driven by constructs derived from technological, organizational, and environmental contexts. This research highlights the importance of incorporating process virtualization into our understanding of Green IT in business and technological processes. Going beyond the mist of Green IT conceptualization, we postulate that virtualization is the driving force for organizations to integrate sustainability into business and IT practices toward a greener business environment. We reasoned that virtualization helps consolidate both IT-based and non-IT-based resources which help increase the efficiency of organizational resource utilization. We further argue that virtualization contributes to business flexibility in terms of time and space to efficiently conduct business processes which help cost savings and improve the overall process effectiveness. This work, thus, extends prior research that has studied business sustainability.

Second, we envisioned two additional generations of Green IT diffusion, and explicitly compared different pathways of Green IT migration through virtualization processes. As this study has sought to build theoretical synergy by developing a research model that takes in theoretical perspectives of champion support, financial resource commitment, firm size, regulatory support, and competition intensity, our model may help address the predicament which Damsgaard and Lyytinen (1998) referred to the insufficiency of relying solely on innovation diffusion theory for study standards diffusion.

Third, our proposed model has important theoretical implications to further justify the debate on "IT value paradox" (Carr, 2003; Thatcher and Pingry, 2007). As prior studies posited that IT would soon be standardized in the same or similar way as electricity and therefore its value shall diminish, we believe that the modeled generations of Green IT evolution can help explain that extensive use of Green IT initiatives such as virtualization would be able to produce significant performance impacts on both IT and business. In congruence with the contention of Zhu et al. (2006), this study can confirm that systematic utilization of Green IT approaches via both business and technological virtualization processes could be an intermediary stage that organizations need to undergo before they can migrate to the next stage where Green IT has been widely adopted and integrated with other IT and business approaches.

Finally, by specifically addressing the aforementioned research gap, this paper serves as a call to the IS literature to incorporate process virtualization into their models of organizational level decision-making toward contemporary technology diffusion. By enriching our understanding of virtualization, the model sheds light on how to assess the technological readiness for Green IT from four different approaches.

Many limitations of the study could be demonstrated, but we tend to focus on key limitations here. First, we felt that future research is needed to empirically validate the interplay between the PVT constructs, TOE variables, and DoI stages. Such scientific research could uncover some interesting interactions and enrich our understanding of process virtualization in organizational level decision-making. Second, while we took steps to analyze the antecedents of Green IT initialization, studying the following two stages, namely Green IT integration and maturation, is encouraged in the future. We believe that future data on these two additional stages will help researchers more thoroughly validate the DoI theory in the arena of Green IT. Such studies may be particularly relevant and would help us understand the complexities of Green IT diffusion given the increasing attention and use of virtual technologies in organizations.

5.2. Implications for practice

The previous section offered a useful integrative framework for managers to assess the readiness of their organization to undertake Green IT initiatives, as well as to assess the technological, organizational, and environmental conditions under which Green IT will be launched. To better pursue business value, it is vital for these organizations to build up competencies in all three above-mentioned contexts.

5.2.1. Technological context

The success of implementing the Green IT initiatives through virtualization will heavily depend on the companies' use of virtualization technologies – both for conducting business processes as well as for enforcing Green IT practices. Organizations can perform cost-effective business process change or reengineering with green in mind. For example, providing capabilities to perform online electronic commerce or business activities will aid the automation of business processes to reduce carbon footprints. Additionally, for example, the use of Green buildings, telework, remote conferencing and online collaboration, and green sourcing will help contribute to Green IT goals of organizations. Green buildings will help increase energy efficiency. Telework or telecommuting will help: decrease travel costs, meet employee demand, decrease fuel consumption to-and-from the office, and decrease office expenses from eliminating office size. Remote conferencing – video conferencing and teleconferencing implementations between facilities or between offices and client sites – and online collaboration will help: decrease fuel consumption from car or plane rides, decrease travel costs, access remote talents, and meet employee demand. Green sourcing uses green supply chain process to provide environmental responsibility.

Today's virtualization technologies provide most of the business drivers to make Green IT happen. The modern trend in green computing is virtualization and consolidation of servers and storages. Server virtualization allows one to create multiple logical servers onto a handful of physical servers. There are different ways one can use servers in their green workplace. For example, most organizations have several small servers that each performs the function of a single legacy application that cannot be removed because it is still being used by some processes. These servers are excellent candidates for consolidation. Through consolidation and virtualization, one can remove unnecessary server machines from their workplace, or can use them for new functions. Similarly, organizations do not have to spend thousands of dollars on data storage anymore be-

cause through the use of intelligent SANs (Storage Area Network) one can save considerable amount of money. Like servers, each disk drive costs money to buy, to operate, and to cool. Storage virtualization – like server virtualization – allows one to reduce the sheer number of disk drives in their datacenter.

The business benefits for doing consolidation and virtualization are the following. (1) Decreases the overall number of devices running in the server room, along with the square footage needed to house these devices. (2) Decreases the energy required to run servers and storage, along with the associated cost and greenhouse gas emissions. (3) Decreases the cost of future investments in physical servers and storage devices – by operating server room assets at higher utilization rates, many companies will require fewer purchases in the future. (4) Virtualization addresses urgent IT issues such as company running out of computing or storage capacity, company must reduce consumption to meet budget cuts, and company face electricity supply limitations. (5) The time needed for maintenance and management is considerably reduced. Using server virtualization, IT departments can quickly change virtual server configurations, avoiding the time-consuming labor required by physical servers. Likewise, management of storage space is simplified when data is centralized on only a few systems.

Cloud computing may serve as a good player in the current Green IT movement, especially for: those companies who are looking to avoid upfront costs associated with building their own IT infrastructures; IT departments that do not have the internal resources to maintain an enterprise-level data center and associated services; or companies that want to add supplemental computing capacity or services that are not already built into the company's infrastructure. Primarily because Cloud computing leverages shared infrastructure to deploy and balance IT resources for computing tasks in real-time and it can significantly reduce carbon footprints while maintaining the levels of service.

5.2.2. Organizational and environmental contexts

The likelihood that companies will successfully implement Green IT initiatives depends on several factors. The primary factor is Champion Support. Having the support of Champion is critical to success of any project but, particularly for Green IT initiatives as they require education and a shift in attitude. Lack of implementation barriers is another important factor among others. Companies implementing Green IT initiatives may face barriers that inhibit the successful approval and implementation of these initiatives. Some of these potential barriers could be: (1) lack of buy-in from all levels of an organization, (2) inadequate funding, (3) inadequate skill sets to execute the initiatives, (4) unclear or poorly defined objective, (5) undefined linkage between the initiative objective to a business objective, (6) unknown impact of the initiatives on the overall business, and (7) inadequate infrastructure to support the technical requirements of the initiatives.

5.2.3. Green IT governance

Governance refers to the management infrastructure to implement Green IT initiatives. It must be considered to be the operating model that defines the administration of Green IT initiatives to understand impacts, prioritize actions and manage company's responses. In this model, the roles, responsibilities, accountability and control of Green IT initiatives need to be clearly established.

The key management challenges to make Green IT implementation successful follows. (1) Think green – The CIO and Champion Support must articulate the enterprise vision and emphasize a sense of urgency in implementing green initiative to increase stakeholder buy-in. (2) Plan – developing a Green IT plan for the enterprise must be the first step toward implementation of greener practices. (3) Establish a baseline and determine a metric – developing a baseline and a way to measure "greenness" progress should be built into a total carbon footprint reduction plan at the outset of an initiative and can be the key to overall project success. To test the effectiveness of green practices, companies must identify and employ some form of measurement: both the Green Grid and SPECpower provide excellent information describing means of deploying and measuring these types of metrics. (4) Track and monitor success – once a metric is determined, continue to track and monitor a project's success rate. (5) Collaborate – reach out to other organizations to gather best practices and lessons learned, gauge success stories and assess project failures before deciding to embark on a similar initiative. (6) Leverage the circumstances – with rising energy costs and current economic environment, green initiatives will likely be met with unprecedented support.

5.6. Methodological implications and validation approaches

To yield useful knowledge for organizations, the theoretical and structural approaches laid out in this paper can be further developed and tested. We presented major concepts and underpinnings for the study of undertaking Green IT initiatives via virtualization and stated nine propositions regarding relationships among these constructs. Empirical tests of these relationships are needed in future research. Methodologically, refinement of these concepts and articulation of specific research hypotheses is the next step. We hereby outline a general analytic strategy for applying the theory of process virtualization and illustrate its application to the study of Green IT. Our research strategy could be specified in more detail and tested for its usefulness across a range of virtualization technologies and organizational contexts. We believe that the proposed framework can be captured at organizational levels. The specific variables and measurement approaches will depend on the particular virtualization technology, context, and interaction processes of interest to the researcher. We acknowledge that there is a tradeoff between comprehensiveness and parsimony. It is advised that researchers should follow the methodology described by Moore and Benbasat (1991) to develop the survey instrument used in a target industry (e.g. manufacturing, service).

At the organizational level, instrument items relating to process virtualization could be adopted from Overby et al. (2010) to mirror the contextual attributes of Green IT. In essence, we suggest that the items which Overby et al. (2010) applied in automobile industry (i.e., 3 items for *sensory*, 3 items for *relationship*, 2 items for *synchronism*, and 3 items for *identification*), should be accordingly and carefully modified to more accurately fit the target industry. The dependent variable at the initiation stage can be measured by how the potential benefits of virtualization-driven Green IT are rated before the organization begins employing virtualization technologies. Researchers can follow the empirical approach proposed by Zhu and Kraemer (2005) to adopt such four items as cost reduction, market expansion, entering new business, and value chain coordination. Stage II Green IT integration can be measured by an aggregated index in terms of seven items ranging from marketing, sales, and after-sales services to procurement and value chain coordination. Stage III Green IT maturation can be measured by the extent of organizational usage of virtualization to support its value chain activities. The items can be operationalized by the percentages of total sales to consumer/businesses, total services to consumers/businesses, and total procurement that are conducted on the Green IT initiatives. These items can reflect the extent to which virtualization has been fully incorporated into value chain activities. Other validated instrument items rooted in the ToE theory can be derived from prior relevant studies such as Zhu and Kraemer (2005) and Zhu et al. (2006). In addition to these theoretical and methodological issues, a possible approach to testing the framework is to directly gauge its explanatory and predictive power. One solution, which depends on the sample size, would be to use Structural Equation Modeling (SEM) to validate and analyze all proposed paths. The SEM approach would allow future researchers to examine the framework's construct validity (e.g. discriminant and convergent validity) and the proposed causal relationships. Future tests and refinements of the proposed model will be extremely useful to advance knowledge on Green IT. Replicating the study in different industries would enable such tests.

We also acknowledge that it may become problematic when researchers attempt to link Green IT initialization to integration and maturation and to validate the relationships due to the fact that it might be difficult to collect data from organizational decision-makers about processes, decisions, among others, especially over time. One possible way of overcoming this difficulty is to conduct a longitudinal analysis by employing a task force of researchers who design and collect such data over certain period of time. Another alternative is to conduct a longitudinal case study analysis in which the virtualization-driven Green IT dynamics over time (i.e., initialization → integration → maturation) can be more accurately captured, traced, and evaluated. However, this might inevitably raise issues of generalization. Therefore, we believe that triangulation, a combination of quantitative data (collected by a task force of researchers in the field) and qualitative data on a few investigated cases, might prove fruitful. Crossing the quantitative–qualitative divide, triangulation may overcome the intrinsic biases and the problems that come from single method, single-observer and single-theory studies and thereby increase the credibility and validity of the results. In spite of the above challenges offering exciting opportunities for further refinement and validation of the theoretical model, the current study has provided a holistic theoretical view upon which other researchers might base their studies on. Because of the increasing importance of the role of Green IT in business sustainability across the globe, researchers should continue investigating the preliminary model developed here. This can be achieved by further refining the measures and factors proposed in this model, by testing the relationship among the dependent and independent variables, and by seeking empirical evidence across different cultures.

6. Conclusion

With an increasing number of business, governments, and nonprofits facing challenging environmental conditions triggered by the incontrovertible problem of climate change, consumers are becoming ever greener and increasingly support sustainable products and practices. Notwithstanding a global economic slump, organizations have realized the importance of business sustainability and attempted to cater to consumers' "greener appetite". As such, it is imperative that organizations understand how to undertake Green IT initiatives and seek viable solutions in order to further improve business sustainability and identify cost savings over current practices. In light of the growing concern about the emergence of Green IT as an important strategic weapon augmenting business sustainability, we highlighted the importance of understanding the effects of virtualization on both technological and business processes. The objective of the study was to illustrate how business transformation via virtualization may help organizations assess their potential to undertake Green IT initiatives. In this paper we develop an integrative framework by synthesizing a multitude of theories and the relevant literature. The theoretical method used to capture PVT, TOE, and DoI theories provides a useful lens for examining the potential to carry out Green IT initiatives at the organizational level of analysis. To our best knowledge, the proposed model is the first attempt to synthesize theoretical underpinning that helps organizations to assess their potential toward Green IT initiatives via the virtualization processes. The current study has made an original contribution in defining the research model and developing the dimensions that constitute it. It also provides a research-ready instrument whose properties are sufficiently validated. We hope that the study provides a general theoretical framework which sets the stage for future research on Green IT and stimulates further research in this emerging paradigm in IS domain. This paper breaks ground for future research to empirically examine or theoretically extend the roles of process virtualization and other critical factors in enabling this transformation.

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