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IT AND ECO-SUSTAINABILITY: DEVELOPING AND VALIDATING A GREEN IT READINESS MODEL

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Abstract

Green Information Technology (IT) is emerging as an increasingly important issue as organizations come under pressure to address environmental sustainability concerns. Despite increased attention from business, government and more recently, Information Systems (IS) researchers, a measure to determine the capability of organizations to Green their IT remains elusive. The purpose of this paper is to develop a Green IT Readiness (G-readiness) model, identify its key dimensions and develop a reliable and valid instrument to operationalize it. The validity of the proposed model is tested using structural equation modeling based on data collected from a cross-sectional and cross-country survey of Chief Information Officers and other IT managers. The study makes an original contribution to the IS literature in an area that is attracting increasing managerial attention yet lacking in research, that is, the interaction between IT and eco-sustainability.

Keywords: *Green IT, Green IS, Capability, Readiness, G-readiness, Eco-sustainability*

Introduction

Green Information Technology (IT) is a multifaceted construct that is intended to address both IT and non-IT (by using IT) related sustainability problems (Elliot and Binney, 2008). Chen et al. (2008, p. 187) too, note the potential for IS ("the application of interacting information technologies to create purposeful systems"), to both contribute to the deterioration of the environment and mitigate environmental deterioration when used in automotive, informative and transformative roles. Although the importance of Green IT has been strongly suggested through practitioner reports (CFO, 2009; Gartner 2008; Info~Tech 2007a, 2007b) and emerging academic articles (Chen et al. 2008; Elliot 2007; Elliot and Binney 2008), the capabilities that business and other organizations need to build in order to green their IT and the extent to which they have progressed along the Green IT path has not been reported in the literature. In particular, there is no literature that has modeled a Green IT capability construct and developed a valid and reliable instrument to measure this construct.

The purpose of this paper is to propose a model to measure the Green IT capability construct and develop a reliable and valid instrument to operationalize it. This study can therefore be considered as a preliminary attempt to advance the Green IT research through theorization, model construction and measurement development. The study makes an original contribution to the IS literature in an area that is attracting increasing managerial attention yet lacking in research, that is, the interaction between IT and eco-sustainability. The paper is structured as follows: First, the theoretical foundations for the model are established. Second, the development of the G-readiness construct is presented. Third, the implications of the model are discussed. Finally, conclusions are drawn, limitations of the study are identified and the potential for future research are highlighted.

Theoretical Background

Background to Green IT

The past decade has seen many businesses realize the long term effects of pollution and taking responsibility for their actions through social and environmental responsibility initiatives in ways that improve their environmental footprint. Corporate social responsibility (CSR) and compliance with new stringent energy legislation and regulations over the next few years will see government and business alike forced to reduce their impact on the environment through sustainable policy, energy efficiency and following environmentally safe practices (Climate Group, 2008). As IT plays an integral role in almost all facets of businesses, and as each stage of the IT lifecycle from manufacturing to usage and disposal can pose environmental damages (Elliot and Binney, 2008), it naturally follows that demands for CSR and "environmental sustainability" should be extended to IT too. A business's capability to comply with the mounting demands of different environmental groups and government regulations and take actions to reduce its environmental impact might affect its competitiveness (Carroll 1991; Gartner 2008; Hendry and Vesilind 2005; Rao and Holt 2005). Interestingly, however, the role that IT has in both causing and resolving eco-sustainability has only recently began to emerge in academic IS literature (Chen et al. 2008; Elliot, 2007; Elliott and Binney 2008).

The concept of IT is broadly used in this paper to refer to the IT infrastructure and capability of a firm. Previous IT research distinguishes between *the technical infrastructure* and the *IT human* and *managerial capability infrastructure.* Duncan (1995) highlights that extant literature typically defines the IT infrastructure in terms of the basic technology components, with some definitions extending this to include resource planning and management factors that may affect the design and capabilities of infrastructure. IT infrastructure is also conceptualized as a pyramid of three layers: *IT and communications technologies* (e.g. physical servers and network devices); *shared services* (e.g. enterprise-wide databases and electronic data interchange (EDI)); and *business applications* that utilize the shared infrastructure (e.g. sales analysis, purchasing) (Broadbent and Weil 1997). Importantly, people with knowledge, skills and experience bind the technology components into reliable, shared IT infrastructure services (Broadbent and Weil 1997). Ravichandran and Letwongsatien (2005) posit that human, technological and relationship resources impact on the functional capabilities of IT departments, which in turn impacts on the capability of IT to support the core competencies of an organization.

In this paper, the technical IT infrastructure encompasses the physical IT and communications resources of an organization, along with the shared services and business applications. It encompasses an organization's network, storage, data, and application (information systems) assets as well as the network critical physical infrastructures (Byrd and Turner 2000; Rasmussen 2006). Some of an organization's IT applications can be directed towards solving sustainability problems. For example, videoconferencing and telepresence applications can have a direct impact on travel related emissions. IT systems are needed for tracking, measuring and reporting a business's environmental footprint and energy consummation. Electronic billing can remove (at least from the service providers' side) paper ouput of the billing process. GPS-based vehicle, transport and logistics systems can improve the environmental footprint of transport and logistics operators. IT enables communication between people and thereby is an important coordinating mechanism for business processes. Most business processes such as logistics, would be much more environmentally concerned if the processes could be automated, informated and integrated (Chen et al, 2008). An important aspect of the use of the IT technical infrastructure to solve sustainability problems is to ensure that the applications themselves are Greener in their architecture. The IT human infrastructure on the other hand consists of the IT personnel who ensure a sustainable operation of each layer of the technical IT infrastructure and who develop systems to support a business's overall sustainability (Broadbent and Weil 1997). The IT managerial capability pertains to the capability of a firm to ensure that the technical IT and IT human infrastructures support the core competencies of an organization (Ravichandran and Letwongsatien 2005).

This paper conceptualizes Green IT from the IT infrastructure and capability perspective. This implies that eco-sustainability considerations need to be incorporated within the IT technical and human infrastructure and IT managerial capability dimensions of the IT infrastructure to solve both IT and non-IT (by using IT) related sustainability problems. Sustainability refers to meeting the needs of present generations without compromising the ability of future generations to meet their needs (Hart 1997). Environment is one of the three pillars of sustainability. The other two are community and economy. Sustainability has strategic implications for business in regard to production economies, cost competitiveness, investment decisions and asset valuation (Enkvist et al. 2007).

Eco-sustainability considerations have been ignored in traditional management theory, which has typically adopted a narrow view of the business environment, focusing on political, economic, social and technological aspects (Hart 1995). With the increased awareness of environmental issues by the general community, eco-sustainability has emerged not only as an important organizational challenge but also opportunity. Hart (1997) describes three stages of eco-sustainability, namely *pollution prevention, product stewardship* and *clean technology*. Stage one, pollution prevention, focuses on the control and prevention of polluting emissions and effluents during organizational production and operations processes (Hart 1997). Pollution control means cleaning up waste once it has been created and can be achieved via the use of pollution-control equipment, whereas pollution prevention means minimizing or preventing pollution before it occurs and can be achieved via improved management, material substitution, recycling or process innovation (Hart 1995, 1997). Stage two, product stewardship, requires environmental impacts to be considered throughout the entire life-cycle of the organization, including raw-material sourcing, product design and development processes (Hart 1995, 1997). Stage three, clean technology, requires investment in technologies of the future. Such technologies can cause significant changes in the production process with a view to reducing the level of environmental impact along a product's life cycle from design to consumption (Hart 1997).

Chen et al. (2008) identified three goals of eco-sustainability and argues that these surround issues for *eco-efficiency, eco-equity* and *eco-effectiveness*. Eco-efficiency refers to a businesses' ability to deliver "competitively priced goods and services…while progressively reducing ecological impacts" (DeSimone and Popoff, in Chen et al. 2008: 190). Eco-equity focuses on "equal right of people to environmental resources" and a business's "social responsibility for the future generations" (Ibid: 192). Eco-effectiveness on the other hand, "aims to stop contamination and depletion…by directing individual and organizational attention to the underlying and fundamental factors of environmental problems… through a fundamental redesign of the system" (Ibid: 195).

The combination of the eco-sustainability and the IT infrastructure perspectives can offer useful insight in conceptualizing Green IT. As more organizations become concerned with Green IT, there is a need to understand their capability for implementing and sustaining Green IT strategies and polices. A number of organizations are expected to jump on the Green IT bandwagon during 2008-2010 pushing the Green IT consulting services market to an estimated US $4.5 billion by 2013 (Mines 2008). Thus, while currently leading-edge executives are focusing on green issues, this will become mainstream and green business initiatives, including those within the domain of Green IT, might move from niche projects to becoming a part of core business practice (Mines and Davis 2007). While the opportunities and potentials of Green IT might be attractive, a measure of the Green IT readiness (G-readiness) of organizations has not been provided in extant literature. Without such a measurement, organizations will be unable to determine their current performance in relation to Green IT initiatives and this will subsequently impede their ability to improve these capabilities.

G-readiness as a Capability

Although the construct of "readiness" can be traced in organizational change, information systems, business process reengineering (BPR) and innovation literature (Clark & Cavanaugh 1997; Grover et al. 1995; Guha et al. 1997; Raymond et al. 1998; Todd 1999), it has become very popular in the e-commerce and e-government literature. Several researchers have used the "readiness" or "e-readiness" construct in empirical studies (e.g. Lai et al. 2006). At a global scale, since 2001, the World Economic Forum publishes its annual report on the "Network Readiness" of countries (Mia and Dutta 2007). Two dimensions of the e-readiness (readiness) construct can be identified in the literature:

- Readiness as a precursor condition (or set of conditions) for the implementation of initiative such as a change, IS or innovation (e.g. Guha et al. 1997; Raymond et al. 1998; Todd 1999)
- Readiness as an indicator of the agility of a business and a capability that needs constant building, re-building and upgrading (hence maturity) (e.g. Clark & Cavanaugh 1997; Mia and Dutta 2007)

This paper promotes the construct of readiness as a capability. Organizational capabilities can be explained in the context of the resource-based view of the firm (Barney 1996; Pavlou and El Sawy 2006). The resource-based view of the firm considers firms to be heterogeneous bundles of resources whose characteristics can predict organizational success (Barney 1996; Bharadwaj 2000). From this perspective, resources are seen as basic inputs into gaining and maintaining competitive advantage, while organizational capabilities are the firm's capacity in acquiring and utilizing its resources to perform tasks and activities for competitive gain (Barney 1996; Bharadwaj 2000). Thus IT capabilities represent the routines by which firms deploy and manage IT resources to enable and support critical business activities (Bharadwaj 2000; Ravichandran and Lertwongsatien 2005; Tallon and Kraemer 2004). Extending these views to Green IT capabilities, these represent the means by which firms deploy ecological considerations in building and managing IT resources to enable and support green initiatives across the key areas of sourcing, operations and services and end of life IT management.

Development of the G-readiness Model

Green IT and G-readiness are the main constructs of interest in this research. In order to develop the G-readiness model and ensure the accuracy and validity of its measuring instrument, this study follows structured frameworks and procedures outlined in previous research (Boudreau et al. 2001; Churchill 1979; Hair et al. 2006; Straub et al. 2004). The first stage involves defining the domain constructs of Green IT and G-readiness. Stage two operationalizes the constructs by generating measuring items. In stage three, sample design and data collection issues are covered. Stage four contains data analysis to test the validity and reliability of the developed model and instrument.

The Green IT and G-readiness Domain Constructs

Defining a construct's theoretical meaning and conceptual domain are necessary steps in developing a model and an accurate and valid instrument to operationalize the model. Clear domain definition is also an essential procedure in ensuring the content validity of an instrument.

Green IT means many things to different people. In order to conceptualize Green IT, we take insights from previous literature on IT infrastructure, green supply chain and emerging practitioner oriented Green IT publications. From a supply chain perspective green supply chain refers to integrating environmental thinking into the product design, sourcing, manufacturing, warehousing, distributing and end of life product management aspects of a supply chain (Rao and Holt 2005; Srivastava 2007). Turning to IT, for most CIOs and IT vendors such as Dell, HP, Intel and Sun, Green IT is all about data centre efficiency. Therefore, narrowly defined, Green IT implies technologies and initiatives to reduce the power, cooling and real estate costs associated with data centre operations (Info~Tech 2007b; Mines 2008; Mitchell 2008; Nunn 2007; Rasmussen 2006). However, Green IT should be seen more than data centers and encompass not only hard technological solutions but also soft business practices in acquiring, using and disposing IT. Particularly, the insight from green supply chain literature (Rao and Holt 2005; Srivastava 2007) and IT infrastructure indicate that the boundary of Green IT conceptualization can range from green purchasing through internal operations to end of IT life management. Therefore, in this paper Green IT is defined as:

> Green IT is a systematic application of environmental sustainability criteria to the design, production, sourcing, use and disposal of the IT technical infrastructure as well as within the human and managerial components of the IT infrastructure in order to reduce IT, business process and supply chain related emissions and waste and improve energy efficiency.

Thus defined, Green IT refers not only to Greening the IT artifact but also to using IT to achieve sustainability in business and supply chain processes. Further Green IT includes hard technologies as well as soft systems and business practices spanning the IT lifecycle from sourcing through building and use to disposal. Environmental considerations can be embedded in policy frameworks, in operational routines as well as in IT human infrastructure and managerial considerations and practices. Thus:

> G-readiness is defined as an organization's capability (and state of maturity) in applying environmental criteria to its IT technical infrastructure as well as within its IT human infrastructure and management across the key areas of IT sourcing, operations and disposal.

G-readiness demonstrates the comparative levels of Green IT development among businesses and serves as a benchmark for measuring an enterprise's progress to participate in the global low-carbon E-economy. Thus *G-readiness* is a measurement of the Green-IT *capabilities* of an organization.

Content Analysis of G-readiness

The opertionalization of the G-readiness construct follows two exploratory strategies. The first strategy involved a thorough and extensive review of existing practitioner Green IT whitepapers and consultant reports (Accenture 2008; ACS 2007; CFO 2009; Gartner 2008; Goasduff and Forsling 2007; Info~Tech 2007b, 2008a; Mines 2008; Mitchell

2008; Nunn 2007; Rasmussen 2006). In addition, literature on green supply chain (Rao and Holt 2005; Srivastava 2007) green strategies (Enkvist et al. 2007; Fuchas 2007; Hart 1995 1997; Olson 2008) adoption of environmental technologies (Gonzalez 2005), IT infrastructure (Broadbent and Weil 1997; Duncan 1995; Ravichandran and Letwongsatien 2005) and Green IT (Chen et al. 2008; Elliot 2007; Elliott and Binney 2008) were reviewed. From this review we identified a number of underlying themes. First, it is important that IT personnel and IT management are both aware of, and concerned about greening their IT across the key areas of sourcing, operations and disposal (Info~Tech, 2008a). This will typically require a change in mindset in terms of understanding the need to reduce the negative environmental impact of IT as well as seeing the potential of IT to enable environmentally sustainable business practices (Hart 1997; Info~Tech 2008b). Second, as organisations become increasingly aware of the importance of policies for environmentally sustainable business practices as part of their corporate social responsibility, progressive organisations are extending these policies to IT (Goasduff and Forsling 2007; Olson 2008). Third, like many business initiatives, discrepancies exist between the intentions reported in Green IT policies and the operalization of those intentions in practice (CFO 2009; Info~Tech 2007c). Fourth, there are a number of technologies that are recognised as offering Green advantages (Info~Tech, 2007c). For example, the virtualisation of servers and use of thin clients are reported to offer benefits in terms of efficiency, security and offering (consequential) environmental advantages (Elliot and Binny 2008). Fifth, although the importance of managing Green IT is well recognized, current practices vary significantly (CFO 2009; Gartner 2008). For example, whereas some organisations allocate the responsibility to govern Green IT to IT managers, others consider Green IT as part of enterprise wide sustainability initiatives.

The second strategy led to a desk-research on the Green IT strategies and practices of seven conveniently selected companies – SAP, IBM, Deloitte, ANZ, Australia Post, BHP, Telstra. In the case studies, the interest was to know what exactly the sampled organizations are doing in Greening their IT and if there are any commonly encountered barriers. ANZ's Carbon Disclosure Project[1] highlighted to what extent Green issues are top of mind within the management team. From IBM's Big Green project, Telestra's "Next Gen initiative" and SAP's SGreen application, it was evident that developing Green practices and Green innovation are partly a technology issue and partly a human issue. The cases also revealed a number of practices aimed at reducing the environmental foot print of IT (such as banning screen savers and retiring energy inefficient systems in ANZ and Telstra) and using IT to improve sustainability (such as Telework in IBM). The importance of policy and environmental governance were clear in all cases. The policy frameworks cover from environmental preferable purchasing policy in Telstra to greenhouse gas management and energy conservation programs in BHP.

The resulting G-readiness dimensions taken from the combination of the two strategies are – *attitude, policy, practice, technology and governance*. Combining the above definition of G-readiness with these five dimensions yields:

> G-readiness is an organization's capability as demonstrated through the combination of attitude, policy, practice, technology and governance in applying environmental criteria to its IT technical infrastructure as well as within its IT human infrastructure and management across the key areas of IT sourcing, operations and disposal to solve both IT and non-IT (by using IT) related sustainability problems.

The attitude and practice dimensions of G-readiness are elements of the IT human infrastructure; the policy and governance dimensions are elements of the IT managerial capability and the technology dimension is an element of the IT technical infrastructure. We now describe the five dimensions of Green IT Readiness using examples from our exploratory desk-based research.

Organizations are likely to adopt very different attitudes at the corporate level to dealing with eco-sustainability, and these differing attitudes will impact their expectations of Green IT (CFO 2009; Hart 1997; Info~Tech 2008a). *Green IT attitude* is therefore defined as an organization's IT human infrastructure's sentiment towards climate change and eco-sustainability. It measures the extent to which both IT and business are aware and concerned about the impact of IT on eco-sustainability. For example, ANZ's Top management attitude towards Green IT is highlighted from statements in its Carbon Disclosure Project[2]. The sentiment to environmental concerns from the use of IT is further strengthened by the involvement of top management through the initiatives of ANZ CIO, who's intention was to

1 http://www.anz.com/Documents/AU/Aboutanz/ANZ_CDP5_Response_FINAL.pdf

2 http://www.anz.com/Documents/AU/Aboutanz/ANZ_CDP5_Response_FINAL.pdf

remove a total of 400 servers from the bank's infrastructure by the end of 2008 both to reduce electricity cost and carbon emissions.

Green IT Policy encompasses the frameworks an organization puts in place to apply environmental criteria in its IT-related activities. It measures the extent to which Green issues are encapsulated in organizational procedures guiding the sourcing, use and disposal of the IT technical infrastructure and the activities of the IT human infrastructure (Goasduff and Forsling 2007; Info~Tech 2007a, 2007b, 2008b; Olson 2008). For example, Telstra has a Green Purchasing Environmental Policy that was launched in June 2002. BHP on the other hand intends to have greenhouse gas management and energy conservation programs at all of its sites that have annual emissions greater than the equivalent of 100,000 tons of CO2. BHP has also put in place a health, safety, environmental responsibility and sustainable development (HSEC) policy[3.] The maturity of Green IT policy reflects whether environmental considerations are systematically permeating the IT activity value chain and are repeatable or they are disorganized and based on uncoordinated efforts.

Policy captures an organization's intent to Green IT. However, not all policies are expected to be smoothly implemented nor are all practices expected to be policy led. Organizations are likely to vary in the actual practice of analyzing the Green track record of IT hardware, software, and services providers (CFO 2009; Info~Tech 2007c). They are also likely to vary in their practice in operating the IT and network critical physical infrastructure in data centers and beyond data centers throughout the organization in an eco-friendly manner (Accenture 2008; CFO 2009; Info~Tech 2007d). For example, some are enforcing advanced Configuration and Power Interface (ACPI) to slow down processors (Info~Tech 2007a). ANZ has banned screen savers and is retiring energy inefficient systems. In 2005, IBM USA's Tele-work program involved over 20,000 employees, saving more than 5 million gallons of fuel and avoiding more than 50,000 tons of CO2 emissions. A number of companies either recycle their IT hardware at the end of its life or dispose it in an environmentally friendly way (CFO 2009; Mitchell 2008). For instance Deloitte's Green IT practices involve "replacing traditional computers with thin laptops, embracing LEED (Leadership in Energy and Environmental Design) for new data centers, and introducing application centralization and platform standardization[4.] *Green IT Practice*, therefore, pertains to the actual application and realization of eco-sustainability considerations in IT infrastructure sourcing, operation and disposal.

The *G-readiness technological* dimension refers to technologies and information systems for (a) reducing the energy consumption of powering and cooling corporate IT assets (such as data centers) (b) optimizing the energy efficiency of the IT technical infrastructure (c) reducing IT induced greenhouse gas emissions (d) supplanting carbon emitting business practices and (e) analyzing a business's total environmental footprint (Accenture 2008; CFO 2009; Info~Tech 2007c; 2007d; Chen et al 2008; Elliot and Binny 2008). For example SAP's Recycling Administration Application can help organizations meet regulatory reporting and documentation requirements, manage the recycling declaration and payment processes more efficiently, and reduce risk and cost of environmental reporting. The SAP Environmental Compliance application is designed to help "organizations ensure compliance with environmental laws and policies and reduce associated costs, efforts, and risks on plant and corporate level. It streamlines all environmental processes by seamless integration with operations control data, production control systems, and components from SAP software for environment, health and safety, enterprise asset management, materials management, the SAP Manufacturing Integration and Intelligence (SAP MII) application, business intelligence and knowledge management"[5].

Green IT Governance is the operating model that defines the administration of Green IT initiatives and is closely related to the policy construct. Roles, responsibilities, accountability and control for Green IT initiatives need to be clearly established. Businesses should determine whether the responsibility for Green IT initiatives should be assigned to CIO's or to environmental managers (CFO 2009; Gartner 2008). In the ANZ and Deloitte, IT leads Green IT initiatives, while in others, IT's role is restricted to providing either tools or insights (Gartner 2008). SAP on the other hand has an internal campaign, called sGreen, with the goal of launching green environmental program that defines global roles and responsibilities. Deloitte's Green IT operating model is based on a three step process of planning sustainability measures, implementing and tracking the measures and addressing green organizational change[6]. Governance also includes allocation of budget and other resources to Green IT initiatives and defining metrics for assessing the impacts of Green IT initiatives. Indeed, governance capability will require standard administrative processes for developing Green IT initiatives to be put in place.

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3 http://sustainability.bhpbilliton.com/2003/caseStudies/cs_environment11.html

4 http://www.computerworld.com.au/index.php/id;251353255;fp;4;fpid;2359)

5 www.sap.com

6 http://www.deloitte.com/dtt/article/0,1002,sid%253D171726%2526cid%253D191008,00.html

Using the above definitions and dimensions of Green IT readiness, a content analysis of the Green IT practitioner and research literature was undertaken. This has resulted in an initial pool of 103 items. After an initial pool of items was identified, a team of five researchers reviewed the items. This has resulted in the deletion of some items and edit of the instrument to capture the essence of the domain constructs of the G-readiness dimensions. After this discussion, the resulting questionnaire was then submitted for ethics approval to a Collage Ethics Committee. Based on feedback from the College Ethics' Committee, additional items were dropped. The process resulted in reduction of items from 103 to 66. The 66 items are given in Appendix A with original sources of references.

Data Collection

Data for the study were collected through a survey of organizations between December 2008 and March 2009. To define the sampling frame for the study, we targeted organizations in Australia, New Zealand and USA with more than 100 employees but excluded those in the agriculture, and mining sectors. These two sectors are excluded because previous research indicates that the development of the IT infrastructure in these sectors is not matured (Molla and Peszynski, 2009; Mia and Duta, 2007). On the other hand, existing practitioner research (Info~tech, 2007c; Nunn, 2007; Climate Group, 2008) indicates that Green IT initiatives are likely to be top of mind in organizations that have a relatively developed IT infrastructure. Another criterion was to target Chief Information Officers or their equivalent. The decision to survey organizations from the three countries was motivated due to both research design and operational considerations. In terms of research design, a three country survey captures different experiences and ensures that the G-readiness construct is widely applicable. For example, while US organizations tend to focus more on energy efficiency, in other regions, climate change and environmental sustainability concerns tend to be top priority (Info~Tech, 2008a). Thus, surveying more than one country normalizes some of the biases that could have otherwise been in the data. Operationally, there are known commercial database providers with names and e-mail addresses of CIOs in Australia, New Zealand and USA.

Virtually all commercial database providers contacted for the purpose of the study do not have a product that covers the three countries. As a result, two providers were selected. Australian and New Zealand sample were drawn from a database rented from IncNet Australia whereas US samples were drawn from the Top Computer Executives database. IncNet was chosen because to the best of our knowledge, it is the only business database that provides names and e-mail addresses of IT managers. The Top Computer Executives database is widely used in previous IS research. The sampling criteria were then passed to the two commercial database providers. IncNet provided an initial list of 1305 contacts from Australia and 215 from New Zealand. 1000 records were rented from the Top Computer Executives database. Upon inspection of the data set, 354 of the Australian and 13 of the New Zealand contacts were outside the sample frame (mostly non-CIO contact and in some cases from industries excluded form the sample frame) and were therefore excluded. After initial screening of the rented databases, a total of 2153 CIOs or their equivalent (951 Australian, 202 New Zealand and 1000 US) were invited to complete the on-line survey. The initial invitation was followed with three rounds of reminders. A total of 146 responses were received (See Table 1). Three were unusable hence removed from the analysis leaving 143 usable responses (95 Australian; 14 New Zealand and 34 US) with an 11% response rate (See Table 1).

Table 1. Response Rate

	Australian Sample	New Zealand Sample	USA Sample	Total
Initial sample size (a)	951	202	1000	2153
Undeliverable & Decline (b)	379	107	298	784
Total response (c)	94	15	37	146
Effective response rate	16%	16%	5%	11%

Note: Effective response rate = c /(a-b)

Baruch (1999) had suggested a norm referenced response rate of 36% (+/-13%). Compared to Baruch's recommendation, the current response rate is low. A number of reasons could explain this deviation. First, Baruch's recommendation is based on a sample of articles drawn from the 1975, 1985 and 1995 volumes of five journals and might not be strictly applicable in 2009. In fact, one of the findings of Baruch's study is the declining trend in the average response rate from 64% (+/-16%) in 1975 to 48% (+/-23%) in 1995. If this trend continued, the popularity of on-line surveys gives enough reason to suspect such might have been indeed the case, the norm response rate in 2009 is likely to be lower than 36%. Second, Baruch's norm is based on management and behavioral sciences journals and not information systems journals. Third, Burch's norm has not considered either the initial sample size or the magnitude of the data points (number of cases). Although the response rate in the current study is lower than Baruch's suggested norm, it is comparable to response rates of other information systems studies that target senior executives (Bhatt and Grover, 2005; Fink and Neuman, 2007) and to studies on the adoption of environmental technologies (Gonzalez, 2005).

To estimate the presence and extent of non-respondent bias, it was not possible to compare respondents with non-respondents. This is because the rented database contained only names and e-mail addresses. Therefore, non-response bias test was undertaken following Lewis-Beck et al (2004) and Armstrong and Overton's (1977) suggestion and comparing early respondents with late respondents. This test, which is also referred to as extrapolation (Armstrong and Overton 1977) is based on the assumption that late respondents, especially those that responded after reminders were sent out, are likely to have characteristics similar to those of non-respondents. There is no literature that guides on what characteristics to use in comparing early and late respondents. Therefore, we compared the first 21 respondents with the last 21 respondents on all items using Mann–Whitney U test. The result shows that the two groups of respondents are significantly different on only one item (3i) (*early respondent mean rank, 17.64, late respondent mean rank, 25.36, p= 0.036; z= -2.09)*. This implies that even if non-response bias can not be completely ruled out, it is not statistically significant. Overall, in view of the preliminary nature of this study, the non-response-bias test and response rates reported in information systems research, the 143 responses can be considered as reasonable.

Most of the respondents (83%) were CIOs or IT (systems, infrastructure, and information) managers. Others held job titles such as Enterprise Architect, Software Development Manager, Office Manager, IT Coordinator, Directory of Sustainability and IT Group Leader. While 69% classify their organizational size as medium and 24% as large, the remaining were small (Table 1). In terms of industry distribution, most respondents were from manufacturing (21%), government (16%) and services (13%) sectors. Participating firms differ in terms of their IT profile. Forty one percent of all respondents operate IT shops with less than 50 servers, 20% between 50 and 150 and 34% more than 150 servers. Other demographic characteristics are given in Table 2.

Table 2. Demographic profile

Industry classification	Frequency	Percentage		Organizational size	Frequency	Percentage
Others	3	2%		Small	19	13%
Utilities & Transport	8	6%		Medium	92	64%
Trading	10	7%		Large	32	22%
ICT	12	8%		Total	143	100%
Finance & Insurance	12	8%				
Education	12	8%		**Server size**	**Frequency**	**Percentage**
Health	14	10%		Less than 50	59	41%
Services	19	13%		50-150	29	20%
Government	23	16%		More than 150	48	34%
Manufacturing	30	21%		Missing	7	5%
Total	143	100%		Total	143	100%

Instrument Assessment

Factorial validity was followed for validating the instrument (Straub et al., 2004). To assess the instrument and test the initial conceptual constructs, we used confirmatory factor analysis (CFA) and LISREL 8.8 program. Since the data are captured with a Likert scale, polychoric correlation and generally weighted least-squares (WLS) are used to estimate the parameters in the model (Jöreskog & Sörbom, 2001). The evaluation of the confirmatory factor model follows the process that Hair et al., (2006) and Straub et al., (2004) suggest. One of the critical considerations in using CFA-based models is the sample size vis-à-vis the number of parameters to be estimated. Although there is no ideal sample size, some consider around 200 as "good" (Byrd & Turner, 2000) while others argue that a sample size should be at least 10 times the number of parameters to be estimated (Raykov & Marcoulides, 2006). Since the sample size in the current study is less than 200, the number of parameters to be estimated is reduced by constraining the measurement model from a congeneric model (i.e. each item measures a hypothetical factor with different accuracy and its measurement error is different) into a parallel model (i.e. all items measure a hypothetical factor with the same accuracy and their measurement errors are the same) (Graham, 2006). This approach reduces the number of parameters to be estimated and provides an adequate sample size to parameters ratio for using CFA.

Further, it improves the accuracy of parameter estimation, statistical power and the objectivity of results (MacCallum et al., 1996; Mulaik, 1993).

To evaluate the measurement properties of the G-readiness model and its constructs, convergent validity, discriminant validity and factorial validity tests were conducted. Convergent validity is used to test if all the items that are used to measure a particular construct do indeed measure a single construct. That is, whether or not a construct is unidimensional or multidimensional. The convergent validity tests involved three steps. First to calculate chi-square (χ^2) values for each of the constructs. Second, when chi-Square (χ^2) rejects a factor at $p<0.05$, to use modification indices (MI) to identify common factors among items. Third, to drop items that did not fit into any factor from subsequent analysis. This process produced 39 items in 13 factors. Discriminant validity among the 13 factors was then tested using a pair of factors model comparison analysis. In one model, the covariance between the two factors was constrained to 1 (i.e. assuming that the two factors are the same) while in the other model, the covariance was set free (Straub et al., 2004). The result (Table 3) dropped six items (3A, 3F, 3I, 4E, 5I, 5N) and produced a 10 factor and 33 items model, that is, one factor in attitude, one factor in policy, two factors in practice, four factors in technology, and two factors in governance. Coefficient *H*, which is recommended over Cronbach's α for reliability coefficient in CFA (Handcock & Mueller, 2001), indicates that all factors are reliable (*H*>0.80).

Table 3. Factor structure of the G-readiness construct

Component	Factor	Items	Factor Loading (λ)	χ^2	*df*	*p*	RMSEA	SRMR	CFI	*H*
Attitude	ATT	3C	0.94	0.55	4	0.97	0.000	0.011	1.00	0.96
		3D	0.94							
		3E	0.94							
Policy	POL	4A	0.60	9.39	11	0.59	0.000	0.063	1.00	0.93
		4D	0.60							
		4F	0.90							
		4G	0.90							
		4J	0.90							
Practice	PRA1	5A	0.92	0.02	2	0.99	0.000	0.003	1.00	0.92
		5B	0.92							
		5Q	0.60							
	PRA2	5D	0.81	1.69	4	0.79	0.000	0.024	1.00	0.85
		5E	0.81							
		5K	0.81							
Technology	TEC1	6A	0.59	2.57	2	0.28	0.045	0.031	1.00	0.85
		6D	0.85							
		6E	0.85							
	TEC2	6H	0.86	0.00	1	1.00	0.000	0.000	1.00	0.85
		6K	0.86							
	TEC3	6J	0.84	0.00	1	1.00	0.000	0.000	1.00	0.83
		6M	0.84							
	TEC4	6L	0.71	5.62	13	0.96	0.000	0.037	1.00	0.84
		6O	0.71							
		6P	0.71							
		6S	0.71							
		6T	0.71							
Governance	GOV1	7B	0.89	0.00	1	1.00	0.000	0.000	1.00	0.88
		7D	0.89							
	GOV2	7E	0.86	4.33	8	0.83	0.000	0.036	1.00	0.92
		7F	0.86							
		7G	0.86							
		7H	0.86							

Factorial validity is used to assess whether the 10 factors that pass convergent and discriminant validity represent the same higher level construct (i.e. g-readiness) and to detect and drop any cross-loading items. As a result of this test one item (6R) is dropped resulting a 10 factor, 32 items G-readiness model. The model has sufficient validity (χ^2 (457)=507.54 at p=0.051). The goodness-of-fit indices (RMSEA=0.028, SRMR=0.063, CFI=1.00, PCFI=0.92) illustrate that the measurement model fits the data well and the parameters estimated in this study are likely to be generalizable into other samples (Mulaik, 2009). To validate the theoretical constructs and measurement model, factor scores based on the results from convergent, discriminant and factorial validity were calculated. The resulting first and second order models are presented in Figures 1-6.

The *Green IT Attitude* is uni-dimensional (ATT). It is comprised of items that reflect energy efficiency concerns in managing the IT technical infrastructure. This implies that when it comes to IT management, rather than green house gas emissions and e-waste pollutions, energy consumption is of primary concern. The *Green IT Policy* dimension is uni-dimensional (POL) too. It reflects not only the maturity of policy frameworks that directly affect the Greening of the IT technical infrastructure but also those that guide the use of IT in reducing a business's carbon foot print (that is using IT as part of eco-solution). In terms of *Green IT Practice,* two sub-components are identified covering the sourcing and IT infrastructure design and energy consumption audit and monitoring aspects. The first is referred here as procurement (PRA1) and the second energy audit and monitoring (PRA2). Both dimensions of the practice refer to solving IT related sustainability problems (such as emission, e-waste and energy) and those items that refer to the practice of using IT as part of the solution (for example 5I, 5J, 5P) did not make up the final model. *The Technology* dimension contains four sub-components. The subcomponents are subsequently named as IT technical infrastructure (TEC1), data center air-flow management (TEC2), data centre cooling systems (TEC3), power-delivery systems (TEC4). All of the technology components of G-readiness focus on technological solutions that improve IT's energy and water use and that reduce emission and e-waste. *Green IT Governance* has two sub-components: strategic foresight (GOV1), and resource and metrics (GOV2).

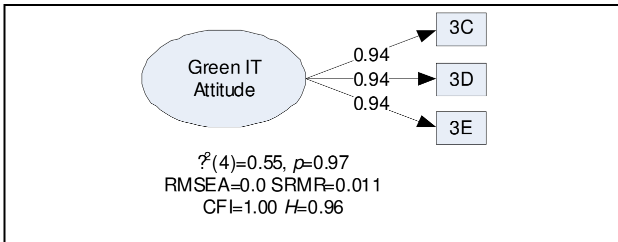

Figure 1. Confirmatory Model of the Attitude Construct

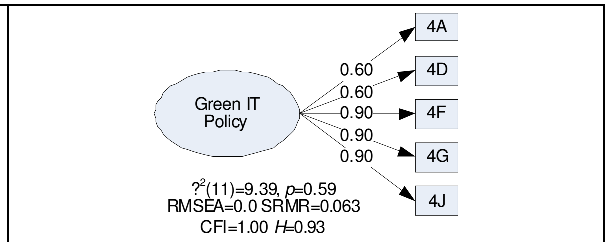

Figure 2. Confirmatory Model of the Policy Construct

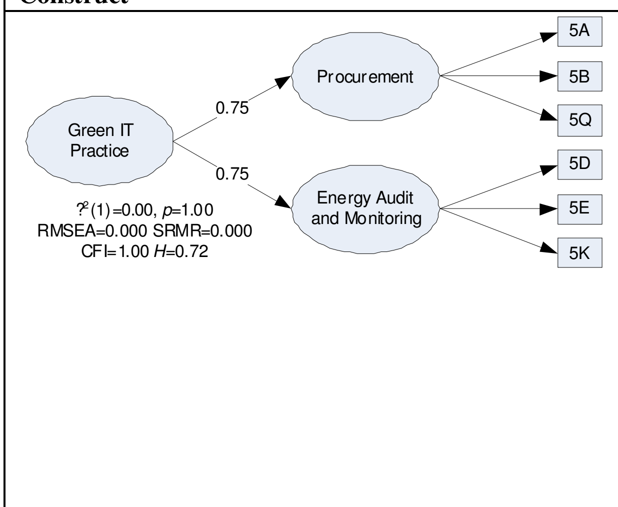

Figure 3. Confirmatory Model of the Practice Construct

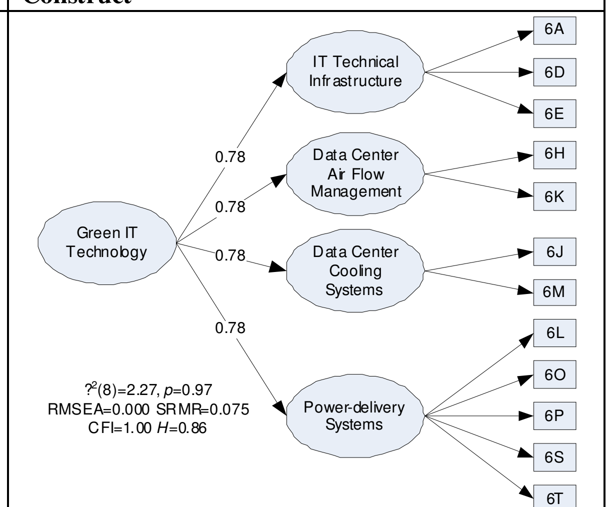

Figure 4. Confirmatory Model of the Technology Construct

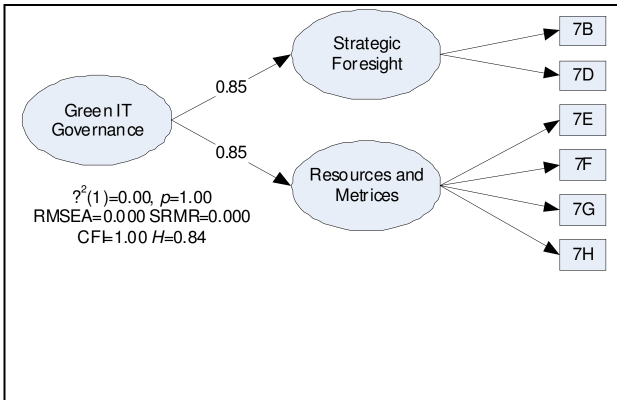

Figure 5. Confirmatory Model of the Governance Construct

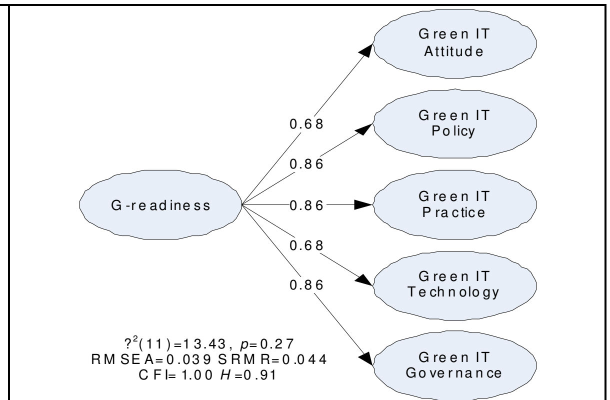

Figure 6. Confirmatory Model of G-readiness

To determine the predictive validity of the model, a G-readiness factor score GFC) was calculated based on the factor score regression weights of each of the five components. Attitude constituted 9.8%; policy 26.8%; practice 26.8%; technology 9.8% and governance 26.8%. The GFC is then correlated with item 7J, which is a global measure of readiness as "Our organization demonstrates adequate readiness for Green IT" using polyserial correlation. The result signifies that the model has high predictive validity: r=0.829 at p(one-tailed)< 0.001.

Discussion

Green IT is a relatively recent research field. There is very little academic research on the topic. The advance of Green IT research field, like other research fields, requires theorization, model construction, and measurement development (Hair et al. 2006). This is because "theory construction and a cumulative tradition, the ultimate objectives of a research field, are inseparable from measurement" (Byrd and Turner 2000:192). This study develops the G-readiness model as a capability and identifies its main pillars. The model is based on previous literature on IT infrastructure and eco-sustainability and emerging practitioner and academic research on Green IT.

For any field of study to progress in theorization, clear definition of a construct is an essential first step. Indeed "defining a construct using rigor is an important aspect of theory building. Lack of rigor often leads to competing and fuzzy conceptualizations" (Pankaj et al. 2009: 22). The study offers a theoretically grounded definition of Green IT. Likewise, the study offers a clear definition of G-readiness as a capability (hence varying in maturity among organizations) of applying eco-sustainability criteria to the technical, human and managerial IT infrastructure of an organization not only to solve IT related sustainability problems but also to use IT as part of the solution to achieve sustainability. Both definitions clearly state the "genus" (the type of thing defined- *Green IT and G-readiness*) and "differentia" (what distinguishes them from others of the same genus- *drawing from the IT infrastructure, capability and eco-sustainability perspectives and covering both sides of the IT and eco-sustainability equation, that is IT as part of the problem and as part of the solution*) (Pankaj et al. 2009: 22). The definitions further have conceptual clarity (in terms of both "Green" and "IT") and offer details of specific variables, elements, or components (for example those covering the IT lifecycle and the five G-readiness dimensions) – additional qualities of a good definition (Byrd and Turner 2000; Pankaj et al. 2009). These definitions therefore represent one of the academic contributions of this paper.

The G-readiness model represents another original contribution to the information systems literature. The theoretical hypothesis for the G-readiness model is that the G-readiness is comprised of five dimensions that demonstrate an organization's intention and execution to reduce both IT and non-IT (by using IT) related sustainability issues such as energy, waste, emission and water. Through the rigorous process followed, the final model is comprised of a higher level G-readiness construct, five components, eight sub components and 32 items (see Figure 7). The G-readiness model will be useful to understand the capability of businesses in addressing IT related emissions, energy and waste. It however needs further development and refinement to capture the capability of using IT as part of the solution in solving eco-sustainability problems. The model will allow IT managers to approach Green IT not only from the IT technical infrastructure but also the human and managerial perspectives. In addition, the model, rather than viewing Green IT from one domain of the IT activity chain, is based on a lifecycle approach covering IT sourcing, operation and disposal. The value of such a framework and hence the contribution of this paper to IT management practice is significant. The model offers a common platform for practitioners to assess and benchmark their Green IT initiatives and progress.

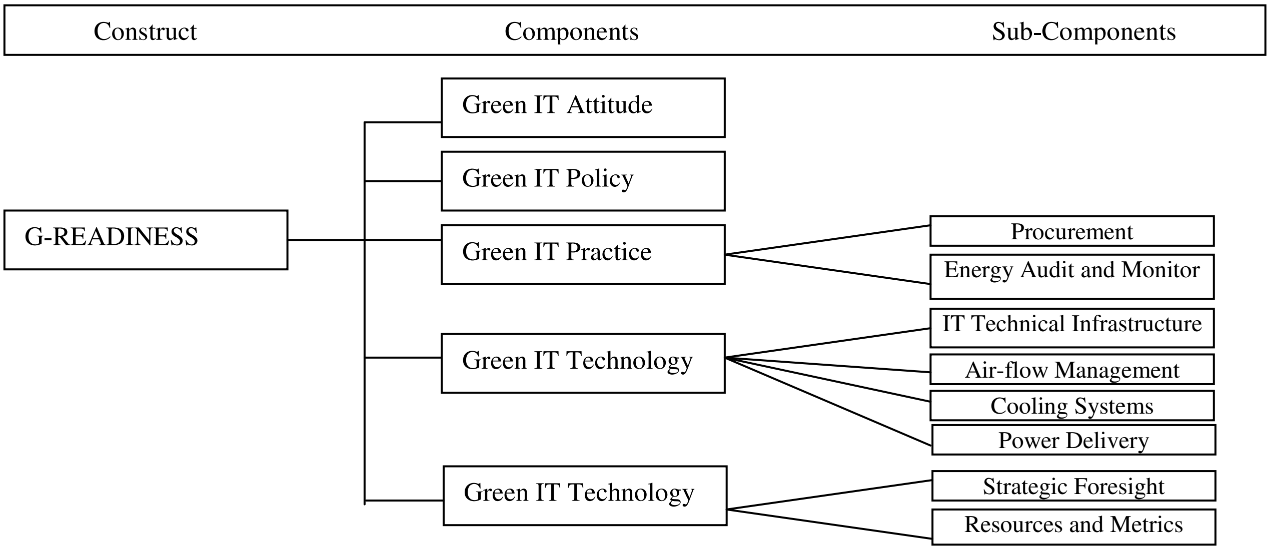

Figure 7. The G-readiness Model

A simple operational application of the model for practitioners is to assess G-readiness to identify areas that need improvement. Such an assessment is inherently subjective. If it is done by a group of managers for a single organization, it first requires developing a shared understanding of the G-readiness items. For example, by using a tally sheet, managers (either individually or as a group) can evaluate their performance across the 32 items on the scale of 1(low) to 7 (high). The item scores can be averaged to produce average scores of the 10 subcomponents. On the basis of a seven-point scale, the maximum value of a sub-component 7. The sub-component score can then be averaged to produce a score for the five basic components of G-readiness. Aggregating the five components will yield a G-readiness score out of a maximum of 35. On the basis of this simple algorithm, evaluation of the 143 respondents shows that their G-readiness score is 19.30 which can be interpreted as average. Figure 8 provides further details of the G-readiness at a component level for respondents in each of the three countries.

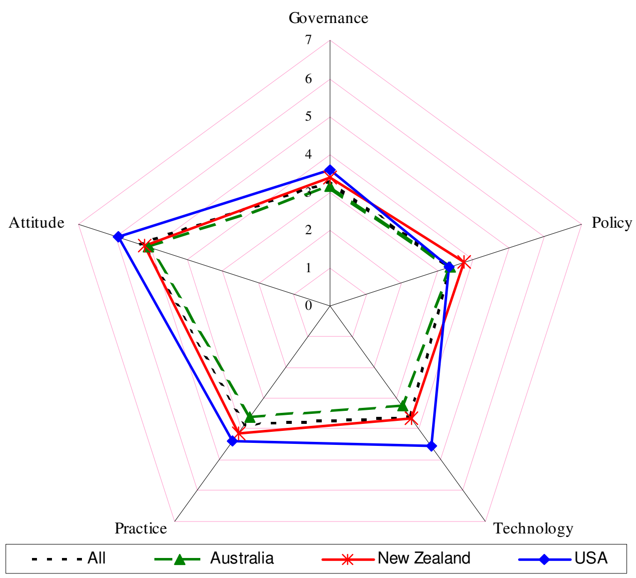

Figure 8. G-readiness Results for Australia, New Zealand and USA

Conclusion, Limitations and Future Research

Businesses are under increasing pressure from customers, competitors, regulators and community groups to implement sustainable business practices. Balancing economic and environmental performance to be green and competitive is therefore a key strategic issue. Usually coined as, “Green Information Technology”, the role of IT in causing and resolving ecological sustainability, in maintaining low cost IT shops, in building green reputation capital and in supporting corporate green strategies has hardly been researched. This study argued that as much as E-readiness has been and still continues to be a critical attribute to succeed in the digital economy, G-readiness is a critical capability to make the digital economy ecologically sustainable.

The current study has made an original contribution in defining the G-readiness construct and model and developing the dimensions that constitute it. It also provides a research-ready instrument whose properties are sufficiently validated. Although the definitions of Green IT and G-readiness are comprehensive and include both sides of the IT and eco-sustainability equation, the developed model is more useful in capturing the capability of an organization in resolving IT related sustainability problems. However, as IT is embedded in internal and supply chain business processes, the trickledown effect of Greening IT will touch many other areas and can have significant impact on the overall sustainability of a business. The rigorous procedure followed in validating the model indicates that the five dimensions fit well with the first order construct of G-readiness. The developed model is comprised of a higher level index, five component indexes, 10 sub-indexes and 32 items. The model can be used by other researchers to establish cause-and-effect relationship models. As demonstrated in the previous section, it can also be used by practitioners as a decision tool to locate, measure, and manage their Green IT capability and identify strategies to improvise it.

Future tests and refinements of the proposed model will be extremely useful to advance knowledge on Green IT. First, the model can be further enhanced and refined to capture the capability of using IT as part of the solution in solving eco-sustainability problems. Second research using a larger sample size can test if the results obtained in the current study are replicable. Third, the developed instrument has not been tested for test-retest reliability and external validity. Since factorial validity was the primary technique used in testing the construct validity, common method bias might not be completely ruled out. Fourth, due to data limitation, there was no holdout sample to confirm the derived model. Thus, the model can only be considered as preliminary and needs further confirmation. Replicating the study would enable such tests. Fifth a qualitative study of how managers would interpret and assess or measure the values of the 31 items suggested here would provide insights as to the reliability of the items. Sixth a detailed practitioner guideline on how to apply the developed models in view of the inherently multi-dimensional nature of the evaluation problem represents another avenue for future research. Lastly, future study based on a single country survey can enhance this study. Notwithstanding the above limitations which offer opportunities for further refinement of the model, the current study has provided an original framework upon which other researchers might base their studies on. Because of the increasing importance of the role of IT in eco-sustainability, researchers should continue investigating the preliminary model developed here. This can be achieved by refining the measures and factors proposed in this model, by testing the relationship among the different G-readiness factors, and by exploring the relationship between the g-readiness factors and other antecedent and/or consequent variables of interest.

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Appendix A: Initial Instrument

Initial Item Measures for G-readiness's Attitude Construct
Seven point scale anchored by 1= Strongly Disagree and 7= Strongly Agree

		References
3a	Our organisation is concerned about emerging regulations in greenhouse gas emissions	Chan & Yam (1995) Info~Tech (2007a) Info~Tech (2007c) Mitchell (2008)
3b	Our organisation is concerned about our IT's energy consumption	
3c	Our organisation is concerned about the energy consumption of cooling and lighting our data centres	
3d	Our organisation is concerned about the efficiency of powering our IT infrastructure (storage, servers, network)	
3e	Our organisation is concerned about IT's contribution to greenhouse gas emissions	
3f	Our organisation is concerned about our business's overall environmental footprint	
3g	Our organisation is concerned about our IT suppliers' environmental footprint	
3h	Our organisation is concerned about our clients' environmental footprint	
3i	Our organisation is concerned about the environmental impact in discarding IT at the end of its life	

Initial Item Measures for G-readiness's Policy Construct
Seven point scale anchored by 1= Not at all developed and 7= Extremely well developed

		References
4a.	Corporate social responsibility policy	Goasduff & Forsling (2007) Hart (1997) Info~Tech (2007a) Info~Tech (2007b) Info~Tech (2008b) Mines & Davis (2007)
4b.	Green supply chain management policy	
4c.	Environmental sustainability policy	
4d.	Shifting to green sources of energy	
4e.	Environmentally friendly IT purchasing policy	
4f.	Green data centres policy	
4g.	Policy on the use of IT to reduce the business's carbon footprint	
4h.	Policy on employees use of IT in an energy efficient manner	
4i.	End of IT life management	
4j.	Green information technology policy	

Initial Item Measures for G-readiness's Practice Construct
Seven point scale anchored by 1= Not at all practiced and 7= Practiced to a great extent

		References
5a.	Preference of IT suppliers that have a green track record	Accenture (2008) CFO (2009) Elliot & Binney (2008) Rao & Holt (2005) Info~Tech (20007c) Whitby (2007) Info~Tech (2007d) Rammussen (2006) Info~Tech (2007a) Alsever (2008)
5b.	Gives weight to environmental considerations in IT procurement	
5c.	Shortens IT equipment refresh periods to gain access to more energy efficient equipment	
5d.	Considers environmental factors in the design of the site infrastructure (lighting, power delivery, cooling systems) and IT infrastructure (servers, storage and network) of data centres	
5e.	Audits the power efficiency of existing IT systems and technologies	
5f.	Switches off data centre lights and equipment when not needed	
5g.	Operates existing IT systems in an energy efficient manner	
5h.	Enforces PC power management	
5i.	Implements IT projects to monitor the enterprise's carbon footprint	
5j.	Prints double-sided on paper	
5k.	Analyses IT's energy bill separately from the overall corporate bill	
5l.	Relocation of its data centre near clean sources of energy	
5m.	Recycles consumable equipment (e.g. batteries, ink cartridges, and paper)	
5n.	Disposes of IT equipment in an environmentally friendly manner	
5o.	Uses electricity supplied by green energy providers	
5p.	Engages the service of a professional service provider regarding Green IT	

5q. Prefers hardware vendors that offer end of IT life “take-back” options	

Initial Item Measures for G-readiness’s Technology Construct
Seven point scale anchored by 1=Not at all and 7=Great Extent

	References
6a. Server consolidation and virtualisation	Accenture (2008)
6b. Desktop virtualisation	CFO (2009)
6c. Storage virtualisation	Elliot & Binney (2008)
6d. Data de-duplication	Brocade (2007)
6e. Storage tiering	Gonzalez (2005)
6f. Print optimisation	Info~Tech (2007c)
6g. Rightsizing IT equipment	Info~Tech (2007d)
6h. Data centre airflow management	Mines (2008)
6i. Free cooling in large scale data centres	Mitchell (2008)
6j. Water cooled chillers with variable speed fans and pumps	Nunn (2007)
6k. Hot aisle/cool aisle data centre layout	Rasmussen (2006)
6l. Upgrades to more efficient transformers and UPS	Rossi (2007)
6m. Airside/waterside economizer	
6n. Liquid cooling for IT equipment	
6o. Install more energy efficient lights	
6p. High voltage AC power	
6q. DC powered IT equipment	
6r. High efficiency stand-by power systems	
6s. Retire energy inefficient systems	
6t. Computers that have functions to monitor workloads and to shut down components when unused	

Initial Item Measures for the G-readiness’s Governance Construct
Seven point scale anchored by 1= Strongly Disagree and 7=Strongly Agree

	References
7a. Our business has set C02 targets to reduce our corporate carbon footprint	CFO (2009)
7b. We have defined a role for coordinating our business’s green initiatives	Gartner (2008)
7c. Top management discuss Green IT issues as a priority	Info~Tech (2008)
7d. Responsibilities are clearly defined within each Green IT initiative	Rao & Holt (2005)
7e. Our CIO plays a leading role in all green (IT and non-IT) initiatives	
7f. We have earmarked a budget and other resources for Green IT	
7g. We have established metrics for assessing the impact of Green IT initiatives	
7h. Our organisation has mechanisms for monitoring IT suppliers’ green performance	
7i. IT is responsible for its own electricity costs	
7j. Our organisation demonstrates adequate readiness for Green IT	