Roadmapping the next wave of sustainable IT

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Abstract

Purpose – *This paper aims to explore the strategic dimensions and drivers of sustainable IT and roadmaps its likely development as a disruptive innovative force over the next decade as it moves beyond the datacenter and throughout the IT organization, the firm, markets, and society at large. Its purpose is to provide a comprehensive view of the emerging industry to inform sustainable IT strategy development and stimulate future research.*

Design/methodology/approach – *This paper uses a qualitative three-phase process to develop the technology roadmap for the sustainable IT industry. The phases are domain analysis, which features a comprehensive literature review and expert panel depth interviews; roadmap development, which involved two technology roadmapping brainstorming sessions; and follow-up activity, to confirm roadmap session results with the expert panel.*

Findings – *The paper defines the emerging field of sustainable IT and its green IT and sustainable IT services dimensions. It identifies market segments, products and services, technologies, compliance and reporting requirements, organizational changes, and value migration and roadmaps a likely future landscape for the development of sustainable IT strategy.*

Practical implications – *Developing a sustainable IT strategy is a major issue for most organizations. Managers and researchers can use the results of this study to better understand the dimensions of sustainable IT and its likely future growth paths. Researchers will find the comprehensive approach to the topic useful for planning future technological innovations and determining their disruptive potential. Managers can use the results to benchmark their current situation and develop strategies for the next generation of sustainable IT service solutions.*

Originality/value – *This paper is the first to apply technology roadmapping to the emerging sustainable IT industry. It provides a strategic planning perspective of the future of the industry as it migrates from green-IT strategies for reducing the costs and energy use of computing to sustainable IT services that hold the potential for transforming complex environmental and social responsibility problems into business opportunities.*

Keywords *Sustainable IT, Green IT, Strategic planning, Technology roadmapping, Information technology*

Paper type *Research paper*

1. Introduction

The notion of ''sustainable IT'' has gained in popularity as IT managers have become more aware of IT's impact on the environment and society. This recognition has developed slowly over the course of the past two decades starting with the Energy Star program in 1992. However, during the past decade it has been the internet-driven rapid growth of datacenters, their associated energy costs and carbon footprints that motivated the initial development of sustainable IT strategies, often called ''green IT'' or ''green computing.'' Datacenters can account for 25 percent or more of total IT budgets and account for up to 50 percent of energy costs for enterprise scale e-commerce companies (Mitchell, 2007; Forrest *et al.*, 2008; McKeefry, 2008). Datacenter demand is expected to grow at an estimated 20 percent CAGR over the next decade (Wong, 2007). Green IT also includes the goals of

controlling and reducing the environmental footprint of IT operations by minimizing the use and discharge of hazardous materials, conserving water and other scarce resources, and reducing IT-related waste. Accordingly, the heavy focus on green IT has led to well-defined energy efficiency strategies that can be quickly implemented and offer the benefits of lower costs, lower carbon footprints, and can often increase the performance of datacenters and IT operations. Going forward, those benefits and the push from new energy use and environmental regulations will ensure that green-IT development will remain a high priority for IT organizations well into the future (Harmon and Auseklis, 2009).

The focus of green IT is on reducing the energy costs of IT operations. As beneficial as the cost reduction and energy use compliance activities are to the corporation, there is only indirect benefit for customers and other stakeholders. Companies may choose to not pass cost reductions on to customers in the form of lower prices. But, governments, non-governmental organizations (NGOs), unions, the media, and other stakeholders may demand that business do more to ameliorate the environmental, ethical and social consequences of their IT-related business activities on a broader scale (McKeefry, 2008). Corporations are expected to do much more in terms of improving product and service design, rethinking the value chain, and reengineering IT processes to minimize negative impacts and to solve the environmental and social problems that may result from their use (Daoud, 2008; Olson, 2008; Deloitte Touche Tohmatsu, 2009).

Accordingly, sustainable IT services (SITS) constitute the emergent second wave of strategies that is moving sustainable IT beyond the green IT emphasis on energy efficiency to one of creating a service-oriented sustainable IT innovation platform (Harmon and Demirkan, 2011). A SITS-based innovation platform enables the development of applications to address the broad range of environmental and social issues both within the corporation, throughout the value chain, and society at large. Where green IT is about internal cost savings, SITS is about innovation and positioning the corporation for IT-enabled corporate social responsibility (CSR) leadership (Zarella, 2008; Deloitte Touche Tohmatsu, 2009). SITS holds the promise for enabling the IT organization to fulfill a much broader societal mission. This broader approach to sustainability will require changes in the nature of how value is conceived and delivered if competitive advantage is to be realized at the corporate and societal levels (Porter and Kramer, 2006; Esty and Winston, 2009). SITS strategies will spur innovation, develop new markets, redefine processes, and require both cultural and operational changes in IT organizations. The new sustainable IT charter will integrate the IT organization's business role with global sustainability and social responsibility requirements (Pohle and Hittner, 2008; Deloitte Touche Tohmatsu, 2009; Harmon and Demirkan, 2011). These changes reflect a shift in customer requirements from a primary focus on tangible cost-benefits of IT as a product (e.g. reduced energy usage) to the more intangible green benefits of sustainable IT as a service for implementing socially responsible business models (Senge *et al.*, 2008; Harmon and Demirkan, 2011).

Given the complexity and evolving nature of the sustainable IT discipline, it is useful to consider what its future development might look like. This paper uses a strategic planning approach to develop a technology roadmap for the sustainable IT industry's markets, products and services, technologies, regulations, organizational changes, and value migration. The roadmap provides an industry-wide perspective of major components of the sustainable IT ecosystem. While considerable evidence from the literature and actual practice exists for the green-IT domain, the SITS domain is nascent and just beginning to come into view. Technology roadmaps, and especially the strategic planning variant, provide managers with the ability to identify new markets, assess opportunities and threats, anticipate technological change, plan new products and services, and facilitate organizational changes (Kappel, 2001; Albright, 2002; Phaal *et al.*, 2004; Popper, 2008).

Technology roadmapping methodologies typically includes the following steps as identified by Daim and Oliver (2008): identify key market trends and drivers; define products and services; assess technologies to support the products and services;

establish linkages between markets; products/services, and technologies; develop plans to acquire or develop the technologies; and assign resources to accomplish the plans. In addition, strategic planning oriented technology roadmaps can assess the necessary organizational changes to adapt to the changes in the business environment and the type of value created (Phaal *et al.*, 2004).

The purpose of this paper is to develop a technology roadmap for the sustainable IT industry that provides insights for its evolution as it transitions from the green-IT product orientation to the development of sustainable IT services that can address the full range of corporate sustainability requirements. The presentation is organized as follows: section 2 provides a review of the background literature on sustainable IT, market trends, and value dimensions. Section 3 presents the sustainable IT technology roadmap and its development methodology. Lastly, section 4 addresses the roadmap's limitations; implications for future research; and insights for managers seeking to adapt their organizations to meet emerging sustainable IT requirements.

2. Literature review

The development of sustainable IT, and its green IT and SITS domains, as a major strategy emphasis for IT organizations is the direct result of emerging market conditions driven by energy prices, environmental regulations, and customer and societal values. These factors have served to create new market opportunities, develop new technologies and solutions, and drive the rethinking of the role of the IT organization as an enabler of corporate sustainability strategy.

2.1 Green IT

Green IT has been defined as the practice of maximizing the efficient use of computing resources to minimize environmental impact (Deloitte Touche Tohmatsu, 2009). Until recently, green IT issues, such as energy consumption for datacenters and IT operations were virtually ignored. However, unresolved green IT issues, due to the rapid increase in energy consumption by datacenters and energy access and availability concerns, have become major limiting factors in terms of deploying new IT systems, especially for large enterprises (Wang, 2007). Energy costs for datacenters are increasing at 20 percent CAGR and starting to crowd out investments in new equipment, IT R&D, and business expansion plans (Bailey *et al.*, 2007; Harmon and Auseklis, 2009). High-energy costs and the increasing concern about carbon dioxide emissions from IT operations are the driving forces behind the green IT movement (Forrest *et al.*, 2008; Harmon and Auseklis, 2009). These trends are exacerbated by declining IT budgets and challenging economic conditions that are very likely to continue and provide plenty of motivation for companies to adopt green IT solutions (The Green Grid, 2007; Dubie, 2009; Harmon *et al.*, 2010).

The following observations support the major green-IT trends:

- The continuing fast growth of the internet for e-commerce, communications, entertainment, business processes, and storage will continue to drive the development of datacenters and increased energy use (Bailey *et al.*, 2007; Fanara, 2007; Wong, 2007).
- Datacenter characteristics, such as low-server utilization rates, high equipment power densities, and heat densities that increase cooling requirements, are leading causes of poor energy efficiency (Forrest *et al.*, 2008; Stanford, 2008; Torres *et al.*, 2008; Deloitte Touche Tohmatsu, 2009).
- Energy availability and access limitations will drive conservation and use of alternative energy. Major internet enterprises such as Microsoft, Amazon, Yahoo, and Google have been forced to ''off the grid'' alternative sources of electricity due to their inability access power in major urban environments (Dietrich and Schmidt, 2007).
- Concerns about the carbon footprint from IT operations will drive energy-use regulations and green IT initiatives (Dietrich and Schmidt, 2007; Forrest *et al.*, 2008).

2.2 Sustainable IT services

SITS, the second wave of sustainable IT, reflects the migration from product-oriented green IT to the service domain as IT organizations shift from energy cost issues to sustainability driven innovation (Harmon and Demirkan, 2011). SITS is defined from a total societal value perspective as the systematic integration and alignment of IT service components for ecological and social responsibility oriented corporate sustainability solutions. The goal is to create business and customer value while ensuring that the value to society at large is concurrently enhanced (Harmon and Demirkan, 2011; Kotler and Keller, 2012). IT service components include software, hardware, telecommunications networks, data, storage, maintenance, technical support and consulting that is necessary to design, deploy, operate, and maintain innovative sustainable IT services. SITS represents refocusing of the IT organization's priorities from internal efficiencies to that of seeking to align with the corporate sustainability strategies. SITS, therefore, is focused on using IT capabilities to meet the triple-bottom-line economic, environmental, and social responsibility obligations of the firm (Elkington, 1999; Savitz and Weber, 2006; Deloitte Touche Tohmatsu, 2009).

Environmental and social responsibility issues shape markets (Esty and Winston, 2009). Turning these issues into competitive advantage is what drives SITS strategies. Environmental issues include climate change, energy usage, water usage, air pollution, hazardous materials, waste management, land use, and oceans and fisheries (Global Reporting Initiative, 2006; Senge *et al.*, 2008). Social responsibility addresses the responsibilities of corporations and individuals to society at large. These issues include legal, business ethics, labor, human rights, community, product and service responsibility, and philanthropy (Savitz and Weber, 2006; Olson, 2008). CSR issues impact and are impacted by the corporate ecosystem, stakeholders, and society at large (Senge *et al.*, 2008; Harmon and Demirkan, 2011). The goal of SITS developers is to understand each issue and devise solutions that mitigate risk and facilitate the creation of competitive advantage. These corporate sustainability issues are very visible and can heavily impact the firm's brand and market position depending on how successfully they are dealt with. The goal is to increase customer and societal value as a means of creating sustainable business value.

2.3 Sustainable IT market trends

Table I presents a literature-based summary of the market trends that are driving the development of sustainable IT's first-wave green IT and second-wave SITS domains. For

Table I Sustainable IT market trends

Green IT	*Sustainable IT services (SITS)*
Declining IT budgets	Need to address IT's total economic, environmental and social impact
Rapid growth of the internet	Government environmental regulations that impact the IT value chain
Rapid growth of IT, especially data centers	Stakeholder activism: NGOs, government, consumers, and community groups
Concern about IT's impact on the environment (carbon footprint)	Corporate sustainability and CSR reporting
Increasing energy use by datacenters and IT operations	Triple-bottom-line (TBL) reporting
Rapid increase in energy costs	Need to align IT strategy with corporate sustainability and CSR strategies
Increasing datacenter power density	Need to transform IT operations to reflect service orientation, sustainability requirements, and business strategy alignment
Increasing datacenter cooling requirements	New market opportunities driven by sustainability requirements
Low server utilization rates	Corporate positioning and branding strategies
Restrictions on energy access and availability	Trend toward cloud-based IT services
Drive for IT energy efficiency (reduced costs)	Smart technology initiatives
Compliance with energy-use regulations for IT products	Increased emphasis on customer value and societal value from IT
Lower energy costs = increased business value from IT	
Lower carbon footprint = less regulatory and social risk	

green IT, the principal drivers are cost reduction through energy efficiency, compliance with IT energy use regulations, and emerging concerns about IT's carbon footprint. The market trends supporting the development of SITS strategies are more broad-based in terms of addressing economic, environmental, and social responsibility requirements and the need to align with corporate sustainability and CSR strategies.

2.4 The value dimensions of sustainable IT

Green IT and SITS differ in terms of desired value outcomes. The creation of business value is the primary motivation of green IT strategy. Although SITS does have business value goals, the primary desired outcomes are the creation of customer and societal value as the means for achieving business goals.

2.4.1 Business value. Sward (2006) and Baldwin and Curley (2007) define business value in terms of the benefits created for the business that results from the sale and use of IT products and services. A business value orientation places the emphasis on rapid returns for the firm. This often results in internally-focused, short-term initiatives that are focused on reducing costs since they provide the quickest path to returns. Business value is predominantly product referent in that the value is thought to be inherent in the product and is captured through its sale. Vargo and Lusch (2004) refer to this type of value as supportive of a goods-dominant logic (G-D logic) that is value-in-exchange oriented. G-D logic is based on the ''value added'' by products (services are incidental to this view) that is then exchanged with the customers for compensation (Vargo and Lusch, 2004).

Business value metrics include increases in revenue, market position, and cost savings that result from business investments. In sum, ROI is the standard for measuring business value. This is exemplified by the green-IT focus on energy-cost savings. This internally-oriented approach can overlook the long-term best interests of the customer and society at large, which can be detrimental to the firm's interest as well. The focus on internal costs often precludes the development of market-based innovation and tends to render a business value orientation to not be sufficient for the creation of customer and societal value.

2.4.2 Customer and societal value. Alternatively, the primary focus for SITS is the creation of customer and societal value, which can be coincident, through the development of innovative market-based solutions. Both types of value are externally oriented and customer referent. Customer value is the overall benefit derived, as the customer perceives it, at the price the customer is willing to pay (Sheth *et al*., 1991; Nagle and Holden, 2002). Service providers must have a detailed understanding of the benefits required by the market and the benefit/cost tradeoffs that customers are willing to make (Harmon *et al*., 2009). Customer value is based on the notion that market-oriented or customer-oriented firms will be more effective than competitors in creating and delivering superior value to their customers. By so doing they can achieve their business goals. The customer's satisfaction and resulting loyalty are key metrics. In the SITS instance, the customer value segments are eco-proactive in nature. IT services should enable solutions for environmental problems (Harmon *et al*., 2010).

The societal marketing concept extends the customer-value orientation to include the needs of society at large which are thought to be coincident with customer needs (Kotler and Keller, 2012). This concept holds that it is the firm's task to determine the needs, wants, and desires of chosen target markets and to deliver satisfaction that is superior to that of competitors and preserves or enhances the consumer's and society's well being (Kotler and Keller, 2012). Therefore, the societal marketing concept is based on the creation of two types of value, shorter-term customer value, and longer-term societal value. The intent is, over time, all customer value will become societally motivated. For SITS, the societal value CSR-proactive segment will look for solutions that emphasize corporate sustainability and corporate social responsibility benefits.

Both customer value and societal value are amenable to a service-dominant logic (S-D logic) conceptualization, which is based on the creation of value-in-use (Vargo and Lusch, 2004; Vargo and Akaka, 2009). Services, such as SITS, are consistent with the S-D logic paradigm.

The customer-societal orientation emphasizes collaboration with customers and other stakeholders to facilitate the co-creation of value in order to attain higher levels of satisfaction. Customer and stakeholder engagement and the co-creation of value-in-use are the essential elements of SITS. Conversely, green IT is internally focused and based on product-oriented exchange value.

2.5 Value drivers

Value drivers are perceptions based on the customer's motivations and the evaluations of the product or service, the credibility of the service provider, and the confidence the customer has in the brand (Sheth *et al.*, 1991). Value drivers facilitate the processing and retrieval of information, summarize the customer's beliefs about the firm and its products and services, create positive attitudes that add value to a brand, and provide the reason to buy (Harmon *et al.*, 2009). For marketers, value drivers inform the design requirements of the products and services and subsequent market strategy. They are useful for understanding the underlying value creating dimensions of business value, customer value, and societal value.

The literature identifies five classifications of value drivers: economic value, performance value, supplier value, buyer motivations, and buying situation (Sheth *et al.*, 1991; Harmon *et al.*, 2009):

1. *Economic value (product/service referent)*. The buyer's perceptions regarding the cost of acquiring, installing, using, and disposing of a product or service. This dimension is derived from the cost element of Sheth's functional value (Sheth *et al.*, 1991). The concept addresses the cost savings and ROI impact deriving from the purchase of the product (Nagle and Holden, 2002; Keen and Digrius, 2003).
2. *Performance value (product/service referent)*. The buyer's perceptions of the utility are associated with the functional features, advantages, and benefits of a product or a service. This class of value driver is associated with functional value (Sheth *et al.*, 1991).
3. *Supplier value (customer referent)*. The buyer's perceptions about the credibility and trust associated with the supplier form the foundation for collaborative relationship building that leads to brand acceptance. A strong brand is indicative of a strong market position and a long-term history of satisfying customers (Aaker, 1996). Strong brands provide the supplier with greater pricing power. Supplier value is associated with Sheth's emotional value and epistemic (knowledge) value (Sheth *et al.*, 1991).
4. *Buyer motivation (customer referent)*. The buyer's pre-purchase psychological state can influence the decision process (Zaltman, 2003). Psychological motives arise from the buyer's needs for recognition, esteem, belonging, novelty seeking, and knowledge acquisition. Buyer motivations are often subjective and emotional (Monroe, 1973). This value driver is analogous to Sheth's emotional value and epistemic value (Sheth *et al.*, 1991).
5. *Buying situation (customer referent)*. The buying situation can influence value perceptions by inhibiting or facilitating buying behavior. Sheth *et al.* (1991) referred to the buying situation as conditional value. The primary situational dimensions are:
   - *Task definition*. The use purpose for which the product or service will be applied. The task may reflect different buyer and user roles (Belk, 1975).
   - *Resource capability*. The physical, financial, intellectual, and technological resources of the buyer can impact sales decisions (Sheth *et al.*, 1991).
   - *Time horizon*. The length of the decision horizon affects purchase strategies. Buyers with shorter horizons tend to be less price-sensitive (Wright and Weitz, 1977).
   - *Social influences*. Buyers seldom make decisions in a vacuum. The existence and composition of a buying center (initiators, users, influencers, deciders, approvers, buyers, and gatekeepers) impacts all phases of the purchase decision (Zaltman, 2003; Kotler and Keller, 2012).

- *Experience level*. The buyer's experience level influences the motivation to buy or rebuy and influences price expectations (Sheth *et al.*, 1991).
- *Availability*. Availability of information about the company or service for the purpose of assessing costs, performance, risks, and expected value (Tversky and Kahneman, 1973; Sheth *et al.*, 1991).

2.6 Green IT and SITS differential value dimensions

Table II depicts the value dimensions signatures for green IT and SITS in terms of value drivers and value outcomes (business, customer, and societal). Green IT, with its focus on energy efficiency, cost reduction, and total cost of ownership (TCO) has very clear value dimensions in terms of economic and performance value. The goal is creation of business value. The economic-performance value drivers are of primary performance as decision factors in making product choices. Green IT is internal in nature and product focused value-in-use. Supplier value issues relate to the internal perceptions of the IT organization by internal customers in terms of their past history and ability to do the job.

For SITS (both eco-proactive and CSR-proactive), supplier value is a primary driver since it is collaborative, relationship based, and relies on the co-creation of value-in-use, the foundation for effective service development and marketing (Vargo and Akaka, 2009). For SITS users the supplier's image, brand associations, credibility, trust, and authenticity (ecological and social) will drive the purchase choices, market positioning, and branding decisions. There is a strong emotional component that underlies all of this. Buyer motivations are related to the individual decision maker's desire to be seen as a leader in terms of environmental and CSR consciousness.

The situational influences, beyond the specific task requirements, are subjective and intangible in nature. For the eco-proactive segment, metrics will be associated with the specific outcomes from the ecological solutions implemented. But, the buyer's experience and social influences will likely drive satisfaction. For the CSR-proactive segment, metrics will be highly subjective and the experience and social influences will also be strongly in play. IT firms that wish to target these segments will need to be very culturally astute and authentically interested in collaboration and long-term relationship building to target these markets.

Table II The value dimensions of green IT and SITS

Value drivers	*Business value (cost-centric green IT)*	*Customer value (eco-proactive SITS)*	*Societal value (CSR-proactive SITS)*
Economic value (product/service referent)	Energy cost reduction TCO ROI profitability (firm) Value-in-exchange	Environmental costs TCO ROI (customer) Value-in-use	Environmental costs Social costs ROI (societal) Value-in-use
Performance value (product/service referent)	Product orientation Datacenter efficiency Carbon footprint reduction	Service orientation Eco-proactive solutions Minimize environmental footprint	Service orientation CSR proactive solutions Ensure long-run viability of environment and society
Supplier value (customer referent)	Internal orientation (IT + firm) IT's organization image IT's technical capabilities	External orientation: (customers and markets) Supplier's brand image Credibility, trust Ecological authenticity Collaboration Co-creation of value	External orientation: (stakeholders and markets) Supplier's brand image Credibility, Trust Societal authenticity Collaboration Co-creation of value
Buyer motivation (customer referent)	Cost leadership Fast implementation Bottom line cost saving	Environmental leadership	CSR leadership
Buying situation (customer referent)	Immediate time horizon Complete the cost-reduction energy efficiency task	Ecological tasks Buyer's experience Social influences	Integrated CSR tasks Buyer's experience Social influences

3. Strategic planning roadmap for sustainable IT

Our technology roadmap project was developed to assess the future landscape of sustainable IT as the industry moves from green-IT dominance to the service-oriented SITS dimensions. We wanted to address the question: What changes in markets, products and services, technologies, compliance reporting, organizational development, and value goals would likely take place as the sustainable IT strategic transition occurs? The background work was initiated during the second quarter of 2009 and culminated in the initial roadmap development during the first quarter of 2010. Final revisions of the roadmap were completed by year end.

3.1 Methodology

A three-phase process was utilized for this study to develop a strategic planning technology roadmap (Phaal *et al.*, 2004). The phases are domain analysis, development of the technology roadmap, and follow-up activity (Walsh, 2004). Our approach is qualitative in nature and intended to provide perspective for existing events and to stimulate creative interpretations of emerging trends based on available evidence (Popper, 2008; Gerdsi *et al.*, 2010). That perspective is gained through the use of an extensive literature review, depth interviews with an expert panel, and brainstorming the development of the sustainable IT roadmap with industry experts.

3.1.1 Phase I: domain analysis. The domain analysis phase focused on the development of domain expertise sufficient to define the scope and boundaries of the sustainable IT discipline. This was a two-step process that featured the development of a comprehensive literature review which was followed by personal interviews with high-technology industry executives.

The literature review encompassed the topics of green IT, green computing, sustainable IT, corporate sustainability, and corporate social responsibility. Our review focused on the business and engineering academic databases, professional industry publications, consulting reports, case histories, technology industry publications, corporate social responsibility reports, company websites, and proprietary company documents.

To further assess the domain, personal interviews were conducted with senior IT and corporate strategy executives from 12 multinational technology companies in the semiconductor, computers, network infrastructure, and enterprise software companies. The companies were headquartered in the US (six), EU (three), and Asia (three). The selection of the companies for our expert panel was based on their industry, company size, verifiable expertise in the sustainable IT domain, and their willingness to participate in the research. The telephone interviews were 60-90 minutes in length. The interview topics were formulated from the results of the literature review and CSR guidelines from the Global Reporting Initiative (2006). A list of potential topics was sent to each respondent prior to the interview. The depth-interview approach enables probing on elements of the discussion and inclusion of new topics as they are mentioned by the interviewee (Seidman, 2005). The interview results were then content analyzed. Resulting topic clusters were compared with and subsequently integrated with the domain content from the literature review. The survey panel respondents were then provided with the domain research results and asked for their comments and revisions. A set of dimensions and potential roadmap issues was arrived at in this manner.

3.1.2 Phase II: developing the sustainable IT technology roadmap. Two roadmapping sessions were held in January 2010 with six IT professionals from US technology firms and IT consultancies who were not expert panel participants. Companies represented were from the semiconductor, enterprise software, network infrastructure, datacenter deployment, and IT consulting industries. All participants were highly conversant in sustainable IT issues. The roadmapping sessions were facilitated by our research team. The first brainstorming session focused on both the green IT and SITS dimensions. A second session, focused primarily on the emerging SITS dimension, was required to complete the roadmap. Roadmap pathways were generated for market segments, products/services, technology,

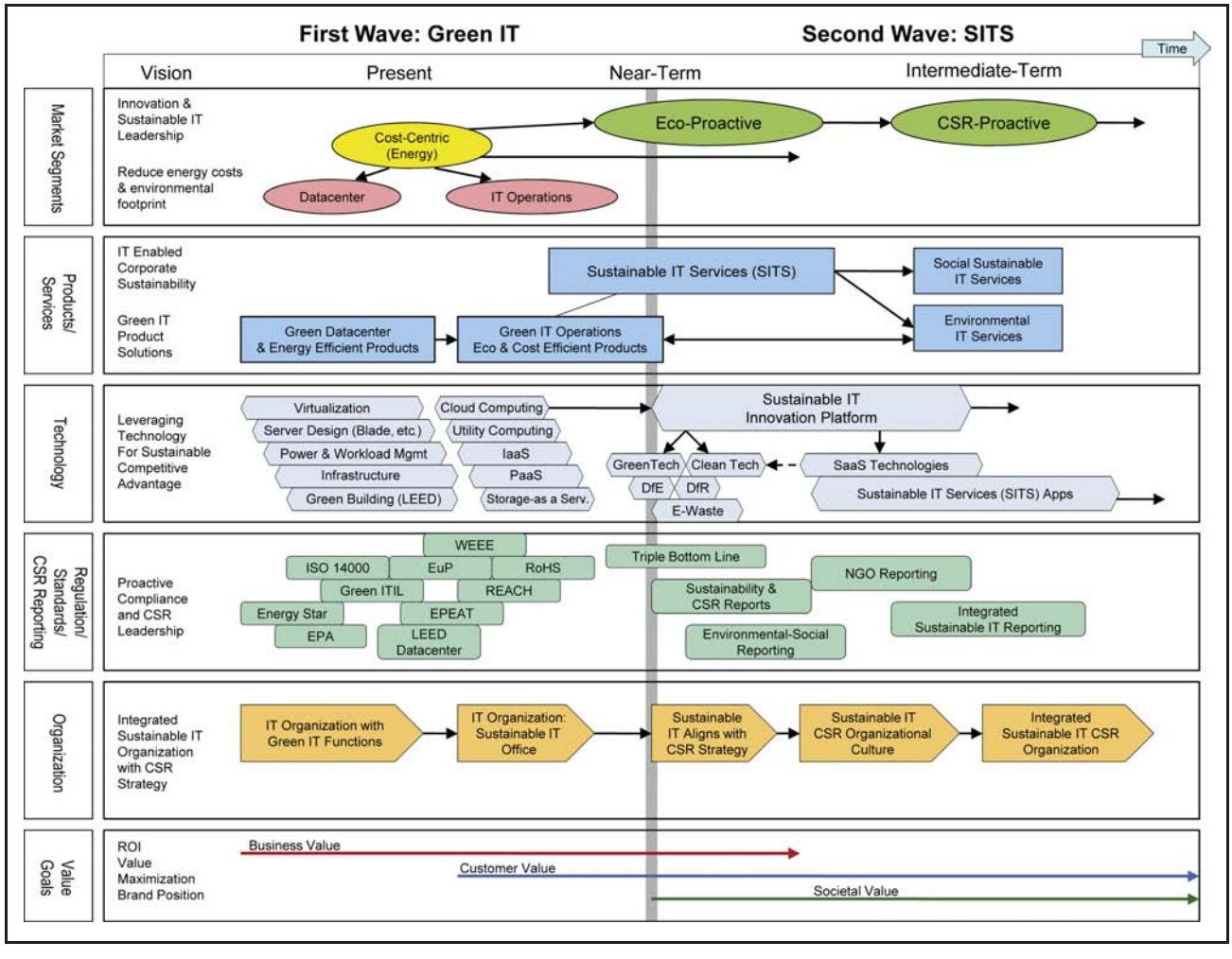
standards and reporting requirements, organizational changes, and value migration. The potential pathways were identified in the literature review, supported by the panel interviews, and judged appropriate by the roadmapping team. The chosen pathways are consistent with the strategic planning roadmap categories described by Phaal *et al.* (2004). The team considered other potential pathways such as business objectives, trigger issues, and processes, but finally agreed that the preferred dimensions, elements, and pathways fairly represented the strategic perspective they wanted to portray.

3.1.3 Phase III: follow-up activity. Finally, the resulting sustainable IT technology roadmap and an accompanying narrative were sent out to the original expert panel for comment. Responses were reviewed by the roadmapping team and minor adjustments were made to some elements on the product/services, technology, standards/reporting, and organizational pathways. As expected, the SITS dimension generated the most comments and exhibited the greatest variability. The revised draft was reviewed and approved by panel members. A subsequent review by the roadmap team in December 2010 resulted in only a minor revision of the business value vector which was extended to cover the eco-proactive segment.

3.2 The sustainable IT technology roadmap

Figure 1 presents the strategic planning technology roadmap for the development of sustainable IT from an industry-wide perspective. The time scale for the roadmap addresses the present (end of year 2010) state of green IT as it has developed over the past the

Figure 1 Sustainable IT technology roadmap: strategic planning perspective



decade, the near term (one to three years in future) for the transition of internal-focused green-IT solutions to externally focused eco-proactive SITS, and the intermediate term (three to five years and beyond) for the development of more complex SITS innovation. The roadmap represents both of the identifiable waves of sustainable IT; the green IT first wave that is presently being implemented and the nascent SITS second wave. Early SITS-based solutions are being introduced into the market by companies such as IBM, HP, Cisco, KPMG, Raytheon, and Intel (Harmon and Demirkan, 2011). Our roadmap provides evidence of this phenomenon and insights concerning its future development.

3.2.1 Market segments. The current target market for sustainable IT is the ''cost-centric'' green IT market (Deloitte Touche Tohmatsu, 2009; Harmon *et al.*, 2010). The cost-centric segment has two sub-segments; one focused on energy efficiency in datacenters and the other on energy efficiency of IT operations. In each case, the primary supplier is the IT department that serves internal IT customers in the firm's business units (Murugesan, 2008; Olson, 2008; Stanford, 2008).

An emerging ''eco-proactive'' segment that is IT-services oriented was identified by our research. The eco-proactive segment is defined by technology firms that develop and launch sustainable IT services for customers seeking environmental solutions. Early evidence of this segment includes the 2008 launch of the ''Smarter Planet'' initiative by IBM (IBM, 2009) and the ''Global Workplace Initiative'' by HP that is streamlining its operational footprint (HP, 2010). These solutions are often developed for internal use and subsequently commercialized. They tend to focus on networked intelligent systems that employ cloud-based software-as-a-service applications. Over the next two-to-three years, we expect this segment to continue to grow rapidly. For example, Cisco has launched its ''Smart + Connected Communities'' initiative to transform physical communities to ecologically sustainable connected communities (Lindsay, 2010). Siemens has launched IT services for data-center efficiency and a ''City of the Future'' initiative for managing the sustainable city. The initiative offers a smart systems approach to communication, energy use, building efficiency, industrial automation, traffic management, and public transportation options that reduce costs and environmental impact (Tay, 2010). This fits with the eco-proactives' goals to seek sustainable IT based solutions that minimize or eliminate the environmental impacts of their firm's operations while simultaneously reducing costs.

A logical extension of the eco-proactive segment is the ''CSR-proactive'' segment. Our team believes this segment is nascent and will evolve as customers extend their environmental motivation to also address social responsibility requirements such as ethical and philanthropic behaviors (Harmon and Demirkan, 2011). Our research indicates that this segment will take some time to strengthen, perhaps five years or more. The primary issue is the lack of measureable business value returns for IT organizations from CSR initiatives. This will change as the IT organization aligns more with corporate social responsibility strategy and becomes more of a profit center rather than a cost center. Moreover, corporate sustainability, which is more ecologically defined, and CSR, which is more business centered and value-in-use focused, are converging (Montiel, 2008). Eventually, the eco-proactive segment will merge into the CSR-proactive segment. Early indications for this segment include engagement by leading IT firms with NGOs such as Climate Savers, The Green Grid, The Uptime Institute, Open Cirrus Partnership and other social responsibility organizations. In addition, firms are engaging in philanthropic work such as donating computers, educating disadvantaged children, and other civic projects that further both corporate and social responsibility goals (IBM, 2009; Wellsandt and Snyder, 2009; HP, 2010). Drucker (1984) called strategic CSR ''taming the dragon;'' or turning social problems into profits. Over time, as the initial green IT cost-centric target market matures and commoditizes, value is migrating to the emerging opportunities in the broader sustainable IT services segments that focus on environmental and CSR requirements.

3.2.2 Products/services and technologies. We discuss the product and service dimensions jointly. Many of the solutions in the green IT and SITS markets are still in the early stages of technological development and deployment and have not been systematically configured or

integrated in terms of fully featured products and services. To discuss the product or service is to discuss the technology:

1. *First wave*. Green datacenter products and technologies:
   - *Virtualization*. Datacenter virtualization affects server hardware and operating systems, storage, networks, and application infrastructure. Virtualization enables increased server utilization by pooling applications on fewer servers while using less power, physical space, and labor. Virtualization extends the life of older datacenters with no space for expansion. Virtual servers use less power and have higher levels of efficiency than standalone servers (Barroso and Hölze, 2007). Multiple operating systems can run concurrently on a host server which can be segmented into several virtual machines each with a separate operating system and application. Fewer servers mean higher utilization rates, smaller server footprints, lower cooling costs, less headcount, and improved manageability (Ryder, 2008; Ou, 2006).
   - *Server design*. Energy use by servers has risen in proportion with the increase in installed base (Fanara, 2007). The shift to multiple cores and dynamic frequency and voltage scaling technologies hold great promise for reducing energy use by servers which are more efficient at peak levels (Barreto *et al.*, 2007; Barroso and Hölze, 2007). Server refresh replaces old servers with new energy efficient designs (Wellsandt and Snyder, 2009).
   - *Power and workload management*. Power and workload management software adjusts the processor power states to match workload requirements. It makes full use of the processor power when needed and conserves power when workloads are lighter. Some companies are shifting from desktops to laptops for their power-management capabilities (Wilbanks, 2008).
   - *Data center infrastructure*. Infrastructure equipment includes chillers, power supplies, storage devices, switches, pumps, fans, and network equipment. Many data centers are over ten years old and can use several times more power for cooling than is used for computing (overall as used for computing, mostly for cooling (Fanara, 2007; Lawton, 2007). The solution is to build new energy efficient datacenters or retrofit existing centers.
   - *Green datacenter buildings*. Intel and other companies are working with the US Green Building Council to develop standards and technology requirements for green datacenters (Stansberry, 2009).
   - *Cloud computing*. The term ''cloud computing'' refers to a computing model where massively scalable IT-related capabilities are provided as a ''service'' (Rhoton, 2009). Cloud computing infrastructure enables developers to create, deploy, and run services that are high performance, reliable, and free the user from location and infrastructure concerns. Cloud computing services include utility computing, software as a service (SaaS), platform as a service (PaaS), and (IaaS) infrastructure as a service (Perry, 2008; Greer, 2009; Linthicum, 2009). Cloud computing is introduced here since it has great potential to lower computing costs especially from a hardware and infrastructure perspective. However, its greatest impact is likely to be in the second wave as this technology is essential for the provision of innovative SITS applications.
2. *Second wave*. Sustainable IT services and technologies:
   - The sustainable IT innovation platform integrates SITS applications (SaaS) with green tech and clean tech solutions to solve environmental problems. We believe a similar approach will eventually address social issues as well.
   - Cloud-based SITS applications. Companies such as IBM, HP, Cisco, and Siemens are pioneering the development of sustainable IT services for internal use that they subsequently offer to their customers (IBM, 2009; HP, 2010; Lindsay, 2010; Tay, 2010). Major SITS applications include electric power supply management, water

management, traffic and public transportation management, wind farm, solar-electric, and solar thermal power management, smart grid management, intelligent levee management, and data-centric modeling of the environment (Greer, 2009).

- Clean technology applications range from ''cleantech'' which is new technology that addresses the root causes of environmental problems. Alternatively, ''greentech'' is end of the pipe technology that seeks to ameliorate existing problems. The technologies include design for environment (DfE), design for recycling (DfR), asset decommissioning, e-waste minimization and disposal, remanufacturing (Daoud, 2008; Deloitte Touche Tohmatsu, 2009; Hanselman and Pegah, 2007).

3.2.3 Regulations, standards, and reporting. Corporate sustainability associated regulations and reporting requirements for IT products, and increasingly services, are well established in Europe and increasingly in North America and worldwide. These directives and regulations impact product and service design where regulators believe over 80 percent of environmental impacts are determined (Premier Farnell, 2007). Most of the regulations affect first-wave green IT products. The sustainability and CSR reporting requirements will affect SITS as IT applications become more aligned with corporate strategy.

1. First-wave green IT regulations and standards:
   - European Waste and Electrical Equipment Directive (WEEE). Producers must take back old equipment free of charge to reduce electronic waste. Impacts design for environment (DfE) throughout the product lifecycle (Hanselman and Pegah, 2007).
   - European directive on the Restriction of Hazardous Substances (RoHS). Linked with WEEE, RoHS Restricts lead, mercury, cadmium and other substances used in the manufacture of electronics (Hanselman and Pegah, 2007).
   - Restriction, Evaluation, and Authorization of Chemicals (REACH). Regulates chemical production and use to for health and environmental purposes (Schneiderman, 2009).
   - Eco-Design of Energy using Products (EuP). Regulates the lifecycle energy efficiency of products (Schneiderman, 2009).
   - Electronic Product Environmental Assessment Tool (EPEAT). International product registry (www.epeat.net) rates IT products on environmental criteria.
   - The Energy Star 5.0 2009 standard (www.energystar.gov) regulates energy efficiency for desktops, workstations, and notebooks. Version 1.0 of the server specification was released in May 2009 (Shah, 2009).
   - Efforts are underway for a Leadership in Energy and Environmental Design (LEED) standard for certifying green datacenters (Miller, 2009; Stansberry, 2009).
   - ISO 14000 is the standard for environmental management systems. The goal is to reduce the environmental impact of businesses. It specifies requirements, guidelines, and systems for implementation (Esty and Winston, 2009).
   - Green Information Library Infrastructure Library (ITIL) is an evolving set of standards for IT services that align investments with business performance (Kalm and Waschke, 2009). Green ITIL is currently centered on green IT efficiency and carbon reduction for datacenters and the application of Six Sigma, Lean, and Agile tools among other recommendations.
2. Second wave: SITS standards and reporting.

At present there are no SITS standards or reporting requirements. This is the result of the early stage of the industry and lack of verifiable evidence on SITS applications and efficacy. We believe that standards will evolve as regulators, companies, industry associations, NGOs, customers, and other stakeholder gain experience with the capabilities and limitations of SITS applications. For the foreseeable future it is likely that SITS applications and results will be reflected in triple bottom line reporting, annual reports, CSR reports, and

NGO report cards. As the SITS market develops and as IT organizations become more sustainable-IT oriented they will undoubtedly want to release their own reports.

3.2.4 IT organizational changes. We believe that IT organizations will continue to evolve as they react to market forces and become more sustainable-IT oriented. At present, most IT organizations have some green IT functions as they are addressing energy use in datacenters and IT operations. As these efforts become more central to IT operations they well expand from energy to a more comprehensive view of IT's impact on the environment. An emerging organizational change is to create a sustainable IT office (Wellsandt and Snyder, 2009). As sustainable IT efforts become more aligned with CSR efforts at the corporate level the IT organization will need to become more market and society oriented which will drive change in organizational culture; from one where the major emphasis is on technology, to one that embraces innovation for the betterment of society (Harmon and Demirkan, 2011).

3.2.5 Value goals. We include the ''value goals'' path for the purpose of highlighting the different types of value created by green IT and the two flavors of SITS, eco-proactive and CSR proactive. Clearly, both green IT and SITS applications will need to create business value or the IT organization will not be viable. However, there is a major difference in how that value is created and strategies to be followed. For green IT, business value is the primary motivation. Achieving favorable ROI for the organization is the goal. This is achieved through strategies targeting energy efficiency that can lower IT costs. For the external customer-facing SITS strategy, business results are achieved by first satisfying the customer and subsequently addressing the customer's societal needs. This creates competitive advantage, strong brands, and defendable market positions that can drive sales and profitability. Therefore, customer value and societal value are the primary motivations for SITS. The business value vector extends to the eco-proactive segment and should theoretically extend to the CSR-proactive segment for SITS as the IT organization becomes more strategically aligned with corporate sustainability and social responsibility initiatives. The rationale for CSR-based business value is that satisfying societal and customer value requirements should also achieve favorable business value outcomes.

4. Discussion and limitations

The sustainable IT technology roadmap provides an early-stage view of the emerging field of sustainable IT and its green IT and SITS dimensions. The literature on green IT has grown dramatically in the past few years. We are very confident in the segment definitions, focus, applications, and technologies, regulations, and organizational development aspects, and value goals of this first wave of sustainable IT as presented in the roadmap.

The situation for SITS is quite different. There is almost no academic or professional literature on sustainable IT services. What evidence exists for SITS is found in reports by consulting firms, corporate annual and CSR reports, corporate advertising, IT conferences, and seminars. Cloud-based SITS applications are being commercialized, but most are not yet fully developed or integrated into well defined product and service platforms. However, we are confident that an eco-proactive segment is developing. Firms such as IBM, HP, Intel, and Cisco are bringing products and services that address the environmental needs of this emerging market (IBM, 2009; Watson *et al.*, 2009; Wellsandt and Snyder, 2009; HP, 2010; Lindsay, 2010). Furthermore, we are confident that the IT organization will have to evolve from its internal orientation to be more externally oriented in terms of customers, the environment, and society. We see the need for the sustainable IT organization being fully integrated with corporate sustainability strategy.

The limitations of the study are associated with the nature of the topic and our research approach. First, sustainable IT is a new discipline. Green IT is a relatively mature dimension, but it is still evolving. It is the green IT dimension that is most documentable from the literature. The SITS dimension is just starting to emerge. Smart systems based SITS applications from the large IT companies are just now starting to come to market. It will take

some time to see how the SITS markets, services, and technologies play out. The SITS dimension is the most speculative, but our work does reflect the perspective of leading professionals from companies that are developing these approaches.

Our research approach is qualitative and designed to map the sustainable IT domain. Its very nature is exploratory. The relatively small size of the research panel and the roadmapping team is offset by the realization that the IT-professional participants were all active in the development of the discipline from a practitioner's perspective. The research panel and roadmap team were very familiar with the concepts. However, as the field matures, new entrants, smaller entrepreneurial start-ups, and academic researchers will likely bring new conceptualizations and innovative technologies into play.

5. Conclusions, future research, and implications for managers

This paper has presented foundational support for the emerging discipline of sustainable IT. The major contribution is the development of a strategic planning technology roadmap for sustainable IT that explores its green IT and sustainable IT services dimensions in terms of target markets, products and services, technologies, regulations and standards, organizational changes, and value motivations. We have defined the market trends and relevant value drivers that support sustainable IT's development.

Future research will determine how disruptive sustainable IT becomes and determine if it achieves that status of a sustaining innovation. Some basic questions need to be addressed. Does corporate sustainability actually create business, customer, and societal value? How can such performance be measured? Can IT organizations actually use sustainable IT as a migration path to become better aligned with corporate social responsibility strategy? Research on the future development of smart-systems based SITS applications would seem to provide a potential avenue for this research.

Finally, for managers working in this field the sustainable IT strategic planning roadmap can provide a benchmark for their current situation and insights on what is likely to follow as they plan for the next generation of solutions and strive for market leadership. In our opinion, sustainable IT will continue to be a major issue for IT organizations as they navigate the changing business requirements that are increasingly reflecting a greater concern about IT's environmental and social responsibilities. IT organizations need to change to remain relevant. Our roadmap should help them with that navigation effort.

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