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Effecting Transformation Towards a Green Computing Infrastructure: A Case Study on Asia Pacific University

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***Abstract:** Energy consumption and environmental concerns have become organizational priorities as sustainability becomes a business imperative. Within the last decade Green Computing has become a key dimension in IT management owing to the economic opportunities and stakeholder pressure, however, the strategic relevance of Green Computing has largely been neglected as a corporate strategy. This case study on Asia Pacific University aims to deliver a holistic Green Computing Framework for the University. This Framework addresses the key facets of an organization: strategy, technology, infrastructure, operations and administration, as an avenue for the University to assess its Green readiness as it moves towards a Green Computing infrastructure for competitive advantage. The absence of a Green Computing readiness framework is critical for the University to understand the key factors in implementing a sustainable business practice. A sustainable energy-efficient learning centre will account for a healthy environment while maintaining a high standard of educational excellence.*

***Keywords:** Green Computing, Green Readiness, Sustainability*

I. INTRODUCTION

Sending mankind to the moon was one of the biggest technological challenges of the twentieth century. In the twenty first century humanity faces a bigger test and that is addressing climate change (Climate Group, 2008). This is all the more significant as the Intergovernmental Panel on Climate Change (IPCC, 2013) reports that the human factor on the climate system is clear which arises from the growing greenhouse gas (GHG) concentrations in the atmosphere. Andwith a global population of nearly 6.7 billion (Tomlinson, 2010) this is a serious concern. The advancement of Information Technology (IT) has transformed many economies into e-economy and in a similar vein has aided in addressing climate change issues (Molla & Cooper, 2009). The above implies that IT can be seen as a tool to be embedded within an organization's corporate policy to reduce organizational footprint. It presents new organizational capabilities in reaching this new milieu that can best be tackled through a structured approach. This research paper presents a Green Computing framework as a structured approach for the Asia Pacific University of Technology and Innovation (APU) to achieve Green Computing (GC) transformations in reducing its carbon footprint. The following discusses the Green conceptual background.

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1.1 *Climate Change*

At different periods throughout Earth's history it has warmed and cooled (Webber & Wallace, 2009).

Human activity has accelerated the rate of warming, increasing its severity. One-third of the Earth's natural resources hitherto have been consumed; continued use of resources at this rate is detrimental (Talebi & Thomas, 2009) as Climate change, the phenomena associated with global warming can bring natural disasters and adverse repercussions to human health (Py,akuryal, 2009). International efforts to reduce Green House Gas (GHG) have resulted in new regulations that will affect the way organizations conducts its business. Green Technology can promote an environmentally-conscious use of resources and technology to sustain the environment and reduce energy.

1.2 *Green Technology*

The field of Green Technology (GT) entails evolving methods and materials, generating new techniques to produce renewable energy within the safe perimeters of the environment (Shinde, 2013). The shift from fossil-fuel economy to one that uses renewable energy has made the reduction of CO_2 emissions possible (Pyakurlal, 2009). Some of the sources of energy are fossil fuel, renewable energy (solar, geothermal, hydro), biomass fuel (plants, organic waste) and traditional biomass (wood, crop residue).

GT is simply using science and technology to reduce environmental impact (Harris, 2006) and energy standards were the start of GT. GC focuses on making IT more efficient and is expected to bring changes and innovation of similar magnitude to the IT explosion two decades ago.

1.3 *The Origin of Green Computing*

In 1991, the U.S. Environmental Protection Agency (EPA) launched the Green Lights program with the aim to promote energy-efficient lighting (Harmon & Auseklis, 2009). In 1992, the Energy Star program was introduced to establish a labelling standard for energy efficiency in electronic equipment (Harris, 2006; Willemse, 2008). The term 'Green Computing' was adopted after the commencement of this program (Roy & Bag, 2008) and it has since gained traction within the last decade to become a major research area (Harmon & Auseklis, 2009; Joumaa & Kadry, 2012). There is an abundance of literature on GC. Tomlinson (2010) describes it as a field at the juncture of two trends. The first revolves around environmental concerns across worldwide communities to reduce energy consumption and the second trend involves.

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IT, the study and use of digital techniques to manipulate information and the social phenomena that surround these systems. In essence, GC brings these two areas together; environmental concerns and IT.

II. RESEARCH FRAMEWORK

This research's objectives were formulated to achieve GC transformations for APU's strategic advantage and to evaluate the University's green readiness. The research framework is based on the GC ICT framework developed by Connection Research, a market research organization that focuses on sustainable digital technologies, in conjunction with the Royal Melbourne University of Technology (RMIT) in Australia (Philipson, 2010; RMIT, 2012). While the Connection Research framework focuses on Enterprise and DC, Equipment Lifecycle, End User Computing and ICT as a Low-Carbon Enabler, this research framework has been adapted to form the objectives of the research, as illustrated below.

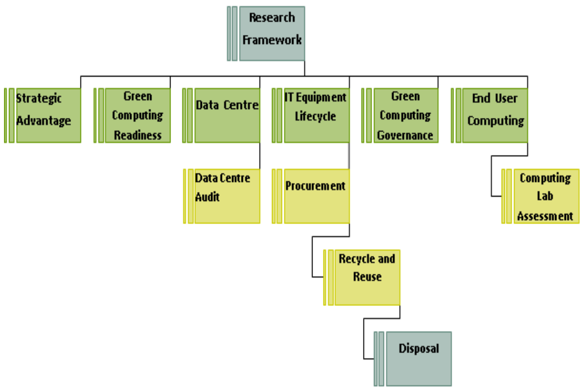

Figure 1: Research Framework adapted from Philipson (2010)

The first area, GC Strategic Advantage,will analyse strategic GC business performance frameworks for the University's competitive advantage. The next, GC Readiness, will evaluate APU's readiness as a step towards a green transformation. The DC, will be audited to determine areas for energy reduction, followed by the IT Equipment Lifecycle, that will study APU's IT equipment lifecycle process: acquisition, recycle/reuse and disposal. GC Governance explores effective methods of IT management. The last area, End User Computing, which is not a main focus of this research, will assess the Power Management policies at APU computing labs.

2.1 Research Methodology

This research by design is a case study on APU to answer two research questions: how can a GC framework bring strategic advantages to the University and how will APU evaluate its GC readiness. Surveys and interviews with APU Management, staff and students will be used as data collections methods.

III. INSIGHTS FROM THE LITERATURE

This section narrates the literature on the research themes.

3.1 Strategic Advantage

GC has become an important agenda in IT management research and is considered a strategic business issue for organizations (Erek et al, 2011; Kounatze, 2009). Organizational focus is not mainly centred on gaining a competitive advantage but of paramount importance is the need to have a competitive advantage (Acumen-insights, 2009). This is emphasized by Lubin&Esty (2010) that sustainability in organizations has become a relevant subject of strategic management, a reason why organizations need to progress from unfocused business investments to consistent sustainability strategies aligned with the core business objectives. A paradigm shift is needed at the strategic level of organizations to support low cost strategies and encourage grounds for competitive differentiation. Zarrella (2008) further suggest that GC has the strategic ability to create a competitive advantage in both the business and sustainability platforms. Hence, a shift towards a GC infrastructure will bring significant benefits to APU by adding greater value to APU's business plan, enhancing its brand name and moving forward its strategic mission and vision. Sustainable strategies offer significant first-mover advantages (Erek et al, 2011), thus, APU can gain the leading edge through strategic planning to earn a GC status.

In order to conceptualize a strategic GC competitive advantage framework for APU, three models have been analysed: Strategic Alignment Model, Sustainable Shareholder-Value Model and Strategic Green IT Alignment Model.

3.1.1 Strategic Alignment Model

The Strategic Alignment Model (SAM) developed by Henderson and Venkatraman (1999) is a most widely applied alignment model with researchers using it as the base of business and IT alignment theories (Coster, 2010; Nickels, 2003). It has four key domains, two external and two internal. The external domains are the strategy domains (business and IT strategies) and the internal domains are infrastructure related (business and IT infrastructure). The SAM is illustrated below:

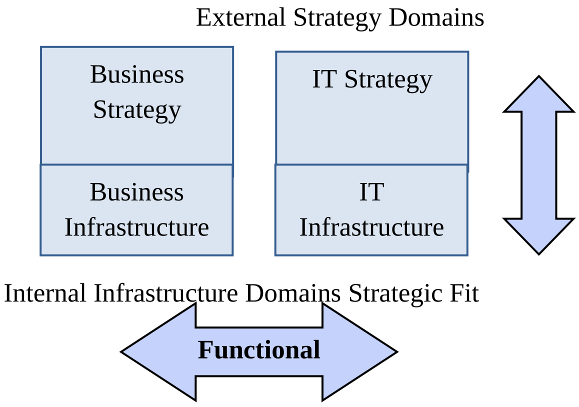

Figure 2: Strategic Alignment Model (Henderson & Venkatraman, 1999)

The Strategic fit describes the connection between the external environment and the internal organizational structure which is the vertical strategy-deployment link to determine the business infrastructure.

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The functional integration, elucidates the harmonization of the business and functional domains directly related to the alignment of business and IT. The model basically attempts to answer managerial questions by understanding the relationships between the domains when a change in strategy occurs (Henderson & Venkatraman, 1999).

The Business Strategy domain drives the organization and identifies the distinctive competencies that the organization distinguishes from its competitors while the IT Strategy dictates the technologies and competencies that create strategic business opportunities, advantages and the external relationships that IT depends on e.g. IT vendors and outsourcing. The Business Infrastructure domain formulates organizational structure, key business processes and skills required to accomplish unique competencies while the IT Infrastructure establishes the IT facets e.g. IT equipment, software, networks and database and processes. This includes implementing the development, operations and maintenance aspects. Santos (2009) claims that the SAM is able to initiate change and may be suitable for the education sector to revisit their mission statement in line with new GC initiatives. However, although the model gives insights to the way business and IT principles are aligned, it provides little guidance on exactly how organizations can achieve a good alignment. As Coster (2010) contends in the changing world of IT the issue of managing business and IT appears to be open ended. The Sustainable Shareholder-Value Model is described next.

3.1.2Sustainable Shareholder-Value Model

The global challenges associated with sustainability viewed through the business can drive new strategies that increase the shareholder value which is the basis of the Sustainable Shareholder-Value Model developed by Hart & Milstein (2003). The model is illustrated below.

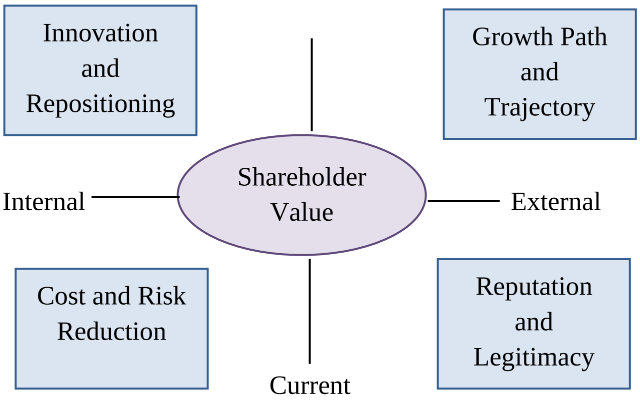

Figure3: Sustainable Shareholder-Value Model (Hart & Milstein, 2003)

The model is built on a two creative-tension dimensions for organizations. The vertical axis reflects organizational needs in managing its current landscape while creating new markets and the horizontal axis represents growth and protecting resources while shaping new external perspectives, technology and knowledge (Hart & Milstein, 2003). It integrates the drivers of sustainability with shareholder value where the drivers of sustainability correspond to increasing trends of industrialization, material consumption and emerging technology, while the shareholder value points to cost and risk reduction, and innovation and repositioning. As indicated by Santos (2009), universities may adopt this model but may require reengineering with reference to shareholder values such as teaching objectives, targets, GC research and initiatives.

3.1.3Strategic Green IT Alignment Framework

As can be seen in the above strategies, it is a truism that there is a lack of comprehensive strategies that interrelate business, IT and GC in yielding a competitive advantage for organizations. This has led to the development of the Strategic Green IT Alignment Framework (SGITAF) as an essential part of an organization's business plan (Erek et al, 2011). It contributes in achieving sustainability targets through a clear strategic orientation between business sustainability and GC strategy. The framework was developed based on a four-case study analyses. It was conceptualized based on the SAM and another model called the Generic Competitive Environmental Strategy by Orsato (2006). While the SAM aligns the business and IT domains, the SGITAF aligns the IT and business sustainability domain (Erek et al, 2011). IT has a strategic presence by designing business processes and creating elements of competitive advantage through efficiency, differentiation technological innovations. However, Erek et al. (2011) argue that because IT has a huge impact on an organization's emissions, GC strategy must be an integral part of IT strategy, linked to the business and sustainability strategy to optimally support environmentalism. It aligns the externally-oriented Green IT strategy with the business' competitive environmental strategy. Similar to the SAM, the SGITAF refers to the strategic fit and functional integration factors as illustrated below:

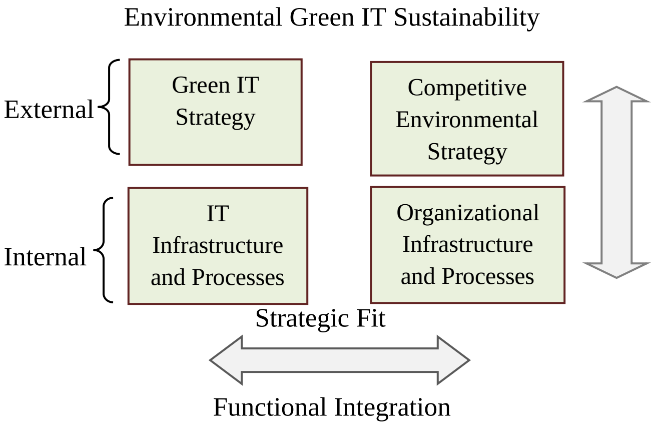

Figure 4: Strategic Green IT Alignment Framework Components (Erek et al, 2011)

The strategic fit removes existing constraints of the internal perspective of Green IT practices with the strategic external perspective. This integrates stakeholder aspects leading to competitive advantage. Sustainable business goals can be achieved by implementing appropriate IT and organizational infrastructure that is the basis for low-impact business processes. Functional integration on the other hand considers the impact of Green IT concerning the strategy, hence, indicating ways how it can leverage the competitive sustainability strategy and environmentally-friendly processes that can increase the sustainability of business processes.

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The four domains above, Green IT strategy, Competitive environmental strategy, IT infrastructure and processes, and Organizational infrastructure and processes are balanced to achieve a strategic Green IT alignment. This conceptualizes the SGITAF with four alignment perspectives or strategies for organizations to select: Green IT for Efficiency, Green IT for transformation, Green IT for innovation and Green IT for responsibility as illustrated below:

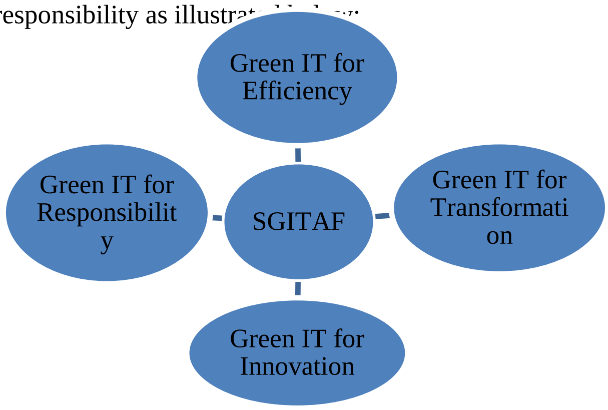

Figure 5: The Strategic Green IT Alignment Framework (Erek et al, 2011)

3.2 GC Readiness

Ebbers et al. (2011) suggest that energy consumption and equipment lifecycle are becoming priorities as they can halt organizations from developing new markets. This arguably is the challenge faced by organizations which leads to how an organization can measure its readiness in order to participate in the climate-neutral digital era. GC readiness reflects how well an organization is able to implement a holistic GC practice, hence, without a clear understanding of GC readiness or g-readiness, organizations may approach GC initiatives in a reactive manner that is undesirable (Molla et al, 2008). Further study by Molla et al. (2008) shows that there is a lack of GC readiness framework, and has not received any academic attention. Thus, they have pioneered the first GC readiness framework in 2008. It was developed by the RMIT University in Australia (Philipson, 2010). Not disapproving the novelty of this inaugural research, it can be argued that the applicability of their readiness framework will need to be tested to observe its usefulness. Nevertheless, in 2009 this framework was piloted as a preliminary proof of concept at four forward-thinking organizations in Australia which received an initial positive response.

The framework was developed based on the concept of e-readiness, prevailing GC literature on CSR and research on sustainable business practice (Molla et al, 2008). Resources such as technology, manpower, capabilities, training and organizational commitment have been identified as constructs of e-readiness (Molla, 2006). This is supported by Webber & Wallace (2009) that senior management support is important for IT and GC initiatives in view of the Return on Investment i.e. a GC business case is required. The insights derived from e-readiness studies led to the formulation of the GC readiness paradigm (Molla et al, 2008) and the main pillars of the GC readiness framework are described below, which provides the pillars of GC readiness framework for APU:

1. Attitude - refers to the affective attitude and characteristics of business, IT leaders and professionals that measure the strategic economical, regulatory, social and environmental awareness related to IT usage (Molla et al, 2008). In determining the inter relations between behaviour and environmental attitudes in encouraging people to act in an environmentally-conscious fashion, a fact discovered by Chan & Yam (1995) and summarized by Molla et al (2008), state that emotional appeal draws a stronger impact than any factual information of harmful effects of pollution or even logical reasoning.

2. Policy - measures the number of GC policies that are developed in an organization, influencing the value chain and evaluated via three areas: procurement, operations and services, and end of IT equipment lifecycle. The policies incorporated in an organization reflect its commitment to technology redundancy to derive the benefits of each technological innovation (Molla& Cooper, 2009). This dimension also includes procurement which refers to the extent to which IT equipment purchasing policies are environmentally safe, operations that encompass the extent of IT services that support issues related to business and IT Equipment Lifecycle which denote recycle, reuse and disposal regulations.

3. Practice - as described above, the policy aspect of GC readiness shapes the intellectual dimension of the framework (Molla et al, 2008; Molla& Cooper, 2009). However, in practice not all policies are executed smoothly for the endorsement of a policy and its actual practice may vary in most organizations. Practice readiness basically measures the extent organizations translate their concerns into policies and policies into actions.

4. Technology - a fundamental success as indicated by Molla et al. (2008) within the technological scope is the creation of a green technological infrastructure. This can include new breakthroughs to conserve energy such as Energy Star, server virtualization and Cloud computing technologies.

5. Governance - a key consideration of the GC readiness dimension is the governance or management of the IT infrastructure (Molla et al, 2008; Molla& Cooper, 2009).It is the operating model that clearly defines the effective administration of GC initiatives (Molla et al, 2008).

3.3 Data Centre

Electricity is a ubiquitous part of human life (Webber & Wallace, 2009). It is also the most important issue in the computing world today from hand-held devices to DCs (Wang, 2008). Recent studies outlined by Harmon & Auseklis (2009) have established that energy consumed by international and American DCs has doubled from 2000 to 2005.Tiwari (2015) reports that the cost of electricity at IT departments can reach 50% of the total electricity utilized by the organization.

3.3.1 Data Centre Audit

This can be achieved by undertaking an energy benchmarking exercise to determine better-performing strategies. The benefits of an audit enables an organization to extend its DC lifespan, capacity and more importantly, to avoid millions of metric tons of carbon emissions.

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A comprehensive audit provides the basis for a transformation that transcends cutting costs (Bauer, 2008; Ebbers et al, 2011). Typically, a DC audit can achieve benefits like savings of 20% - 40% through energy conservation, increased computing performance per kWh, DC infrastructure lifespan and capacity expansion, reduced carbon footprint and improved public image (Ebbers et al, 2011; Scheihing, 2009).

3.3.2 Data Centre Benchmarking Metrics

Through a DC benchmarking research carried out by Lawrence Berkeley National Laboratories,a widely accepted benchmarking metrics, Power Utilization Effectiveness (PUE) has been established (U.S. DOE, 2011). The PUE, a DC efficiency, is the ratio of the DC facility power over the IT equipment power where a reading of 2 is considered to be Standard, 1.4 as Good and 1.1 as Better. The audit at APU aims to derive its DC PUE.

3.4 IT Equipment Lifecycle

It is an important area in view of the many electronic disposal regulations, directives on hazardous substance use and the Kyoto Protocol that are changing the industries' approach in IT product design and manufacturing (Taghaboni-Dutta et al, 2010).

3.4.1 Acquisition and Procurement

The Electricity Journal (2008) reports that a growing number of organizations and consumers look for efficient devices when selecting IT equipment. This is important to minimize the environmental impact upon the end-of-life of these products.

3.4.2 Recycle and Reuse

GC advocates the ER3 principle, which is to eliminate, reduce, reuse and recycle (Harris, 2006). Some parts of the computer can be re-used except for the chips that need upgrading and the mother boards to mount them. Almost all computer parts could be recycled and reused (Harris, 2006) such as the monitor, keyboard, computer batteries and printer cartridges. Murugesan (2008) reports that EPEAT **(**Electronic Product Environmental Assessment Tool)manufacturers offer safe recycling options. Dell was the first technology company to create a product recycling goal, it formed alliances to produce the greenest PC on Earth (Velte et al, 2008). Hewlett-Packard (HP) has a take-back program where an IT equipment that has reached its useful life can be shipped to HP for disposal. It has also formed a joint-venture with WWF (World Wide Fund for Nature) to reduce HP's global GHG emissions. Likewise, APU and other learning centres could conduct programs to educate the general public about the importance of Green policies.

3.4.3 Disposal

Nogareda & Ziegler (2006) concede that waste disposal methods have a positive effect on the future environmental product innovations. For APU, it can help determine action plans to reduce socio-economic and environmental impacts. When this is translated into a cost index, it can assist in making comparable equipment and material choices. Evidence provided by Verma (2007) shows that IT equipment make up two-fifths of lead found in landfills, a fact substantiation by Harris (2006) who indicates electronic products are the fastest growing American trash element.

As aCSR measure, APU could charitably give away its unused PCs to schools or other needy organizations. While it is imperative for APU to understand green product lifecycle in incorporating best practices, the challenge lies in altering the human mindset and behaviour in conforming to a new way of working.

3.5 GC Governance

GC governance is the efficient management in implementing a GC infrastructure (Philipson, 2010). James and Hopkinson (2009) contend that universities desiring more sustainable IT must adopt a holistic approach taking into account all relevant aspects of sustainable development which includes GC governance. Understanding the impact of IT should be stipulated in organizational governance and management processes.

3.6 End User Computing

A simple belief but yet too profound to contain is for every human to discover simple ways in saving energy (Harris, 2006). The Energy Star program that was created to promote energy efficient monitors and other technologies caused the widespread adoption of sleep mode (Roy & Bag, 2008). This is considered as significant because out of the US $250 billion spent annually on powering computers worldwide, only 15% is spent on computing, the rest is wasted idling (Verma, 2007), a fact substantiate by Webber & Wallace (2009) and Willemse (2008) that much of the energy purchased by IT organizations lies idle. James & Hopkinson (2009) propose sustainable printing measures by using double-sided printing to conserve paper. An Energy Star PC utilizes 15% to 25% less energy in comparison to the conventional computer. Energy Star 4.0 saves an annual GHG emission equivalent to 2.7 million vehicles or US $1.8 billion in energy costs alone and allow monitors to be in their dim mode, do not deploy the screensaver feature(Harris, 2006)

IV. THE STRATEGIC GREEN COMPUTING ALIGNMENT FRAMEWORK

A new strategic advantage framework adapted from the SGITAF has been developed and aptly termed as SGCAF (Strategic Green Computing Alignment Framework) in line with this research that uses the term Green Computing to Green IT. The SGCAF has the potential to not only support APU's business strategies but to shape new sustainable business strategies. APU Management has agreed that the framework posits a very useful and applicable model for APU to select an appropriate GC strategy to achieve its corporate sustainability plans, targets and most importantly to leverage on the competitive factor.

The objective of the SGCAF is to help APU and academic institutions to identify GC sources of competitive advantage and to align the GC strategy to its competitive strategy.

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The four different alignment perspectives, GC for Efficiency, GC for Transformation, GC for Innovation and GC for Transformation, determine the cross-domain relationships within the four perspectives and are described below.

4.1 GC for Efficiency

This corresponds to the eco-efficiency environmental strategy where the business strategy is the primary force that promotes superior resource productivity. It aims to achieve competitive advantage based on a low-cost approach while focusing on internal infrastructure and processes resulting in the environmental strategy that encompasses an organization-wide scope where the efficiency of business operations is a major goal. Sustainability is seen as a cost perspective and only efficient GC measures are carried along with operational cost reduction. The environmental strategy runs in relation to the business needs and IT is guided by this strategy. This perspective reveals that environmental practices focused on the organizational infrastructure are set by the competitive environmental strategy that necessitates efficient business functions and determines the terms for the implementation of GC practices.

4.2 Green Computing for Transformation

The driver for this strategy is driven by the eco branding competitive environmental strategy that aims at the differentiation of products and services based on environmental factors. The products and services normally target niche markets and customers who are willing to pay for the environmental differentiation. GC serves is the crucial strategy enabler. GC-related opportunities are a key aspect of top management, exploiting the full environmental potential of the latest technologies and to innovative IT solutions that are appreciated by the stakeholders, like the provisioning of a carbon neutral e-mail service. This perspective enables the competitive strategy on the basis of a specific GC infrastructure not constrained by the organizational infrastructure.

4.3 Green Computing for Innovation

This refers to a focus on a low-cost strategy associated with radical product innovations rather than incremental process improvements. This is suitable for organizations striving for the lowest environmental impact and production costs that can be accomplished via radical technological innovations anticipated by visionary top management committed to environmentalism and business leadership. Thus, this strategy leverages innovations seeking business and sustainability opportunities. IT potentially influences the business-sustainability strategy and product characteristics while the organizational processes are shaped by the environmental practices.

4.4 Green Computing for Responsibility

This strategy has extended scope that covers the whole range of internal processes with the objective of sustainability-based competitive differentiation. The fundamental performance criterion is oriented towards the satisfaction of stakeholders while IT management plays an integral role of leadership to prioritize investments for a high quality, low-impact IT infrastructure. This gives rise to an outstanding organization reputation. Based on the interview, APU Operations Manager revealed that the top three drivers for going green are cost savings, energy reduction and IT infrastructure cost, asserting that the key by-product from this implementation is the creation of an inimitable value: competitive advantage. The manager further indicated that while APU has established a corporate IT strategy, GC, however, is not a part of this strategy as it is currently being formulated by identifying its elements. However, the University has taken an overwhelming stance against carbon emission and identified target areas such as the DC in implementing virtualization, cloud computing, enforcing power management policies at the computing labs and has put forth a green plan for a new green campus to be constructed next year which will house a green building.

V. GC READINESS

The first step towards answering 'when is it worthwhile to be Green' lies in the classification of environmentally-related investment that has the potential to become sources of competitive advantage (Orsato, 2006). A new APU readiness Model with five dimensions has beendeveloped and is illustrated below:

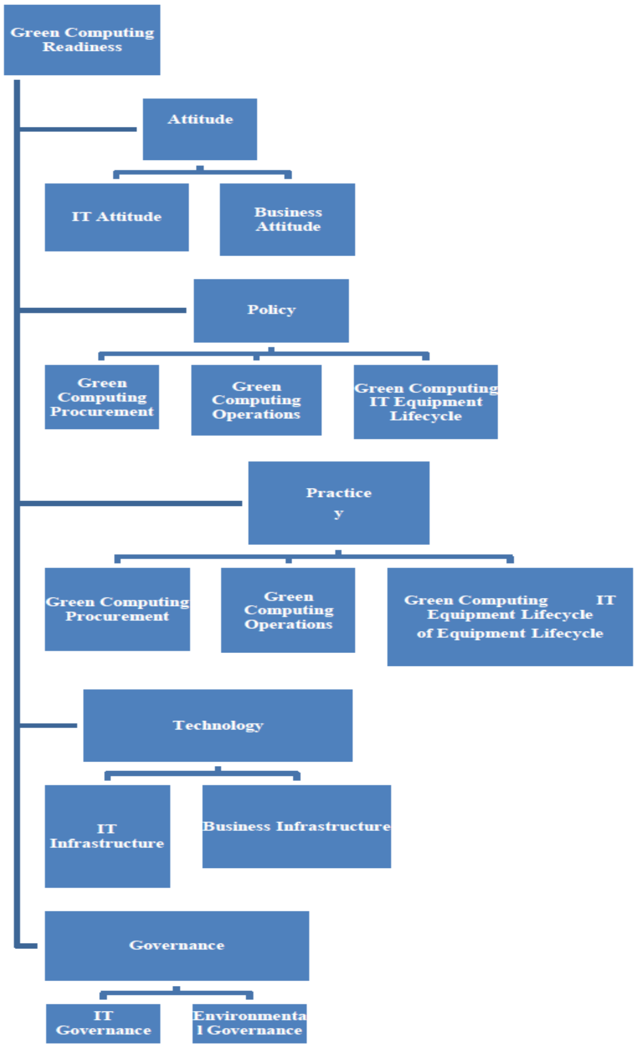

Figure 6: The APU GC Readiness Framework adapted from Molla et al. (2008)

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The five key dimensions: attitude, policy, practice, technology and governance represent a combination that is unique to each organization to deploy environmentally sustainable IT functions and processes that are accountable and measurable. Each dimension is explained as follows:

Dimension 1: Attitude

This refers to the value and awareness APU places on environmental consciousness. Although GC is in its infancy stage at APU, it has embarked on a GC initiative by forging an alliance with Asia Centre of Green Computing Research (ACGCR), a centre seeking to promote an objective and practical research on GC. Through the APU-ACGCR alliance APU offers GC Certifications from the Green Computing Initiative (GCI), a worldwide certification body that focuses on key IT technology areas such as Cloud and Grid Computing, Virtualization, Green Data Centres and Power Optimization. APU is developing GC concepts to be integrated in the diploma and degree level to provide leading edge technology skills to its students.

Dimension 2: Policy

Policy related to the manifesto developed in an organization reflecting its environmental-friendly commitment. The APU Operations Manager explains that there are dual aspects or policies that have been the focus: technology and organizational capability. These two pillars form the University's strategy in setting the GC readiness direction. The technology aspect relates to the technological advancement such as server virtualization for DC efficiency. The capability aspect refers to GC training conducted to hone GC skills and competency levels amongst students and academic staff.The technology policy includes procuring low energy-emission PCs, activating Power Management policies at the Computing Labs IT Equipment Lifecycle to dispose IT equipment safely at the end of its use.

Dimension 3: Practice

This basically measures if the manifesto and policies set above are translated into actionable items. APU Management has concurred that environmental concerns have been factored in the current process and the scope primarily falls under the DC and computing labs areas, owing to the high-energy use. Energy Star PCs have been procured and extensively used at the Computing labs and offices. A take-back program has not been established as IT vendors do not have such policies. The current recycling and disposal policy upholds the University's philosophy on waste reduction. The high-end Computing Lab PCs are delegated to the workforce and upon the end of its lifecycle, are recycled to IT vendors as metal scrap or e-waste for eco-friendly disposal. In line with APU's CSR policy, some well-functioning PCs are donated to charitable organizations. The extent to which the University has taken steps to address the following elements can also be used to determine its GC readiness:

- GC IT equipment lifecycle practice
- Internal energy assessment for carbon footprint reduction
- GC awareness through campaigns and policies

Dimension 4: Technology

This area relates to acquiring effective green technologies to create a green infrastructure. In this regard, APU was one of the earliest universities to implement cloud computing. And while most organizations may utilize environmental management systems such as ISO 14001 and Six-sigma (Rao & Holt, 2005), APU has decided on developing a proprietary standard through its very own Environmental Management Standards.

Dimension 5: Governance

An operating model is deemed necessary for the affective management of GC strategies. As GC is a fairly new initiative an operating model has not been established yet at APU. A new model with the IT department serving as the task force will be created to plan and monitor GC initiatives. Enforcing efficient software development methodologies such as minimizing programming codes will be formulated to increase the effectiveness of the internally-developed applications. Despite the absence of a GC governance model, APU Management has taken an upward trend in managing current initiatives with success.

VI. DC

Recording an average PUE, APU DC performance can be rated as standard consideringthe DC was not built with energy modelling tools. The audit tool has a set of recommended strategies which if implemented can accelerate energy savings by reducing energy, cost and minimizing cooling. The techniques can improve the PUE reading, turning it into a smarter DC. The top DC recommendations are presented below:

- **Air Management: Implement alternating hot and cold aisles**

This is the first step to air management: separating hot and cold air. Cold air is channelledto the cold front aisles of the server rack and the electronic gear moves the air from the front to the rear and/or front to the top. The hot air is returned to the air handler from the hot aisles.

- **Cooling: Shift from air-cooled DX to water-cooled DX or evaporative pre-cooled condensing units**

Air-cooled DX CRAC condensers transfer heat from the DC directly to the outside air. This is a simple process but not efficient at high outdoor air temperatures. Cooling towers can produce temperatures much lower than the outdoor air temperature. This type of condensing allows the CRAC to operate more efficiently. A point for APU to note is that CRAC manufacturers can supply the parts needed for this.

- **Environmental Conditions: Alter the unit cooling set points based on the server thermal demand**

IT equipment is normally designed to run reliably within a specific range of intake air temperatures, and a certain temperature increase of the air is expected before it is exhausted. Programming the cooling system to match this requirement avoids energy waste due to overcooling and ensures efficient IT equipment operation.

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- **Global: To consideran upgrade of all the cooling supply fan, pump, and cooling tower fan motors to premium efficiency**

Premium efficiency motors are typically a few percent more efficient than their baseline counterparts. The efficiency gains are modest but the incremental first cost tends to be low especially in replacing existing ones that have reached the end of their lifespan. Purchasing a premium motor is almost always cost effective for applications with longruntimes.

- **IT Equipment: Evaluate the potential savings in upgrading to newer equipment**

As IT technology evolves rapidly improvements in energy performance are often available in newer equipment. A cost-benefit analysis will decide if it makes economic sense to replace the existing equipment. According to Ebbers et al. (2011) although it may appear unwise to replace equipment before it is depreciated, new models offer the benefits of low-energy consumption and two to three times more computing power than older models. Together with space, energy and cooling reduction it is sufficient to offset any lost asset value.

- **IT Equipment Power Chain: Retrofit existing UPS that is older than 10 years withan efficient one**

UPS technology continuously evolves. If the existing UPS is old and scheduled for replacement, purchase a highefficiency UPS topology. Replacing an UPS that is more than 10 years old with a new unit may prove to be costeffective. Ebbers et al. (2011) outline that new best-in-class UPS models operates with 70% less energy than existing UPS equipment.

- **Lighting: Use Energy efficient lamps and ballasts**

Nontechnologyy in lighting can save a large percentage of the energy used by the older lighting systems.

VII. END USER COMPUTING

In light of the operating costs that have become the concern of organizations, APU has installed energy-efficient Energy Star PCs (Singh, 2012). Power Management Policies have been implemented at the computing labs, for example all labs have been activated with the Turn-off display since December 2011, which is estimated to utilize only about 1 Watt of electricity.

- Unplug phantom power - putting all equipment in one strip will not only save power but it would be favourable when all equipment is switched off. Unplugging power when equipment is not in use eliminates phantom power, reducing 10% of the electricity bill.
- Multiple power schemes could be implemented to deal with different usage models without putting the PC into a standby mode.

VIII. CONCLUSION

In protecting the universal environment, the U.N. Millennium Declaration (U.N. General Assembly, 2000, pp. 1) states, 'We must spare no effort to free all of humanity, and above all our children and grandchildren, from the threat of living on a planet irredeemably spoilt by human activities, and whose resources would no longer be sufficient for their needs'. Based on the survey conducted, the research question has been answered: APU stakeholders, have statistically recorded a positive finding where an overwhelming 89.5% believe that going green will propel APU to higher grounds and will be a preferred choice for students. Only6% disagree. All APU IT staff and 74.2% of academic staff believe that they play an active role by positively promoting GC aspects to instil awareness on the importance of going green. In conclusion, the majority of the University's stakeholders believe in the strategic advantages that GC can deliver to the University. And the second research question on assessing APU readiness, the GC Readiness model will be used to assess the University's readiness.

The literature review and findings from this research have highlighted that transition to a Green Computing landscape is a critical and vital business component. Every effort towards a sustainable Green Computing infrastructure will involve some measure of change and investment. By addressing energy and waste reduction, technological advancement, operational and infrastructure efficiency and most importantly strategic advantage factors, benefits are anticipated for the University that will far outweigh its investment. Hence, in recognizing the varied challenges, a strategic and sustainable Green Computing framework has been developed for the University to move towards a Green Computing infrastructure. It is anticipated to deliver strategic advantages and unique values for the University to realize its Green vision effectively.

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