International Journal of Computer Applications Technology and Research
Volume 7–Issue 10, 390-397, 2018, ISSN:-2319–8656

Assessing the Influence of Green Computing Practices on Sustainable IT Services

Shedrack Mmeah
Department of Computer Science, Ken Saro Wiwa Polytechnic, Bori, Rivers State - Nigeria

Barida Baah
Department of Computer Science, Ebonyi State University, Abakaliki – Nigeria

Abasiama G. Akpan
Department of Computer Science, Ebonyi State University, Abakaliki – Nigeria

Abstract: This study focused on the practice of using computing resources more efficiently while maintaining or increasing overall performance. Sustainable IT services require the integration of green computing practices such as power management, virtualization, improving cooling technology, recycling, electronic waste disposal, and optimization of the IT infrastructure to meet sustainability requirements. Studies have shown that costs of power utilized by IT departments can approach 50% of the overall energy costs for an organization. While there is an expectation that green IT should lower costs and the firm's impact on the environment, there has been far less attention directed at understanding the strategic benefits of sustainable IT services in terms of the creation of customer value, business value and societal value. This paper provides a review of the literature on sustainable IT, key areas of focus, and identifies a core set of principles to guide sustainable IT service design.

Keywords: Green Computing, Sustainable IT Services, Optimization, Virtualization, Workload Managements

1. INTRODUCTION

Green computing or its alternative "Green IT" have recently become widely trendy and taken on increased; their conceptual origin is almost two decades old. In 1991 the Environmental Protection Agency (EPA) introduced the Green Lights program to promote energy-efficient lighting. This was followed by the ENERGY STAR program in 1992, which established energy- efficiency specifications for computers and monitors [13, 50]. The swift growth of Internet-based business computing, often allegorically referred to as "cloud" computing, and the costs of energy to run the IT infrastructure are the key drivers of green computing. Over the last several years the link between energy use and carbon generation and the desire to lessen both has given rise to the green computing tag.

Drastically, increased energy use driven by the rapid expansion of data centres has increased IT costs, and the resulting environmental influence of IT, to new levels. Enterprise data centers can easily account for than 50 percent of a company's energy bill and approximately half of the corporate carbon footprint [15, 25].

Although energy use and its associated cost have been the key driver for green computing, a growing appreciation of the risks of climate change and increasing concerns about energy security have elevated green computing to a global issue. The new administration in the United States has stated intentions to endorse a "green energy economy" which will likely cap carbon emissions; increase energy costs, and holds companies more accountable for their impact on the environment [9].

Due to the immediate influence on business value, it is likely that green computing will remain focused on reducing costs while improving the performance of energy- hungry data centres and desktop computers. However, it is not likely that this first wave of activity will fully extend to the general minimization of the ecological footprint of IT products and services for companies and their customers. Ecological issues involving IT product and service design, supply chain optimization, and changes in processes to deal with e-waste, pollution, usage of critical resources such as water, toxic materials, and the air shed will need to be more fully addressed. Although these first-signal activities are driven more by cost-reduction-based business value there is growing potential for green IT products and services being the deciding factor in terms of the intangible benefits of "greenness" to the customer. Vendors are now able to position products and services in terms of energy consumption and lower costs, but the real benefit over time may be in positioning on environmental and social responsibility of the company itself [27, 32, 40].

"Sustainable IT" and especially "sustainable IT services" are terms that are becoming synonymous with an emergent second signal of green computing innovation. Sustainable IT strategies are driving sustainability beyond just energy use and product considerations. This broader approach to corporate sustainability will necessitate the redesign of the IT organization and indeed the company itself if the strategic benefits of green computing are to be realized. This second signal will include the adoption of ecological strategies that will redefine markets, spur technological innovation, and lead to shifts in process, behavior and organizational culture that will integrate business models with environmental and social responsibility [9, 32]. These changes are being driven by the evolving changes in customer requirements from a sole emphasis on the tangible cost-benefit of reduced energy usage to increasingly intangible green benefits and cultural issues motivated by concerns for global warming and climate change [40].

For this paper, we define green computing as the practice of maximizing the efficient use of computing resources to minimize environmental impact. This includes the goals of controlling and reducing a product's environmental footprint by minimizing the use of hazardous materials, energy, water, and other scarce resources, as well as minimizing waste from manufacturing and throughout the supply chain [1]. Green computing goals extend to the product's use over its lifecycle, and the recycling, reuse, and biodegradability of obsolete products. We define sustainable IT services1 in broader terms to include the impact of IT service strategies on the firm's and customers' societal bottom line to include economic, environmental, and social responsibility criteria for defining organizational success. Therefore, as defined, green computing practices inform a company's sustainable IT service strategies and process decisions.

The purpose of this paper is to review the current literature on green computing and its influences on sustainable IT services with the idea of identifying critical issues and leverage points to improve customer value, business value, and societal value.

1.2 GREEN COMPUTING: THE FIRST SIGNAL

Since its inception, the IT industry has focused on the development and deployment of IT equipment and services that was capable of meeting the ever-growing demands of business customers. Hence, the emphasis has been on processing power and systems spending. Less attention was afforded to infrastructure issues which include energy consumption, cooling, and space for data centres, since they were assumed to be always available and affordable. Over the last decade these issues have become limiting factors in determining the feasibility of deploying new IT systems, while processing power is widely available and affordable [47].

Data centres typically account for 25% of total corporate IT budgets and their costs are expected to continue to increase as the number of servers rise and the cost of electricity increases faster than revenues. One study indicated that the cost of running data centres is increasing 20% per year on average [15]. With annual energy costs for computing and cooling nearly matching the costs for new equipment, data center expenses can squeeze out investment in new products, make data intensive products uneconomic, and squeeze overall margins. The quest for data centre efficiency has become a strategic issue [15].

The high and increasing use of electricity makes data centres an important source of greenhouse gases. For information-intensive organizations, data centres can account for over 50% of the total corporate carbon footprint. For service firms, data centers are the primary source of green house emissions. Data centres, with their high energy costs and increasingly negative impact on the environment, are the driving force behind the green computing movement.

1.3 Factors Driving the Adoption of Green Computing

The following trends are impacting data centers, and to a lesser degree, desktop computers, and driving the adoption of green-computing practices:

- **The rapid growth of the Internet**

The increasing reliance on electronic data is driving the rapid growth in the size and number of data centers. This growth results from the rapid adoption of Internet communications and media, the computerization of business processes and applications, legal requirements for retention of records, and disaster recovery. Internet usage is growing at more than 10 percent annually leading to an estimated 20% CAGR in data center demand [51]. Video and music downloads, on-line gaming, social networks, c-commerce, and VoIP are key drivers. In addition, business use of the Internet has ramped up. Industries such as financial services (investment, banking, and insurance), real estate, healthcare, retailing, manufacturing, and transportation are using information technology for key business functions [2]. The advent of the Sarbanes-Oxley Act with its requirement to retain electronic records has increased storage demand in some industries at 50 percent CAGR [48]. Disaster recovery strategies that mandate duplicate records increases demand further. Finally, many federal, state, and local government agencies have adopted c-government strategies that utilize the Web for public information, reporting, transactions, homeland security, and scientific computing [131.

- **Increasing equipment power density**

Although advances in server CPUs have in some cases enabled higher performance with less power consumption per CPU, overall server power consumption has continued to increase as more servers are installed with higher performance power-hungry processors with more memory capacity [42, 47]. As more servers are installed they require more floor space. To pack more servers in the same footprint the form factor of servers has become much smaller, in some cases shrinking by more than 70% through the use of blade servers. This increase in packaging density has been matched by a major increase in the power density of data centers. Density has increased more than ten times from 300 watts per square foot in 1996 to over 4,000 watts per square foot in 2007, a trend that is expected to continue its upward spiral [13, 42, 45, 47].

3. Increasing cooling requirements

The increase in server power density has led to a concomitant increase in data center heat density. Servers require approximately 1 to 1.5 watts of cooling for each watt of power used [16, 24, 39]. The ratio of cooling power to server power requirements will continue to increase as data center server densities increase.

- **Increasing energy costs**

Data centre expenditures for power and cooling can exceed that for equipment over the useful life of a server. For a typical $4,000 server rated at 500 watts, one study estimated it would consume approximately $4,000 of electricity for power and cooling over three years, at $0.08 per kilowatt-hour, and double that in Japan [2]. The ratio of power and cooling expense to equipment expenses has increased from approximately 0.1 to 1 in 2000 to I to 1 in 2007 [47]. With the likely increase in the number of data centers and servers and the advent of a carbon cap-and-trade scheme, the cost of energy for data center power and cooling will continue to increase [26].

- **Restrictions on energy supply and access**

Companies such as Google, Microsoft, and Yahoo with the need for large data centers may not be able to find power at any price in major American cities [14]. Therefore, they have built new data centers in the Pacific Northwest near the Columbia River where they have direct access to low-cost hydroelectric power and do not need to depend on the overtaxed electrical grid. In states such as, California, Illinois, and New York, the aging electrical infrastructure and high costs of power can stall or stop the construction of new data centers and limit the operations of existing centers [24]. In some crowded urban areas utility power feeds are at capacity and electricity is not available for new data centers at any price [10].

- **Low server utilization rates**

Data center efficiency is a major problem in terms of energy use. The server utilization rates average 5-10 per cent for large data centers [15]. Low server utilization means that companies are overpaying for energy, maintenance, operations support, while only using a small percentage of computing capacity [9].

- **Growing awareness of IT's impact on the environment**

Carbon emissions are proportional to energy usage. In 2007 there were approximately 44 million servers worldwide consuming 0.5% of all electricity. Data centers in the server-dense U.S. use more than 1% of all electricity [10]. Their collective annual carbon emissions of 80 metric megatons of CO2 are approaching the carbon footprint of the Netherlands and Argentina [15]. Carbon emissions from operations are expected to grow at more than 11% per year to 340 metric megatons by 2020. In addition, the carbon footprint of manufacturing the IT product is largely unaccounted for by IT organizations [15].

1.3 Implementing Green Computing Strategies

Transitioning to green computing has involved a number of strategies to optimize the efficiency of data center operations in order to lower costs and to lessen the impact of computing on the environment. The transitioning to a green data center involves a mix of integrating new approaches for power and cooling with energy-efficient hardware, virtualization, software, and power and workload management [10].

- **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. Their infrastructure equipment is reaching the end of its useful life. It is power hungry and inefficient. Such data centers typically use 2 or 3 times the amount of power overall as used for the IT equipment, mostly for cooling [10]. The obvious strategy here has been to invest in new data centers that are designed to be energy efficient or to retrofit existing centers.

- **Power and workload management**

Power and workload management software could save $25-75 per desktop per month and more for servers [50]. Power management software adjusts the processor power states (P-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.

- **Thermal load management**

Technology compaction in data centers has increased power density and the need for efficient heat dissipation. Power use by ventilation and cooling systems is on par with that of servers. Typical strategies for thermal management are variable cooling delivery, airflow management, and raised-floor data center designs to ensure good air flow, more efficient air conditioning equipment, ambient air, liquid heat removal systems, heat recovery systems, and smart thermostats [10, 39].

- **Product design**

For example, microprocessor performance increased at approximately 50% CAGR from 1982 to 2002. However, performance increases per watt over the same period were modest. Energy use by servers continued to rise relatively proportionally with the increase in installed base [13]. The shift to multiple cores and the development of dynamic frequency and voltage scaling technologies hold great promise for reducing energy use by servers. Multiple-core microprocessors run at slower clock speeds and lower voltages than single-core processors and can better leverage memory and other architectural components to run faster while consuming less energy. Dynamic frequency and voltage scaling features enable microprocessor performance to ramp up or down to match workloads. Moving beyond microprocessors, the energy proportional computing concept takes advantage of the observation that servers consume relatively more energy at low levels of efficiency than at peak levels [3]. Therefore, the goal is to design servers that consume energy in proportion to the work performed. Since microprocessors have more quickly acquired energy-saving capabilities, it is expected that CPUs will consume relatively less energy than other components. Therefore, it will be necessary for major improvements in memory, disk drives, and other components to reduce their power usage at higher levels of utilization. Energy proportionality, which promises to double server efficiency with the potential for large energy savings for data centers, should become a primary goal for equipment designers [3].

- **Virtualization**

Virtualization has become a primary strategy for addressing growing business computing needs. It is fundamentally about IT optimization in terms energy efficiency and cost reduction. It improves the utilization of existing IT resources while reducing energy use, capital spending and human resource costs [30, 37]. Data center virtualization affects four areas: server hardware and operating systems, storage, networks, and application infrastructure. For instance, virtualization enables increased server utilization by pooling applications on fewer servers. Through virtualization, data centers can support new applications while using less power, physical space, and labor.

This method is especially useful for extending the life of older data centers with no space for expansion. Virtual servers use less power and have higher levels of efficiency than standalone servers [3].

Virtualization technology was originally developed by IBM (as CP/CMS in the 1960's) to increase the utilization efficiency of mainframes. More recently the concept has been applied to x86 servers in data centers. With the use of a hardware platform virtualization program called a hypervisor, or virtual machine monitor (VMM), multiple operating systems can run concurrently on a host computer. The hypervisor controls access to the server's processor and memory and enables a server to be segmented into several "virtual machines", each with its own operating system and application. For large data centers, server usage ranges from 5-10 percent of capacity on average. With virtualization, server workloads can be increased to 50-85 percent where they can operate more energy efficiently [3]. Less servers are needed which means smaller server footprints, lower cooling costs, less headcount, and improved manageability.

- **Cloud computing and cloud services**

As Internet-based computing centralizes in the data center, software technology has advanced to enable applications to be used where and when needed. The term "cloud computing" refers to a computing model that aims to make high-performance computing available to the masses over the Internet [35]. Cloud computing enables developers to create, deploy, and run easily scalable services that are high performance, reliable, and free the user from location and infrastructure concerns [31]. The "cloud" has long been a metaphor for the Internet. When combined with "computing" the definition turns to services [23].

As cloud computing continues to evolve it has increasingly taken on service characteristics. These services include utility computing, software as a service (SaaS), platform as a service (PaaS), and infrastructure as a service (IaaS).

• Utility computing: The first cloud services were developed by companies such as Amazon.com, Sun, and IBM that offered virtual servers and storage that can be accessed on demand. This is often described as an updated version of utility computing—essentially virtual computing capacity where users pay for what they use when they need it. Early adopters used this service for supplemental and non mission-critical needs. This model could be extended to include virtual data centers as a virtual resource pool [23].

• **SaaS**: This implementation of cloud computing delivers applications through a browser interface to thousands of customers using a multitenant architecture [17, 23, 34]. Salesforce.com is perhaps the best known of the SaaS companies with applications in sales force automation, CRM, human resources, and supply chain management. More recently, Google has adopted a SaaS model for its GoogleApps and Zoho Office [23]. The benefits for customers include: no upfront investment in infrastructure, servers, or software licenses; reduced operating expenses, end-to end business processes integrated with services anywhere/anytime; dynamically scalable infrastructure, SLAs for composite services, mobile device and sensor control, access to leading-edge technology, and less environmental impact (34].

• **PaaS**: An outgrowth of the SaaS model, PaaS delivers development environments as a service [23]. The model provides the required resources to support the entire life cycle for developing and delivering web applications and services over the Internet. Developers can essentially create their own applications as a service that will run on the provider's platform and are delivered to their customers from the provider's servers. Leading PaaS companies are Force.com, Google AppEngine, and Microsoft Azure. The primary advantages are the speed and low cost that can be achieved for development and deployment [46].

•**IaaS:** This cloud offering provides basic infrastructure, such as servers, storage, clients, and networking as an on demand service. Leading IaaS companies include Amazon Web Services, GoGrid, and Flexiscale [43].

• **Total power consumption:**_ In a recent study, this metric was the most popular with 68% of IT managers specifying its use. The cost of power and the volume of kilowatts used are typically included in the baseline assessment [9]. This metric can be useful in tracking power usage by facility, function, application, and employee. Accountability for electricity usage by IT organizations has been highlighted since it is a cost that can easily be tracked and it is a large part of the IT budget. Making power cost a discrete line item in the IT budget invites action to become more efficient and generate cost savings.

• **Power usage effectiveness (PUE):**_PUE is equal to Total Facility Power/IT Equipment Power. IT equipment power is defined as the load associated with computers, storage, network equipment and peripherals [33, 44]. Total facility power is the total power measured at the utility meter. A PUE of 2.0 indicates that data center demand is twice as high as the power necessary to power the IT equipment. A PUE value of 1.0 would indicate 100% efficiency with all power consumed by IT equipment.

• **Data center infrastructure efficiency (DCiE). DCiE = 1/PUE:** This ratio is equivalent to the PUE. In the above example IT equipment uses 50% of the power in the data center. The other 50% is of power demand is typically required for cooling. As IT equipment uses less energy pay as you go, access to the latest technology, faster service delivery and time to market.

1.4 Green Computing Metrics

Power-related metrics currently dominate green computing. Several energy-efficiency related metrics have been proposed to help IT organizations understand and improve the efficiency of data centers. Table 1 presents summarizes the most widely used benchmarks per unit of performance, then less energy is needed for cooling and DCiE will move higher [33].

• **Data center performance efficiency (DCPE). DCPE**
Useful Work/Total Facility Power. This ratio is informed by PUE and DCiE. However, it is much more complex to define and measure "useful work" performance as a standard metric [44].

• **Other energy efficiency benchmarks:** An alternate approach to energy efficiency monitory at the data center level is to build energy efficiency into the initial design of components and systems and to adaptively manage system power consumption in response to changes in workload and environment [36]. These benchmarks include Analysis tool, Energy Bench, SWaP, Energy Star, SPEC Power, and JouleSort.

2. Environmental Impact

• **Carbon footprint:** Regulations to reduce green house gas emissions worldwide will likely be forthcoming soon as a carbon tax or cap and trade scheme is being considered by the U.S. government and the Intergovernmental Panel on Climate Change (IPCC). Already some businesses are requesting that their partners provide information on carbon dioxide production [6]. One emerging strategy is to purchase electricity from renewable energy sources such as wind, solar, or hydro. Google has adopted this strategy, although the low-cost hydro energy it has tapped into has significant environmental drawbacks that offset its attractiveness long term [20]. The key metric here is the volume of carbon dioxide that is produced by various business processes and products—the carbon footprint.

2.0 SUSTAINABLE IT SERVICES: THE SECOND SIGNAL

Sustainable IT services are essential to business success. There is increasing pressure to adopt sustainable business practices. Sustainable IT services are not only about the first-wave green computing focus on data-center efficiency or how to minimize carbon footprints. It is squarely focused on the long-term importance of IT to the organization, its customers and to society at large—all second-wave sustainability issues. Therefore, sustainable IT is about everything an organization needs to do to ensure that IT services delivers superior value to attain a strong market position and to ensure its ability to survive. It is about aligning IT with business strategy to achieve market-leading business value, customer value and societal value. This will ensure the viability of the IT organization itself. There are several elements that comprise sustainable IT services [7].

- **Service sustainability:** At a minimum, this includes effective and reliable processes for delivering IT services. It is about managing performance and doing what is necessary to keep the service running smoothly such as constant security, systems recovery planning, and keeping versions current [7].
- **Temporal sustainability:** To sustain IT services over time an organization has to start with a clear understanding of the value that is to be created. It must have a strong business case, be responsive to business conditions, and create value for the customer and society, as well as the business [7].
- **Cost sustainability:** This includes acquisition and operating costs such as the choice of low cost hardware and software that also offer benefits such as low power consumption and ensure high levels of resource utilization. Life cycle management and replacement costs are also important consideration [7, 11, 28].
- **Organizational sustainability:** Organizational change is inevitable. Whether it derives from personnel changes or major changes in technology, markets, or mergers and acquisitions, IT services must continue to operate and innovate. Well managed systems with good documentation and training are more able to manage change [7].
- **Environmental sustainability:** In an ecological context, IT services must be able deliver customer and business value while ensuring that the Earth's resources are being used at a rate that ensures replenishment. In essence, the goal for environmental sustainability is for IT services to be able to meet the needs of the present without compromising the ability of future generations to meet their needs [40].

We define sustainable IT services from a total societal value perspective as the aggregate value available to society from the systematic integration and alignment of the individual IT service components for the purpose of creating superior societal value. Therefore, all aspects of IT services must meet societal goals for sustainability while meeting customer and business value goals in terms of economic, environmental, and social responsibility requirements [38].

- **From Business Value to Customer Value to Societal Value**

Business value is the overall benefit for business units and the enterprise as a whole that results from IT solutions or services. Business value is evidenced by increases in revenue or market position that derive from meeting customer requirements, providing customer savings or ROI, and making investments in innovation that advance the industry as a whole [1, 43]. Although this definition does recognize the customer and the industry at large, the overall focus of business value is to provide returns to the company. As such, business value often focuses on short-term, cost-based solutions that can overlook the long-term best interests of the customer, society, and resultantly, the business as well. The first wave focus on green computing, with its primary emphasis on cutting energy costs, can certainly increase business value, while increasing customer and societal value (carbon reductions). However, the short-term focus on costs cannot ensure that benefits to the customer and society will continue to be realized over the long term. A sole focus on creating business value is not sufficient for a sustainable IT services orientation.

Customer value is the overall benefit derived from a product or service, as the customer perceives it, at the price the customer is willing to pay [21, 22, 41]. A focus on customer value requirements forces companies to look to the markets and the customer as the core drivers of business activity. With this external focus, customer value is a broader concept than the mostly inward looking business value. IT service providers must first understand how their customers perceive value in terms of the perceived benefits perceived and the perceived price of the service that delivers those benefits [21]. It is necessary to understand what these tradeoffs are and how they might influence service configurations that can maximize customer value and business outcomes. The power of choice will ensure that those configurations that deliver superior value will also achieve superior business value. However, a short-term focus on customer value, which is the default approach given short product lifecycles and competitive pressures, is not sufficient for a sustainable IT services orientation. Some customers are willing to look at their long-term needs in a societal context, but for most consumers cost and performance are the dominant drivers [9].

The concept of societal value holds that companies should meet their market goals in such a way that enhances the customer's and the society's long-term well being. In that way, customer value and business value will be maximized as well. Societal value calls upon organizations to build ethical, social responsibility, and environmental considerations into their business practices. Therefore, companies must balance profits, customer requirements, and social responsibility in their business models. These goals are often in conflict and successful sustainable IT strategies should provide a roadmap for their alignment [38, 40].

- **Toward a Framework for Sustainable IT Services**

Although the need for the development of strategies to address the environmental sustainability of IT services has been apparent for many years, there is no extant body of literature on strategies or best practices. The issues surrounding the first wave of green computing are clearer and focused on reducing energy costs through new data center designs, architectures, facility and server density, and virtualization. Beyond that, companies are approaching sustainability through a fragmented incremental "greener IT" approach [8].

Cost optimization was the primary emphasis of the first wave of green computing. Problems and solutions associated with green computing are well known. The second wave, which we call sustainable IT, or more appropriately, sustainable IT services, has a much broader focus on the role of IT in the society. The primary driver of sustainable IT is corporate social responsibility (CSR), especially as it applies to firm's impact on the economy, environment, and society at large [52].

3.0 CONCLUSION

Sustainable IT has been a major focus for IT organizations for the past decade as the cost of power for data centers has risen rapidly. The focus of the first wave of sustainable IT initiatives has been on strategies to increase data center efficiency. Therefore, infrastructure, power and workload management, thermal management, product design, virtualization, and cloud computing strategies have assumed primacy in terms of both strategic and tactical focus. The second wave of sustainable IT services is nascent and much more difficult to define and implement. It involves defining the role of the IT organization in an enterprise's overall CSR strategy. It will involve establishing a roadmap and baseline metrics, redesigning business processes, encouraging participation, and adapting the organization's culture to new ways of doing things [49]. IT governance and decision making will likely be substantially impacted.

This paper offered a review of current thinking and suggested factors that should be considered for a sustainable IT strategy. Future research should address the relationship between customer value, business value, and societal value and how sustainable IT strategies will impact each. It would seem that these concepts should be mutually supportive. However, many business professionals view them to be at odds with each other, or at least to involve tradeoffs that may not always be beneficial for the company. More research is needed to fully understand the market impact of a sustainable IT services strategy. Beyond cost savings are there benefits from sustainability oriented business strategies that customers are willing to pay for? Does sustainability for IT services create competitive advantage? Finally, a model for the development and implementation of sustainable IT services needs to be developed. This model will likely involve the integration of the IT organization's sustainability initiatives with the enterprise-level model and throughout the corporate ecosystem.

REFERENCES

[1] Akpan, A. G and Onu, F. U. (2016). Carbon Footprint and Nigerian Banks: Exploring Factors of Green Computing Adoption in Data Centres. Nexus Journal of Science and Energy Studies. Vol. 5, no.3, pp. 166 – 172.

[2] Baldwin, E. and M. Curley. Managing IT Innovation for Business Value, Intel Press, 2007.

[3] Bailey, M., M. Eastwood, T. Grieaer, L. Borovick, V. Turner, and R.C. Gray. Special Study: Data Center of the Future, New York: IDC 06C4799, 2007.

[4] Barroso, L. A. and U. Hblze. "The Case for Energy-Proportional Computing," IEEE Computer Society, December, pp. 33-37, 2007.

[5] Barreto, L., H. Anderson, A. Anglin, and C. Tomovic. "Product Lifecycle Management in Support of Green Manufacturing: Assessing the Challenges of Global Climate Change," Proceedings of the International Conference on Comprehensive Product Realization 2007 (ICCPR2007), June 18-20, Beijing, 2007.

[6] Belady, C. L. "In the Data Center, Power and Cooling Costa More Than the IT Equipment it Supports," Electronics Cooling, February, 2007.

[7] Butner, K., D. Geuder, and J. Hittner. 'Mastering Carbon Management: Balancing Trade-Offs to Optimize Supply Chain Efficiencies," Supply Chain Management, IBM Institute for Business Value, pp. 1-13, 2008.

[8] Clifford, A., "Sustainable IT," It toolbox, com: Project Management Community, 2009, Retrieved February 25, 2009 from:

htto://it.toolbox.com./blogs/minimalit/sustainable-it-30 157

[9] Daoud, D. "Beyond Power: IT's Roadmap to Sustainable Computing," IDC Whitepaper, October 2008, www.idc.com.

[10] Deloitte Touch Tohmatsu. "The Next Wave of Green IT," CFO Research Services, Boston: CFO Publishing Corp, 32 pages, January 2009.

[11] Dietrich, J. and R. Schmidt. "The Green Data Center," IBM Global Services, white paper, 21 pages, May 2007.

[12] Dubie, D. "How to Cut IT Costs With Less Pain," Network-world, pp.11,40, January 26, 2009.

[13] Elkington, J. Cannibals with Forks: Triple Bottom Line of2l" Century Business, Oxford: Capstone Publishing Ltd. 1999.

[14] Fanara, A. 'Report to Congress on Server and Data Center Efficiency: Public Law 109-431, U.S. Environmental Protection Agency: Energy Star Program, 133 pages, 2007. Retrieved February 25, 2009 from http://www.energystar.gov/ia!partners/prod development/downloads/E PA Datacenter Report Congress Final I .pdf

[16] Foley, J., "Google in Oregon: Mother Nature Meets the Data Center," Information Week's Google Weblog, August 24, 2007.

[I6] Forrest, W., J. M. Kaplan, and N. Kindler, "Data Centers: How to Cut Carbon Emissions and Costs, The McKinsey Quarterly, Number 14, Winter 2008.

[17] Goodin, D., "IT Confronts the Datacenter Power Crisis," Info World, October 6, 2006, www.infoworId.com.

[18] Guptill, B. and W. S. McNee, "SaaS Sets the Stage for Cloud Computing," Financial Executive, pp. 37-44, June 2008.

[19] Hanselman, S. E. and M. Pegah. "The Wild Wild Waste: e-Waste," SIGUCCS '07, pp. 157-162. October 7-10, 2007.

[20] Harmon, R. R. and K. R. Cowan. "A Multiple Perspectives View of the Market Case for Green Energy," Technological Forecasting & Social Change, 76, Pp.204-213,2009.

[21] Harmon, R. R., H. Demirkan, B. Hefley, and N. Auseklis. "Pricing Strategies for Information Technology Services: A Value-Based Approach," Proceedings of the 42" Hawaii International Conference on System Sciences (HJCSS-42), 10 pages, CD-ROM, IEEE Computer Society, January 2009.

[22] Harmon, R. R. and G. Laird. "Linking Marketing Strategy to Customer Value: Implications for Technology Marketers," In Kocaoglu, et al (Eda.) Innovation in Technology Management, Portland, OR: PICMET/IEEE, Pp. 897-900, 1997.

[23] Knorr, E. and G. Gruman. "What Cloud Computing Really Means," Info World, April 7, 2008, www.inforworld.com.

[24] Lawton, G., "Powering Down the Computing Infrastructure," Computer, Vol.40(2), pp. 16-19, February 2007.

[25] Mckeefry, H. L. "A high-energy Problem," eWeek, March 2008.

[26] Mitchell, R. L. "Power Pinch in the Data Center," Computer World, April 30, 2007, www.computerworld.com

[27] Murugesan, S. "Harnessing Green IT: Principles and Practices." IT Professional. pp. 24-33, January-February 2008.

[28] Nagata, S. and Shoji O. "Green Process Aiming at Reduction of Environmental Burden," Fujitsu Science and Technology Journal, 41(2), pp. 25 1-258, July 2005.

[29] Olson, G. "Creating an Enterprise-level Green Strategy, Journal of Business Strategy, 29(2), pp. 22-30, 2008.

[30] Ou, G., "Introduction to Server Virtualization," Techrepublic.com, 5 pages, May 22, 2006.

[31] Perry, G. "How Cloud & Utility Computing are Different," GigaOM, February 28, 2008. Retrieved March 5, 2009 from: htto://gigaom.com!2008/02/28/how-cloud-utility-computing-are- different!

[32] Pohle, G. and J. Hittner. "Attaining Sustainable Growth through Corporate Social Responsibility," IBM Institute for Business Value, White paper, 20 pages, 2008, www.ibm.com.

[33] Rawson, A., J. Pfleuger, and T. Cader. Green Grid Data Center Power Efficiency Metrics: PUE and DCiE, The Green Grid, Whitepaper No. 6, C. Belady (Ed.), 9 pages, 2008.

[34] Reid, C. K. "SaaS: The Secret Weapon for Profits (and the planet)" Econtent Magazine, pp. 24-29, January-February, 2009.

[35] Ricadela, A. "Computing Heads for the Clouds," Business Week, November 16, 2007, www.businessweek.com.

[36] Rivoire, S., M. A. Shah, P. Ranganathan, C. Kozyrakis, and J. Meza. "Models and Metrics to Enable Energy-Efficiency Optimizations," IEEE Computer Society, Pp. 39-48, December 2007.

[37] Ryder, C. "Improving Energy Efficiency through Application of Infrastructure Virtualization: Introducing IBM WebSphere Virtual Enterprise," The Sagezo Group Whitepaper, 13 pages, April 2008.

[38] Savitz, A. and K. Weber. The Triple Bottom Line: How Today's Best- Run Companies Are Achieving Economic, Social and Environmental Success—and How You Can Too, San Francisco: Josey-Bass Publishers, 2006.

[39] Schmidt, R. R. and H. Shaukatallah. "Computer and Telecommunication Equipment Room Cooling: A Review of the Literature," 2002 IEEE Inter Society Conference on Thermal Phenomena, Pp. 751-766, 2002.

[40] Senge, P., B. Smith, N. Kruschwitz, J. Laur, and S. Schley. The Necessary Revolution: How Individuals and Organizations are Working to Create a Sustainable World, New York: Double Day, 2008.

[41] Sheth, J. N., Newman, B.l, and Gross, B.L. Consumption Values and Market Choices: Theory and Applications, Cincinnati, OH: Southwestern Publishing Company, 1991.

[42] Stanford, E. "Environmental Trends and Opportunities for Computer System Power Delivery," Proceedings of the 20" International Symposium on Power Semiconductor Devices & ICs, pp. 1-3, May 18-22, 2008.

[43] Sward, D. Measuring the Business Value of Information Technology, Intel Press, 2006

[44] The Green Grid. "Get a Grip on Your Data Center Power Efficiency," Power Management Design Line, 7 pages, June 7, 2007. wwwpowermanagementdesienline.com

[45] Torres, J., D. Carrera, K. Hogan, R. Gavalds, V. Beltran, and N. Poggi. "Reducing Wasted Resources to Help Achieve Green Data Centers," IEEE International Symposium on Parallel and Distributed Processing 2008, April 1-8, 2008.

[46] Urquhart, J. "Finding Distinction in 'Infrastructure as a Service," The Wisdom of Clouds — CNET News, January 11, 2009. Retrieved February 25, 2009 from: http'//news.cnet.comJ83Ol-194I3 3- I 0l40278-240.html

[47] Wang, D. "Meeting Green Computing Challenges," Proceeding of the International Symposium on High Density Packaging and Microsyslem Integration, 2007 (HDP '07), IEEE, 2007.

[48] Warmenhoven, D. "Three Years Later: A Look at Sarbanes-Oxley, Forbes, July 27, 2005.

[49] Wellsands, S. and S. Snyder. "Building a Long-Term Strategy for IT Sustainability," Intel Information Technology, White paper, 12 pages, April 2009. Retrieved April 26, 2009 from http://communities.intel .com/ community/openportit/it

[50] Wilbanks, L. "Green: My Favorite Color," IT Professional, pp. 63-64, November-December, 2008.

[51] Wong, H., "EPA Datacenter Study IT Equipment Feedback Summary," Intel Digital Enterprise Group, Cited in: Report to Congress on Server and Data Center Efficiency Public Law 109-43 1, U.S. EPA Energy Star Program, August 2, 2007.

[52] Zarella, E. "Sustainable IT: The Case for Strategic Leadership," KPMG IT Advisory, White paper, 24 pages, 2008. www.kome.com.