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Factors that Influence Sustainability in the Data Center of Small to Medium-Sized Organizations

CAPSTONE REPORT

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Abstract

For

Factors that Influence Sustainability in the Data Center of Small to Medium-Sized Organizations

Selected literature published between 1992 and 2007 is examined to provide information to technology managers of small to medium-sized organizations for making decisions that influence sustainability in the data center. The concept of sustainability applies to use of practices that benefit the environment and business. Efficiencies can save money, increase capacity, and lead to higher productivity and profitability (Hitchcock & Willard, 2006). Three tables list factors for opportunities related to purchase, use, and disposal of electronic equipment.

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Chapter I – Purpose of Study

Brief Purpose

The purpose of this study is to identify factors that influence environmental sustainability (Bruntland, 1987) in data centers within information technology departments (United States Access Board, 2000) of small to medium sized organizations (Whitehouse, 2005). According to the Bruntland Commission, sustainability is defined as, "Meeting our needs while not compromising the ability of future generations to meet theirs" (Bruntland, 1987). The concept of sustainability in this study applies to using practices that benefit the environment as well as business as these new efficiencies can save money, increase capacity and can lead to higher productivity and profitability (Hitchcock & Willard, 2006).

Multiple perspectives are driving the demand for environmentally sustainable practices in the business world. Security concerns of recycling products (Overby, 2007a), safety of workers and local communities (E. Williams, 2005), and fulfillment of regulations that put limits on the use of toxic chemicals (California Integrated Waste Management Board, 2004) and emissions (Environmental Protection Agency, 2006a) are all factors in environmentally sustainable practices. These kinds of concerns reach from manufacturing to the data center and have become a cost of doing business

(Varon, 2007a). The focus in this study is on the environmentally sustainable (a) purchase (Case & Panciera, 2005), (b) use (Tschudi, Xu, Sartor, & Stein, 2004), and (c) disposal of electronic equipment (California Integrated Waste Management Board, 2004) used in the data center. Specifically concentrating on these three areas contained within the IT department domain makes solid business sense. Sustainable purchasing guidelines ensure new equipment coming into the data center contain fewer hazardous materials, use less energy and are more easily recycled (Case & Panciera, 2005). Energy efficiency saves money which allows for increased capacity and can lead to higher productivity and profitability (Shamshoian et al., 2005). Proper disposal of electronic equipment enables the IT department and company to comply with global regulations like the Waste Electrical and Electronic Equipment Directive (WEEE) that went into effect in Europe in August 2006 (E. Williams, 2005) and further U.S. regulations nationwide like the California Electronic Waste Recycling Act of 2003 (Department of Toxic Substance Control, 2006) as well as satisfy consumers who demand the products and services they use are produced using green practices (McGee, 2007).

This study is intended to assist information technology managers who want to address environmental concerns by providing a list of factors that influence sustainability in the data center contained within the information technology department. With increasing energy costs, a growing concern over environmental government regulations (McGee, 2007), and consumer demands that products are produced in an environmentally responsible way, information technology managers are looking for ways to make their departments more environmentally sustainable and reduce their ecological footprint (Hitchcock & Willard, 2006).

This study is designed as a literature review (Leedy & Ormrod, 2005), focusing on literature published between 1992 and 2007 that examines sustainability in relation to the management of the data center within the information technology department. A conceptual content analysis (Palmquist et al., 2005) is performed on selected literature as a way to identify factors that influence environmental sustainability in the management of a data center (Goleniewski, 2003). Data are collected and organized using three pre-selected, broad concepts that represent the areas where information technology managers make decisions regarding green practices. These concepts are (a) environmentally sustainable purchasing (Case & Panciera, 2005), (b) environmentally sustainable use (Tschudi, Xu, Sartor, & Stein, 2004), and (c) environmentally sustainable disposal of electronic equipment (California Integrated Waste Management Board, 2004). Practices and procedures that fall within these categories are identified and coded for existence (see Appendix B).

The results of the content analysis are analyzed and presented in tabular format as a list of factors organized by three tables: (a) environmentally sustainable purchasing (Case & Panciera, 2005), (b) environmentally sustainable use (Tschudi, Xu, Sartor, & Stein, 2004), and (c) environmentally sustainable disposal of electronic equipment (California Integrated Waste Management Board, 2004). These three tables are the final outcome of the study, framed to meet the needs of information technology managers who want to build a more environmentally sustainable information technology department.

Full Purpose

Sustainability proposes that we make and design products that can be reused for other products or purposes, thereby limiting the overall impact on the environment (Bruntland, 1987). However, sustainability is not only about preserving our environment for future generations through conservation of natural resources but also about creating a strategic advantage by differentiating an organization from its competitors (Hitchcock & Willard, 2006). Organizations worldwide are implementing sustainability through environmental management systems (EMS) (Whitehouse, 2005) and committing to ongoing improvements in environmental performance (Stapleton & Glover, 2001). Some are even taking the extra step to have their environmental management systems certified for the international standard ISO 14000 (Johnson, 1997). ISO 14000 (Johnson, 1997) is a voluntary environmental compliance program and major corporations and government are discussing ways to require it as a condition of being a supplier (Johnson, 1997).

In addition to the pressure from corporations and government to conform (Johnson, 1997), there are numerous other reasons why companies might choose to engage in sustainable practices. Some organizations are paying close attention to sustainable practices to achieve greater cost savings, or abide by environmental laws and regulations; others are looking to increase their environmental performance to reduce a potential liability (Stapleton & Glover, 2001).

The increased demand for computing resources and the short lifecycle of electronic equipment generates large quantities of end-of-life systems (Matthews, McMichael, Hendrickson, & Hart, 1997). These systems are considered hazardous waste and can become a liability, thereby making it in the company's best interest to follow the end-of-life materials to their destination to ensure that all components are properly recycled or disposed (California Integrated Waste Management Board, 2004).

Recycling or disposal of electronic equipment involves not only the correct handling of the toxic materials but also the correct handling of confidential or private information contained within the equipment. With rising concerns about identity theft and data breaches, information managers need to know that sensitive data is wiped from machines before they are recycled or disposed (McGee, 2007). A sustainability plan is in the organizations best interest because it insures data is erased from drives, asset tags, and other forms of corporate identification are removed before refurbishing or grinding up the equipment to recycle it (McGee, 2007). Overall, businesses are engaging in sustainable practices to reduce energy consumption and material waste, address environmental regulations and reduce the potential for a poor public image (Johnson, 1997).

In the late 1990s, increased computing, network and storage demands amplified the number of computer servers used in the enterprise environment, which in turn increased the size of data centers (Whitehouse, 2005). According to a study at Lawrence Berkley National Labs (2007), power consumption in data centers doubled from 2000 to 2005 and accounted for 1.2% of U.S. electrical consumption.

A data center is a facility that houses mission critical computer systems and peripherals (Goleniewski, 2003). These data centers consist of information technology from servers, disc drives and networking equipment as well as non-IT devices such as air conditioners, humidifiers, fans, lighting and uninterruptible power supplies (Koomey, 2007). According to Gartner (2006), an IT industry analyst, data centers waste more than 60% of the energy they use to cool equipment plus all of this equipment consumes electricity and most of it not very efficiently (Tschudi, Xu, Sartor, Koomey et al., 2004).

Computers in data centers run continuously, unlike other electronic equipment which powers down at night (Betts, 1994). According to Greenberg (1999), data centers are over 40 times more energy intensive than conventional office buildings. Implementing sustainable energy efficient practices in the data center can have a significant impact on electrical consumption (Greenberg, Mills, & Tschudi, 1999). Some of these energy efficient practices include: improved air management, “free cooling” from either air-side or water-side economizers; and improved uninterruptible power supplies (Greenberg et al., 1999).

Because of this high energy consumption and constant use, power consumption is one critical specification when making purchasing decisions for equipment contained within the data center (Overby, 2007a). Other purchasing concerns arise because computer systems contain toxic materials and the average life of the system is short (Betts, 1994). Therefore, evaluation of new technology purchases needs to consider energy consumption but also the upgrade ability, recycle-ability, and the recycled material content (Information Services Committee, 2006).

According to one study, 70 percent of heavy metals in landfills are from discarded electronic components (N. Anderson, 2006). In addition to this concern of placing toxics into our environment, and thereby generating risks to human health, disposing of this electronic waste can be expensive (Case & Panciera, 2005). These costs are high because toxic waste requires special handling due to the characteristics of toxicity, ignitability, corrosivity or reactivity (Department of Toxic Substance Control, 2006).

Sustainable purchasing, use and disposal decisions are important to the IT manager because they are made on the full life-cycle costs of the equipment (Information Services Committee, 2006). These disposal costs can be reduced if new electronic purchases include the ability to upgrade equipment (rather than dispose of it) and the availability of lease and take-back options (Northwest Product Stewardship Council, 2005).

Information technology managers plan and coordinate the technology-related activities of organizations (U.S. Department of Labor, 2006). They help to determine business goals through the use of technology and are in consultation with top management through detailed plans containing concepts and requirements of new products or services (U.S. Department of Labor, 2006). Through these detailed strategic plans, information technology managers are responsible for the operating costs of the information technology department and managers are making it a priority to reduce these costs through sustainable practices ("Going green," 2007). According to Goldberg (1999), these economic costs can be reduced and the environmental impact minimized, by applying sustainable practices to the purchasing, use and disposal of electronic equipment in the data center.

According to the Commission for Environmental Cooperation (2005), 98% of businesses in Canada, Mexico and the United States are classified as small to medium size organizations. Between business classifications, there are discrepancies in technical capability of an organization based on relative size. Large organizations, the minority, are much more likely to have engineering expertise related to energy efficiency and conservation. In addition, they are more likely to have the internal resources and expertise to develop and implement a sustainability plan (Whitehouse, 2005). The purpose of this study is to assist information technology managers in small to medium size organizations who lack sustainability training or lack the internal technical capability to evaluate, present and implement a successful environmental management system (Esty, Levy, Srebotnjak, & Sherbinin, 2005; University of Strathclyde Library, 2006;

Whitehouse, 2005). According to Hitchcock & Willard (2006), hiring an outside sustainability expert combined with internal IT management support increases the likelihood that sustainability will succeed in that organization. The outside expertise provides IT managers with a general understanding of sustainability specifically in the IT environment.

A literature review (Leedy & Ormrod, 2005), focusing on a collection of materials that address environmental sustainability in information technology is conducted. The literature review allows the researcher to, ". . .evaluate, organize, and synthesize what others have done (Leedy & Ormrod, 2005)." The current interest in information technology as it relates to sustainability has resulted in articles in multiple sources of literature including books, newspapers, academic journals and magazines. The literature review supports this type of data collection to define a set of current factors that support sustainability in an information technology department.

Literature searches are conducted using key terms of: (a) energy efficient data center, (b) green data center, (c) e-waste, (d) electronic waste, (e) green computer, (f) green data center and (g) purchasing green computers. These seven terms result in approximately thirty sources for use in the study. Literature is collected, assessed, and organized for further evaluation. Limiting the literature review to material published between 1992 and 2007 is a way to capture recent technology advancements in the development of energy efficient electronic equipment spurred on by the voluntary labeling program, Energy Star (Environmental Protection Agency, 2007b).

A conceptual content analysis as defined by the Colorado State University Writing Guide (Palmquist et al., 2005) is performed on a sub-set of the selected literature that forms the data set for coding. The coding process is designed to identify factors that influence environmental sustainability in the management of data centers. Conceptual analysis is conducted to identify potential factors in the data center that relate to environmental sustainability. Raw data are organized under the following themes: environmentally sustainable (a) purchase (Case & Panciera, 2005), (b) use (Tschudi, Xu, Sartor, & Stein, 2004), and (c) disposal of electronic equipment. The raw data are placed into three tables and are located in Appendix B.

Data are further analyzed, manipulated, redundancy-deleted and presented in three tables: Table A: Environmentally Sustainable Factors to Consider When Purchasing Electronic Equipment for the Data Center, Table B: Environmentally Sustainable Factors to Consider When Using Electronic Equipment in the Data Center, Table C: Environmentally Sustainable Factors to Consider in the Disposal of Electronic Equipment from the Data Center. The three tables contain the factors sorted by the main concepts that emerged from the coding process. This guide will assist IT managers to plan, identify and implement the factors in environmentally sustainable (a) purchase (Case & Panciera, 2005), (b) use (Tschudi, Xu, Sartor, & Stein, 2004), and (c) disposal of electronic equipment in the data center.

The resulting factor list is a tool for information technology managers in assessing their current state of sustainability practices in the data center. This list can be used to assist in the strategic planning process of the organization by providing areas that can increase efficiency through the reduction of utility costs. Also, the use of this factor list can be used to assess and reduce potential security breaches as they relate to incorrect disposal of electronic equipment. The liability potential of incorrectly disposing of and handling the toxic waste generated through end-of-life electronic equipment could be assessed and mitigated.

Significance

Beyond global warming, other issues are pushing for environmental sustainability (Business Environmental Alliance, 2006) in the data center. With prices of electricity escalating and concern about the availability of current and future energy sources, sustainable practices have become strategically important to the information technology sector (Shamshoian et al., 2005). The Information Technology sector is now paying closer attention to these trends as they are feeling the effects from higher energy bills and the potential negative environmental impact of the pervasiveness of computing equipment in most companies. (Laitner, 2003; McGee, 2007). These include costs associated with operating energy inefficient data centers, and challenges in disposal of end-of-life electronics.

Global warming is a controversial issue that has significant impact on future planning of environmentally sound business practices (Business Environmental

Alliance, 2006). In February 2006, the United Nation's inter-governmental panel on climate change issued a report stating there is very high confidence that human activity plays a significant role by overloading the atmosphere with carbon dioxide (Kluger, 2007). In spite of the critics and lingering debate about this issue, climate change has garnered the attention of the legislature and the White House (Bush, 2007). Since 2001 several significant e-waste measures have been enacted including bills in California and Maine (Griffin, 2005).

Today companies face a variety of environmental issues from how to deal with disposal of toxins contained within electronic equipment to how much electricity they consume that is produced by fossil fuels (Varon, 2007b). In the past the information technology manager was not involved in any of these environmental decisions but it is currently believed that sooner or later an employer, customer, or government agency will want to know how these issues are being managed in the business (Varon, 2007b). This new level of interest and accountability in environmental practices contained within the information technology department is brought about because IT managers are responsible for managing systems that are tied to an estimated two percent of the total greenhouse gas emissions.

Contained within the data center are computer servers, monitors and electronic peripherals that contain toxic materials that must be recycled correctly or they could become a major source of negative environmental impact (Matthews et al., 1997). Also, information technology managers are concerned with the security of data, not following proper electronic end-of-life disposal practices could lead to the release of confidential information or the company being held responsible for improper disposal of toxic materials (California Integrated Waste Management Board, 2004).

This paper addresses the importance for the information technology manager to be informed about how to identify and reduce costs in the data center through energy efficiency and reduce negative exposure through proper purchasing, use, and end-of-life recycling procedures (Varon, 2007c). This study provides a factor list that directs IT managers to specific criteria for addressing the issue of implementation of environmental sustainability to the data center.

Limitations

Even though the birth of the Environmental Protection Agency was December 2, 1970 (Lewis, 1985) and sustainability is defined in the late 1980s, the selection of the collected literature is limited to works published between 1992 and 2007. This date range is chosen to provide the most up-to-date and relevant information concerning sustainability as it relates to information technology departments and their impact on the environment (Walsh, 2007). In addition, in 1992, the US Environmental Protection Agency introduced a voluntary manufacturer-labeling program known as Energy Star, designed to reduce greenhouse gas emissions by enabling consumers to easily identify energy efficient products. The Energy Star Program's first additions were computers and monitors (Lewis, 1985). This program changed the environmental impact of information technology equipment because it required manufacturers to educate customers on their product's energy saving potential, financial savings potential and environmental benefits (Environmental Protection Agency, 2007b). Because of this important development in regulation and new design practices, this study is based on literature introduced after the inception of the Energy Star Program (Nordman, Piette, Kinney, & Webber, 1997).

This study uses literature sources that are limited to authors who have affiliations with the following organizations: universities and educational institutions, state and federal government, state and federal government sponsored organizations, non-profit organizations, industry and professional publications and private corporations. Academic literature is selected because of its peer review process and thus expected quality of content. Both state and federal government literature is selected because the regulatory bodies are currently a key source of information on environmental trends. The remainder of the sources, including trade publications and whitepapers, are essential because the topic is an emerging trend. These publications are geared towards business and reflect market direction prior to regulation.

The literature selected and analyzed, as noted, is limited to two areas of information technology: the management of data centers and the electronic equipment contained within them. This electronic equipment is limited to air handling equipment in the data center, computers, servers, switches, routers, data storage devices, load balancers, racks, and related equipment (Tschudi, Xu, Sartor, & Stein, 2004). These items have been selected because they are some of the fastest growing waste products and energy consuming electronics produced (California Integrated Waste Management Board, 2004; The Green Grid, 2007a).

The data gathered are examined using conceptual content analysis (Palmquist et al., 2005) because content analysis is useful for examining trends and patterns in text or texts. The selected literature is searched for the existence of chosen phrases and coded. The researcher takes the results of the coding process, tabulates them and places them in table form. The table format is selected for data presentation because it is a simple, easy to use guide for reference and application of the sustainable factors by IT managers.

Legislation is reflecting a growing concern and social expectations regarding the environment. For example, locally in Oregon the 2000 Oregon Solutions Initiative introduced by Governor Kitzhaber states that business, government, and communities operate best when economic, environmental, and social considerations are given equal weight. “People, places, and profits” (triple bottom line) legislation alerts businesses to Oregon’s attitude regarding the environment (Novak, 2000). These social expectations toward business, with regard to the environment, are expansive and cover all aspects of business. This study is limited to addressing environmental issues as they relate to the purchase, use and disposal of electronic equipment in the data center.

IT managers are also beginning to see the emergence of Leadership in Energy and Environmental Design (LEED) Green Building Rating System™ certified data centers. These data centers are part of environmentally responsible buildings that may save companies money. LEED uses a whole building approach and focuses on five areas: sustainable site development, water savings, energy efficiency, materials selection, and indoor air quality (Parkinson, 2007). The focus of this study is limited to data centers in their existing structure and allows for modification of fixtures contained within but does not include new building design or construction.

Businesses have implemented various types of training programs to reduce energy use. Some of the popular programs include: instructing employees to turn off lights when they leave a room, turning down thermostats at night, using energy-efficient computer monitors/office equipment, unplugging electronic equipment when not in use, and opening windows to cool/ventilate rather than using air conditioning (Business Environmental Alliance, 2006). The training, instruction and managing of people are expansive topics. The focus of this study is not on training people but is limited to factors that may influence the decisions made by IT managers regarding the purchase, use, and disposal of computer hardware, software and air handling equipment within the data center.

Data center virtualization is aligning the resources with the request for resources. Virtualization technology allows the creation of a set of logical shared resources contained within physical resources (Overby, 2007a). These groups of resources, such as servers, in the data center behave as a single resource from which all services can draw, thereby reducing electrical consumption (Overby, 2007a). For the purpose of this study, virtualization technology, much like other techniques used to reduce energy usage in the data center is limited only to the mention of the technology not the selection process or implementation of the technology.

Problem Area

Although there have been environmental laws and regulations addressing specific environmental issues since the turn of the century (Erickson & King, 1999) sustainability is a relatively new concept. The Bruntland Commission, established by the United Nations General Assembly, is credited with defining the term "sustainability" in their 1987 report, which analyzed the connection and issues between the environment and business development (Bruntland, 1987).

Further studies aligned business and the environment together, leading to the development of the business concept known as the triple bottom line or people, planet and profit (Elkington, 1998). This concept describes the necessity to balance economic, social, and environmental goals and is considered the foundation of sustainability.

Today, business strategists are aware that "eco-efficient" companies are the most successful companies (Johnson, 1997), as the consumer of today not only expects a quality product but one produced by a company that supports sustainable practices. Investors are more likely to invest in a company that takes care of its environmental aspects not only for the obvious cost savings and increased efficiency, but because it assures them you are in control (Johnson, 1997).

Managing the health of an organization is a continual process that changes with trends, technology, and the economy. At the macro level, this concept is broken down into two areas, internal performance variables and external performance variables (Brache, 2002). The IT department is one of these internal variables that can be controlled and managed. The demand for technology based solutions are ubiquitous yet energy costs are skyrocketing (Laitner, 2003) and regulations on disposal of electronic equipment are imminent (Case & Panciera, 2005) making the IT department a liability where an organization has much to lose without an effective sustainability program. Some of these potential losses include: missing opportunities to reduce energy consumption and electronic waste, administration to address environmental regulations, fines and penalties through government audits, loss of confidence by stockholders and financial institutions, and poor public image resulting in lost opportunities to sell product or service (Johnson, 1997).

The IT department is a logical place for organizations to look for changes because data centers are responsible for violating the three basic components of sustainability: economic, social and environmental thus jeopardizing the overall health of the organization. According to Brache (2002), “Organizational health is a function of understanding and managing an intricate and entwined set of variables.” For example, mismanaging the environmental variable in the organization will create a misalignment affecting the whole, which will lead to an unhealthy organization (Brache, 2002).

This study provides a list of factors that can influence IT management decisions towards rebalancing the economic, social and environmental components. This information affects economic organizational decisions and is part of the larger context of information management, information economics and policy (Strassmann, 1996).

Chapter II – Review of References

The review of references is presented as an annotated bibliography of key references used to frame and build this research paper. References are listed in alphabetical order. Each listing begins with the formal citation and is followed by a summary of the information used in the study and the selection criteria used to establish credibility.

California Integrated Waste Management Board. (2004). *Best management practices for electronic waste*. San Jose: California Integrated Waste Management Board.

The main objective of this research project is to develop guidance tools for local California governments and others to ensure that e-waste is managed to protect public health and the environment while conserving resources. This literature provides the results of a survey directed towards local government agencies responsible for the management of e-waste programs and environmental compliance. The respondents provide information about e-waste issues including regulations, procurement and end markets. The information from this study is used to develop the brief and full purpose by examining the regulations that put limits on the use of toxic chemicals. These regulations are one of the perspectives driving demand for environmentally sustainable practices in the business world. This text is also used in developing the definition, environmentally sustainable disposal.

This publication was developed for the Integrated Waste Management Board, Public Affairs Office for Santa Clara County Department of Environmental Health. The findings from this research project provide credible governmental insight into e-waste management and include nationally recognized organizations involved in e-waste management.

Case, S., & Panciera, K. (2005). Computing the true cost of computers. Retrieved March 12, 2007, from http://www.govpro.com/Issue/Article/27965/Issue

This article is particularly relevant because it offers timely purchasing guidelines that do not sacrifice price or performance in choosing products that are better for people and the environment, the basis of sustainability.

The text, located on the GovPro website, an online resource for best practices and information related to aspects of the procurement professional's job. The resource is written by Scot Case, the Director of Procurement Strategies, and Kelly Panciera, a Research Associate, at the Center for a New American Dream; a non-profit organization that works with individuals, institutions, communities, and businesses to conserve natural resources, and promote positive changes in the way goods are produced and consumed. Scot Case is an internationally recognized expert on environmentally preferable purchasing and has written dozens of reports and case studies on green purchasing for the U.S. Environmental Protection Agency (EPA). This text is selected as part of the data set for content analysis

Environmental Protection Agency. (2007). History of Energy Star. Retrieved April 8, 2007, from http://www.energystar.gov/index.cfm?c=about.ab_history

Energy Star is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy. It is designed to help save money and protect the environment through energy efficient products and practices. The US Environmental Protection Agency (EPA), a credible governmental institution cited by many authors, introduced the Energy Star program in 1992 as a voluntary labeling program designed to enhance the marketability of energy-efficient products to reduce greenhouse gas emissions. This text is used in this study to frame a limitation by limiting works published after the inception of the Energy Star program.

Hitchcock, D., & Willard, M. (2006). *The business guide to sustainability*. London: Earthscan.

Hitchcock and Willard present a guide to sustainability that provides tangible examples that organizations can apply through a selected framework most useful to the organization. They explore sustainability as it is applied to organizations through simple, easy to understand practices that are strategic and encourage profitability. This text provided inspiration for the study and is used as foundational material in the development of the brief and full purpose, the problem area and definitions section. This text provides the overall concept of sustainability as described in the brief purpose. This concept is expanded in the full purpose describing sustainability as a strategic advantage that differentiates organizations from there competitors. This text defined the term of ecological footprint and because of its focus it assisted in developing the brief purpose and defined the concept of sustainability.

Hitchcock and Willard are both experts in the field of sustainability and are founding partners of AXIS Performance Advisors established in 1990. Hitchcock is President of AXIS Performance and the author of scores of publications. Willard is CEO of AXIS Performance and earned a Ph.D. in instructional technology from the University of Southern California. Willard also teaches graduate level courses at the University of Oregon including classes on sustainability.

Lawrence Berkeley National Laboratory. (2003). Data center energy benchmarking case study [Electronic Version]. Retrieved March 22, 2007 from http://hightech.lbl.gov/DCTraining/docs/data-center-facility8.pdf.

This study provides some of the earliest information on practices for data center energy efficiency. While the study is intended to assist IT designers in making decisions about the design and construction of data centers, many of the concepts are also applicable to current data centers.

This energy study was conducted as part of Lawrence Berkeley National Laboratory Data Center Load Characterization and Roadmap Project, under sponsorship by the California Energy Commission (CEC). Data centers at four different organizations in Northern California were analyzed during the period of September 2002 to December 2002, with the particular aim of determining the end-use of electricity. Lawrence Berkeley National Laboratory has been a leader in science and engineering research for more than 70 years and has eleven Nobel Laureates associated with it. This U.S. Department of Energy's National Laboratories is managed by the University of California. Rumsey Engineers and the Lawrence Berkeley National Laboratory co-authored the article. This reference is selected as part of the data set for content analysis.

Leedy, P. D., & Ormrod, J. E. (2005). *Practical research: planning and design* (8th ed.). Upper Saddle River: Pearson Prentice Hall.

This resource communicates a straightforward approach to the research method of literature review, is a recommended text used in graduate courses at the University of Oregon, and is frequently cited by other authors in the fields of information management. This resource provides guidance, direction and structure in developing a study framed as a literature review.

Palmquist, M., Busch, C., De Maret, P., Flynn, T., Kellum, R., Le, S., et al. (2005). Content analysis. Retrieved March 31, 2007, from http://writing.colostate.edu/guides/research/content/index.cfm

This reference is a writing guide and is used as a framework to develop the method section of this study through an eight step coding process provided in this guide. The Colorado State University English Department developed this guide as part of an offered graduate course. Over a period of seven years, the graduate students enhanced and revised the guide as part of their course work, which focused on research methods and quantitative and qualitative methods used in research. The instructor of the course, Mike Palmquist, Professor, University Distinguished Teaching Scholar, Director of the Institute for Learning and Teaching, Co-Director of the Center for Research on Writing and Communication Technologies; B.A., English, Writing, Political Science, St. Olaf College; Ph.D., Rhetoric, Carnegie Mellon University oversaw the development of the guide and provided direction and editing.

The Green Grid. (2007). Guidelines for energy efficient data centers. Retrieved March 23, 2007, from http://www.thegreengrid.org/downloads/Green_Grid_Guidelines_WP.pdf

This white paper is included in the study because it covers some of the most current information on best practices, metrics and technologies for improving the operational efficiency of existing datacenters. It is particularly useful because of its timely information on current technology recommendations for existing datacenters which is a limitation of this study. This reference is selected as a data set for the content analysis.

This non-profit source is formed specifically to address the environmental issues of powering and cooling datacenters. The Green Grid is a non-profit trade organization comprised of IT professionals, government organizations and technology companies and is cited by trade and industry publications.

Tschudi, W., Xu, T., Sartor, D., & Stein, J. (2004). High-performance data centers: a research roadmap [Electronic Version]. Retrieved April 10, 2007 from http://repositories.cdlib.org/cgi/viewcontent.cgi?article=2865&context=lbnl.

This text is selected as a key reference because it identifies areas where data center efficiency gains are achieved through adoption of best practices, improved application of existing technology, and research into new technological solutions.

Lawrence Berkeley National Laboratory developed this article with input from industry partners including; data center facility design and operation firms, industry associations, research organizations, energy consultants, and suppliers to data centers. Lawrence Berkeley National Laboratory has been a leader in science and engineering research for more than 70 years and has eleven Nobel Laureates associated with it. The University of California manages this U.S. Department of Energy's National Laboratories. This work was sponsored by the California Energy Commission through the Public Interest Energy Research program. This text is used to support the development of definitions in this study, Environmentally Sustainable use.

Whitehouse, T. (2005). *Successful practices of environmental management systems in small and medium-size enterprises*. Retrieved. from http://www.cec.org/files/PDF/LAWPOLICY/EMS-Report_en.pdf.

This text provides a North American perspective on environmental management systems in the context of liberalized trade. This report was prepared by Tim Whitehouse, Head of the Law and Policy Program of the Secretariat of the Commission for Environmental Cooperation (CEC). The Commission for Environmental Cooperation

(CEC) was established under the North American Agreement on Environmental Cooperation (NAAEC). Comments on this report are provided by Environment Canada, Mexico's Federal Attorney for Environmental Protection and the US Environmental Protection Agency. The content of this publication is useful in defining environmental practices as they relate to small to medium sized enterprises, and supports related ideas presented in the Brief and Full Purpose sections of this paper, as well as definitions for SME and EMS.

Chapter III – Method of Study

The research method selected for this study is literature review (Leedy & Ormrod, 2005). With global warming at the forefront of the news (California Integrated Waste Management Board, 2004), the increasing cost of energy and emerging government regulations for managing electronic waste (EPA, 2007) information technology managers with power hungry data centers and an abundance of electronic equipment are feeling the pressure to respond to these concerns (Merritt, 2007). This surge of awareness and demand for action has created volumes of literature in books, technical journals, whitepapers, and magazines that discuss sustainable practices for information technology departments and data centers (Leedy & Ormrod, 2005). The literature review (Palmquist et al., 2005) is selected because this method supports the collection of human communications, from the previously mentioned variety of sources to discover developing trends in environmental sustainability.

The Colorado State University Writing Guide (2005) defines content analysis as, “A research tool used to determine the presence of certain words or concepts within a set of text” (Palmquist et al., 2005). This study uses content analysis, more specifically, conceptual content analysis (Palmquist et al., 2005) for the data analysis strategy. This strategy focuses on, “Looking at the occurrence of selected terms within a text or texts” (Palmquist et al., 2005). This strategy fits the overall objective of the study as new ideas, practices and technologies emerge from multiple disciplines. This multifaceted selection of literature is analyzed using conceptual content analysis (Berns, 2007) to find out the underlying factors that may influence environmentally sustainable decision-making for information technology managers in small to medium sized companies.

Literature Collection

The literature search strategy begins by identifying key word terms, conducting searches on selected databases, library indexes and the World Wide Web, then reviewing the results and refining the key word terms. This process is repeated to narrow and frame the purpose of this study. The following foundational literature inspired and assisted in the development and framing of this study:

1. Hitchcock, D., & Willard, M. (2006). *The business guide to sustainability*. London: Earthscan.

2. Tschudi, W., Xu, T., Sartor, D., & Stein, J. (2004). High-performance data centers: a research roadmap [Electronic Version].

3. Lawrence Berkeley National Laboratory. (2003). Data center energy benchmarking case study [Electronic Version]. Retrieved March 22, 2007 from http://hightech.lbl.gov/DCTraining/docs/data-center-facility8.pdf.

The following criteria are used to search for articles related to the key factors in this study:

- The literature is published between the years of 1992 and 2007
- The literature contains factors that are pertinent to environmentally sustainable practices in the data center
- The literature is from a reputable source. Reputable sources are determined by:
    1. Primary resources peer reviewed by experts in the field.
    2. It is cited by other credible authors.
    3. It has the author or sponsoring organization's name on it.
    4. The publication has a reputation for accurate information.
- The literature is accessible in print or available in full text format

If all of the above criteria are met, the literature is considered part of the study. Literature that meets the above criteria, but is produced to support the marketing or characteristics of a particular company's technology, is evaluated on a case-by-case basis. This type of literature could contain leading edge technology solutions for sustainable data centers and therefore is not automatically excluded.

The following key word terms are used to search and collect literature for this study.

- Energy efficient data center
- Green data center
- E-waste
- Electronic waste
- Green computer

- Green data center
- Purchasing green computers

The initial literature search is conducted through the University of Oregon, Knight Library system of articles, databases and indexes using key word terms. Databases accessed in the initial search include; IEEE Computer Society, Computer Source, Academic Search Premier, ArticleFirst and LexisNexis Academic. These databases and indexes are selected because of their relevance to the topic and ability to provide timely results. Literature searches are conducted using individual key word terms and combinations using advanced search options, such as Boolean operators, to focus the results. During the searches, the use of key word term “computer” by itself yielded too many results therefore, “computer and data center” are combined using Boolean operators.

The World Wide Web is searched through Google, Yahoo and Google Scholar search engines using the same key word terms and combinations of key word terms and Boolean operators as used in the University of Oregon Knight Library system. Google and Yahoo are selected because they are the most widely used search engines (Palmquist et al., 2005) and Google Scholar is selected because of its focus on scholarly material.

Literature identified using the World Wide Web provides the timeliest information for this study because of the current nature of the topic and the real-time nature of the

Web. It is important to use advanced search features to reduce the number of hits and attempt to limit irrelevant articles. Google Scholar is searched using the same strategy as Google and Yahoo except the Boolean operator “not” is used to exclude paid sites where I did not have access to the full-text article.

The World Wide Web yields a number of important websites that not only identify some potential key word search terms but also definitions and information for this study. These website are listed as follows:

Lawrence Berkley National Labs	http://www.lbl.gov/
Green Electronics Council	http://www.greenelectronicscouncil.org/
Electronic Product Environmental Assessment Tool	http://www.epeat.net/
U.S. Environmental Protection Agency	http://www.epa.gov

Data Analysis

On the final set of thirty sources selected to form the data set for content analysis, analysis is performed guided by the eight steps presented in the conceptual analysis strategy provided by the Colorado State University Writing Lab (2005). This strategy is chosen because it allows researchers to record the existence of words or concepts within text or texts from varied sources (Palmquist et al., 2005). Applying this coding strategy to the broad range of literature allows the researcher to yield the clearest picture of the factors that influence environmental sustainability in an IT department, as reported in the selected literature. Eight steps are described as a framework for the coding process. These eight steps are applied to this study in the following manner:

1. Decide the level of analysis:

For the purpose of this study, phrases are selected for concept coding because coding for a single word such as “energy” or “efficient” could pertain to other unrelated information and skew results.

2. Decide how many concepts to code for:

Three broad concepts are used to identify and organize the data. They include:

1. environmentally sustainable purchasing of electronic equipment (Case & Panciera, 2005)
2. environmentally sustainable use of electronic equipment (Tschudi, Xu, Sartor, & Stein, 2004) and
3. environmentally sustainable disposal of electronic equipment (California Integrated Waste Management Board, 2004)

Practices and procedures that fall under these three categories are identified, recorded, and organized for further study. Figure 1 is provided as an example of the coding template.

Concept #1: environmentally sustainable purchasing practices	
Practice	**Reference**
Lease and take-back options (purchaser buys computing "service" rather than a computer "product").	(Northwest Product Stewardship Council, 2005)

Figure 1: Coding template.

3. Decide whether to code for existence or frequency of a concept:

Since the purpose of this study is to yield a list of factors, coding is done based on the existence of the concept in the text, not its frequency.

4. Decide on how you will distinguish among concepts:

Content analysis allows for the researchers to analyze meaning and make inferences about its content because of the implicit and explicit varied definitions (Palmquist et al., 2005). This general level of interpretation among concepts or key word phrases allows for different sets of words contained in the phrase to be coded even when they appear in different forms (Palmquist et al., 2005). In this situation, a set of translation rules applies to determine if the phrases are acceptable (Palmquist et al., 2005). Translation rules are supported by the set of definitions, provided in the paper. An example of an implicit term for this study is the word "green" that is often used to imply the same meaning as "environmentally sustainable."

5. Develop rules for coding your text:

Listed below are a set of translation rules (Palmquist et al., 2005) to give the coding process consistency.

- If the phrase being analyzed is explicit, it is coded within the pre-defined table.
- Each occurrence of an implicit phrase is interpreted and evaluated by the researcher independently against definitions provided in this paper and in relation to the context in the source document, and added to the pre-defined table if accepted.

6. Decide what to do with irrelevant information:

Information not pertaining to factors that influence environmental sustainability in an information technology department is not coded. Irrelevant information is not included in the study and therefore is discarded.

7. Code the texts:

The coding process occurs by manually searching the text and recording the occurrences of the predefined concepts into a spread sheet (Palmquist et al., 2005). A manual search is chosen because, “A researcher can recognize errors far more easily” (Environmental Protection Agency, 2007b) and allow for interpretation of concepts within context more readily. A spreadsheet is used as a format to record instances of each of the three concepts (see Figure 1).

Data Presentation

8. Analyze your results:

After completion of coding, raw data identified are reviewed and further organized so that similar concepts are merged. Three lists are produced to report the raw data results, one list per predefined concept: 1) environmentally sustainable purchasing of electronic equipment; 2) environmentally sustainable use of electronic equipment (Tschudi, Xu, Sartor, & Stein, 2004); and 3) environmentally sustainable disposal of electronic equipment (California Integrated Waste Management Board, 2004).

Factors derived from raw data are formatted and sorted by main concepts that emerged during the coding process. The next column describes the benefit or impact to the organization or environment (see Figure 2). The first table, sustainable purchase (Case & Panciera, 2005), is used to indicate proactive activities that practice product stewardship by purchasing products that are less toxic, conserve natural resources and reduce waste (Shamshoian et al., 2005). The second table, sustainable use (Tschudi, Xu, Sartor, & Stein, 2004), is used to indicate activities that maximize environmental efficiency while operating the data center facility (Brache, 2002p. 51). The third table, sustainable disposal (California Integrated Waste Management Board, 2004), is used to indicate environmentally sustainable activities for end-of-life electronic equipment. These tables are the final outcome of the study and provide a set of factors that can be used by IT managers as a reference guide for the sustainable purchase, use and disposal of electronic equipment in the data center. A template for the final outcome is provided below, in Figure 2: Template for Environmentally Sustainable Factors Guide.

Environmentally Sustainable Purchase Factors in the Data Center
Factor
Purchasing new servers, select energy efficient multi-core chips.

Figure 2: Template for Environmentally Sustainable Factors Guide.

This reference guide can be used by information technology managers to evaluate the current processes and procedures within the data center or assist in building an environmental management system. The four steps according to Stapleton's (2001) handbook for developing an environmental management system in small to medium sized businesses are; (a) plan, (b) do, (c) check, (d) act (Stapleton & Glover, 2001). The final outcome of this study, a reference guide, provides a set of factors that can be used to explicate the plan stage of Stapleton's four-step process. Comparing each of the three categories in the guide against current activities in the data center provides the organization with a preliminary review of current environmental opportunities, which can be added to the environmental management system (Stapleton & Glover, 2001).

Information technology managers can also use this guide as a planning tool to assist in aligning business and IT strategic objectives as they relate to environmental sustainability. Goleniewski (2003) states that, "Strategy is the framework of choice that determines the nature and direction of an organization" (Goleniewski, 2003 p.

51). Each of the three categories in the guide: purchase, use and disposal become the “framework” for a sustainable planning session to develop future operational decisions around the data center (Hitchock & Willard, 2002).

Chapter IV – Analysis of Data

This chapter provides the results of the conceptual analysis of thirty references (see Appendix A) on factors that influence sustainability in the data center of information technology departments, a description of the findings, and a description of the processes employed to move from the raw data tables to the final outcome for the study.

The conceptual analysis for this study, based on the eight-step method described by the Colorado State University Writing Guide (Palmquist et al., 2005) uses three predefined concepts: 1) environmentally sustainable purchasing of electronic equipment ; 2) environmentally sustainable use of electronic equipment (Tschudi, Xu, Sartor, & Stein, 2004); and 3) environmentally sustainable disposal of electronic equipment (California Integrated Waste Management Board, 2004).

The start of the analysis is the manual coding of the selected texts for the existence of the three aforementioned concepts. The raw data results of the coding are placed in three individual tables one for each pre-defined concept and are listed in Appendix B: Raw Data. Each of the concepts contained within these tables represents a factor located in the selected text that met the criteria as outlined in the methods chapter.

The factors derived from the raw data tables are further analyzed, and similar concepts are combined and placed into three tables that are the outcome for the study (see Appendix A). A statement describing the impact to the environment or the organization is added to each subcategory and is derived from the context of the phrase found in the selected texts. Data are further manipulated in Table 1: Environmentally Sustainable Factors to Consider When Purchasing Electronic Equipment for the Data Center by grouping together factors that influence; product and vendor selection, and purchasing practices. Table 2: Environmentally Sustainable Factors to Consider When Using Electronic Equipment for the Data Center by grouping together factors that influence system modifications or equipment upgrades, room, HVAC and rack configuration, education of workers, alternative power sources and worker practices. Table 3: Environmentally Sustainable Factors to Consider When Disposing of Electronic Equipment for the Data Center by grouping together factors that influence; reuse, recycle and disposal of electronic equipment.

Findings indicate that there are a variety of ways that IT managers can influence the (a) purchase (Case & Panciera, 2005), (b) use (Tschudi, Xu, Sartor, & Stein, 2004), and (c) disposal of electronic equipment (California Integrated Waste Management Board, 2004) to work toward environmental sustainability. The literature coding produced significantly more instances of factors that address sustainable use, followed by purchasing and then disposal. The concepts are tabulated and placed in a table to verify that there is sufficient data (see Figure 3).

Concepts – Raw Data	**Count**
Purchasing	74
Use	138
Disposal	39

Figure 3: Raw Data Count

The raw data are then further organized by combining similar concepts; reducing duplication and placing them into subcategories (see Figure 4). The predominant category with the most occurrences is environmentally sustainable use and within that category room, HVAC and rack configuration is the largest subcategory with 17 entries. The least observed occurrences are for the disposal category with a count of three (see Figure 4).

Concepts	**Count**
Purchase	
Product Selection Guidelines	12
Vendor Selection Guidelines	5
Purchasing Practices	10
Use	
Equipment Upgrade or System Modification	11
Room, HVAC and Rack Configuration	17
Alternative Power Sources	3
Education of Workers	6

Worker Practices	3
Disposal	
Reuse	4
Recycle	4
Dispose	2

Figure 4: Concept Count

Content analysis of the literature shows that there is much similarity found among the 30 pieces of literature selected for coding. Of the 251 concepts coded in the raw data tables, like concepts were combined and reduced down to 77 factors in the final tables.

The literature shows a common theme, demonstrating the importance of reusing electronic equipment. Adamson (2005) states, preference need to be given to products that can be upgraded and reused. The EPA (2001) supports this statement by suggesting systems should be selected not only for upgradeability but can be done so without special tools.

Elsewhere a common theme in the literature is the preference for electronic equipment that bears the Energy Star or EPEAT labeling designation. Bush (2007) requires that 95% of the electronic products purchased for the government meet the EPEAT standard. Case & Panciera (2005) suggest that Energy Star is an easy way to identify energy efficient products.

The data also shows the importance of computers for the secondary market, which extends the useful life of the equipment prior to disposal. Pratt (2007) suggests that donating old electronic equipment is a good intention but bad policy as it could potentially pose a security risk (i.e. theft of data or incorrect disposal methods). Adamson et al. (2005) recommend that systems, which are still fully functional, be donated to schools or non-profit organizations to continue providing service. California Integrated Waste Management (2004) proposes that an effective reuse or recycle program needs to have a mechanism to ensure that recyclers are handling materials in a responsible manner.

A large portion of the literature emphasizes the need to address HVAC air handling deficiencies, including Greenberg’s (1999) emphasis on cold air short-circulating back to HVAC units through missing floor tiles in raised floors. The Green Grid (2007) notes proper location of vented floor tiles and adds proper placement of blanking panels in the server racks to reduce this short-circulating of cold air.

Chapter V – Conclusions

The goal of sustainability, as framed in this study, is to meet current needs without comprising the needs of future generations (Bruntland, 1987). Organizations that are consuming large amounts of energy and depreciating an abundance of electronic equipment are looking for ways to improve their bottom line and act responsibly in the face of pressure from consumers, regulators and increasing expenses (McGee, 2007). This trend of environmental sustainability is moving down the organizational chart from the Chief Information Officer to the information technology manager who is in need of a concise guide that can be used to assist in the management of sustainability in the data center (McGee, 2007).

The outcome of the study is a reference guide grouped in three tables (see Appendix A) to be used by information technology managers to evaluate the current processes and procedures within the data center and assist in building an environmental management system (EMS). The guide provides a starting point by listing 77 factors for IT managers to review and consider in the planning stage of Stapleton's (2001) four step environmental management system for small to medium sized businesses of; (a) plan, (b) do, (c) check, (d) act (Stapleton & Glover, 2001). According to Stapleton & Glover (2001) a barrier for small to medium sized organizations in developing an environmental management system or sustainability plan is the lack of time and or technical resources. However, they do note:

> The key to effective environmental management is the use of a systematic approach to planning, controlling, measuring and improving an organization's environmental performance. Potentially significant environmental improvements (and cost savings) can be achieved by assessing and improving your organization's management processes. Many environmental "problems" can be solved without installing expensive pollution control equipment (Stapleton & Glover, 2001, p.10).

The findings from this study support Stapleton & Glover's (2001) statement that most sustainable endeavors can be implemented "without installing expensive pollution control equipment" premise with a majority of articles recommending simple changes to current organizational processes and small changes in product specifications, vendor choices or education. For example, by choosing to purchase Energy Star or EPEAT compliant products, and by dealing with suppliers who are environmentally conscious through reducing packaging or providing take-back programs; IT managers can make an impact.

This guide is organized around three key categories of information that pertain to the purchase, use and disposal of electronic equipment in the data center and is designed for IT managers who oversee this electronic equipment in small to medium sized organizations. While their companies may be small with fewer than 500 employees (Whitehouse, 2005) this category comprises over 98 percent of businesses in Canada, Mexico and the United States (Whitehouse, 2005) and their activities could have a significant impact on the environment. Small to medium sized organizations lack the funds to invest in research and development for sustainability projects. However, due to their size, these organizations are more nimble and can implement changes very quickly, which can differentiate them from the competition.

The guide consists of three main categories that examine environmentally sustainable factors related to the purchase, use and disposal of electronic equipment in the data center. It is broken down into sub categories of key elements and each section contains a description of the environmental impact or importance of that sub category. IT managers can refer to the guide for ideas on how to; consume less energy which in turn saves money, reduce electronic waste, which can improve the company's image and keeps toxic materials out of the landfills, and more efficiently manage equipment which consumes fewer resources and creates fewer emissions.

The attainment of total sustainability in the data center is a daunting task however; adopting many of these factors will benefit the environment as well as business as these new efficiencies can save money, increase capacity and can lead to higher productivity and profitability (Hitchcock & Willard, 2006).

Appendices

Appendix A: Outcome Guides for IT Managers of Data Centers.

Table 1: Environmentally Sustainable Purchase Factors in the Data Center
Product Selection Guidelines When purchasing electronic products consideration is given to the energy saving features, ability to upgrade, and ability to recycle part or all of products.
When purchasing new servers, select energy efficient multi-core chips.
Specify the most energy efficient power supply for new servers.
Specify Energy Star certified technology.
Choose electronic products that can be easily dismantled for efficient reuse, refurbishment or recycling.
Select computers that can be easily upgraded.
Select EPEAT certified electronic products.
Select energy saving LCD monitors.
Choose products with corn-based plastic or more recyclable metals.
Choose operating systems and software that are easily upgraded.
Select servers with power conscious chips/processors.
Choose products that facilitate recycling with labeled plastics, universal fasteners, single resin plastics and toxic components easily separable.
Choose products to minimize health risk to end-users by reducing emissions of electrostatic fields, electric fields, magnetic fields, and noise.
Vendor Selection Guidelines Preference is given to vendors whose practices reduce landfill, do not use toxic materials, and offer programs that reduce a company's liability.
Select suppliers who offer take-back or trade-in programs.
Choose suppliers who take responsibility for removing their packaging and reuse or recycle it.
Ensure spare parts and service will be available years after production.
Demand transferable licensing for software and hardware.
Require information from supplier on energy management features and hazardous material content.

Purchase Practices Implement purchasing practices that reduce landfill, reduce emissions, reduce the company's liability, and extend the useful life of products.
Consider leasing programs that require the return of the equipment at end of the lease.
Purchase supplies locally to reduce fossil fuel emissions from transportation.
Educate upper management on sustainable practices to aid long-term success.
Choose refurbished computers first.
Choose products that have minimal packaging.
Purchase supplies in bulk to minimize packaging.
Establish policies to extend useful life of electronic equipment.
Require vendors to provide information on environmental practices and policies.
Choose virtual machines before purchasing new systems.
Purchase carbon offsets for emissions generated by computer systems.

Table 1: Environmentally Sustainable Factors to Consider When Purchasing Electronic Equipment for the Data Center

Table 2: Environmentally Sustainable Use Factors in the Data Center
Equipment Upgrade or System Modification Operate or configure electronic systems or equipment in ways that save electricity, maximize usage and reduce emissions.
Upgrade to high-efficiency computer power supplies.
Activate power management modes (sleep, standby, and processor).
Improve server utilization.
Shutdown or consolidate systems that are used infrequently.
Upgrade servers to more energy-efficient multi-core processor chips.
Implement "thin-client" systems.
Improve older less efficient uninterruptible power supplies.
Remove legacy servers.
Deploy server virtualization.
Use air conditioner economizer modes.
Upgrade to energy-efficient HVAC systems.

Room, HVAC and Rack Configuration Reduce the consumption of energy used to cool the equipment through proper room configuration, rack set-up and air handling.
Close openings in raised floors and seal cable openings for effective air distribution.
Ensure proper placement of raised floor air discharge tiles for effective air distribution.
Reduce airflow blockages from cables under raised floors.
Close unused or openings in racks with blank panels.
Ensure effective air distribution for cooling and equipment reliability.
Ensure hot air return plenum is of optimum size.
Design for medium temperature chilled water to eliminate dehumidification.
Use of outside “made-up” air improves the quality of the workplace environment.
Install close-coupling cooling to target individual row, rack or server.
Upgrade pumps, fans and compressors in the cooling system to energy efficient models.
Arrange racks of computers in the data center to align “hot aisle and cold aisle”.
Install Dynamic Smart Cooling in data center.
Locate data center room air conditioning units for efficient air handling.
“Right-size” central plants and ventilation systems.
Direct liquid cooling of components eliminates airflow needs.
Upgrade to energy-efficient lighting.
Eliminate short-circuiting of heated air above equipment racks.
Alternative Power Sources Use power sources that are more efficient, create fewer emissions and are more sustainable.
Evaluate energy-efficient on-site power generation.
Locate data center by a source of sustainable power.
Install solar electric systems.
Educate Workers Education about sustainability leads workers to implement practices that promote energy savings, and reduce landfill, emissions and liability.
Implement information programs to encourage energy efficiency by increasing awareness of conservation.
Encourage an open attitude by management toward employee environmental suggestions.

Add environmental resource management as part of the new employee training process.
Include environmental issues as part of the annual corporate evaluation process.
Implement an energy management-training program.
Educate buyers and system architects on the benefits of energy efficient products.
Worker Practice Employ worker activities that promote energy savings, improve air quality, and reduce landfill, emissions and liability.
Telecommute.
Reduce paper usage through technologies like instant messaging.
Create an IT facilities group, which is trained to address the specialized needs of the data center and reduce its environmental impact.

Table 2: Environmentally Sustainable Factors to Consider When Using Electronic Equipment for the Data Center

Table 3: Environmentally Sustainable Disposal Factors in the Data Center
Reuse Extend the useful life of products by finding additional uses or sharing them and therefore keeping them (and any toxic materials contained within) out of the landfill.
Before disposal, reuse systems that may be out-of-date but still functional.
Resell or donate old computers through proper channels using EPA recommended methods.
Upgrade computer hardware rather than disposing and replacing it.
Institute a policy to not store computers but to donate, reuse or properly recycle.
Recycle Process old equipment in order to regain material (parts, plastic, etc.) for other uses and thereby reduces landfill and toxic materials.
Set-up detailed record keeping or an asset management system for electronic equipment to track working systems and the disposal method used for obsolete systems.
If equipment can't be reused, then it should be broken down for recycling.

Institute a policy or work with a third party to clean all information off the electronic equipment, and remove asset tags prior to reuse or disposal. This includes routers, switches, drives, memory, etc.
When using a third party recycler request verifiable certification that they have the necessary permits and materials are handled in an environmentally responsible manner.
Disposal Reduce toxic materials in landfills and liability to the organization through proper removal of end of life electronic equipment.
Verify that electronic waste is not sent to developing countries for disposal.
If not using a certified third party recycler, verify which equipment is classified as hazardous waste and dispose of it as outlined by the EPA.

Table 3: Environmentally Sustainable Factors to Consider When Disposing Electronic Equipment for the Data Center

Appendix B: Raw Data Tables

Environmentally Sustainable Purchase Factors in the Data Center	Citation
"Replacing old servers with new ones based on multi-core chips."	("Going green," 2007, p. 2)
"Purchasing more efficient power supplies."	("Going green," 2007, p. 2)
"ENERGY STAR certified technology allows computers to automatically switch to standby mode when inactive for a certain amount of time, and thus allowing for energy savings."	(Adamson et al., 2005, p.10)
"Public education is a key component of green procurement because it can exert a strong influence on industry and therefore bring about ecological change."	(Adamson et al., 2005, p.32)
"Preference must be given to office products which bear ecolabels, are upgradeable, and contain recycled materials."	(Adamson et al., 2005, p.33)
"Suppliers which offer a take-back or trade-in program must be sought out and given preference."	(Adamson et al., 2005, p.33)
"Products which use minimal packaging and are energy efficient must be given preference."	(Adamson et al., 2005, p.33)
"Supplies should be bought in bulk in order to minimize wastes from packaging as well as fossil fuel emissions from transportation."	(Adamson et al., 2005, p.33)
"Office equipment that is easily dismantled must be selected in order to encourage efficient reuse, refurbishment or recycling."	(Adamson et al., 2005, p.33)
"Consider leasing programs or purchase agreements that require the retailer, distributor, or manufacturer to take the equipment back at the end of its life."	(EPA, 2001, p.1)
"Choose computers that are designed for disassembly."	(EPA, 2001, p.1)
"Choose computers that can be easily upgraded without special tools."	(EPA, 2001, p.1)
"Choose computers that include expandable memory capacity, which can reduce the number of times a product must be replaced."	(EPA, 2001, p.1)
"Find computers designed for disassembly by considering what raw materials are used in the product's manufacture, distribution, reuse, operation, maintenance, packaging, and disposal, as well as their durability and adaptability."	(EPA, 2001, p.1)
"Specify that packaging adequately protects the goods and materials supplied, while avoiding over- packaging."	(EPA, 2001, p.1)
"Give suppliers the responsibility for removing their packaging: preferably for reuse; secondarily for recycling."	(EPA, 2001, p.1)
"Encourage manufacturers to design cleaner computers without using hazardous materials."	(EPA, 2001, p.1)
"NEC's 2002 PowerMate Eco was the first computer to use lead-free solder, a fully recyclable plastic case, monitors without harmful gases,	(Faludi, 2006, pg 10)

and no toxic flame retardants. (It also used a very efficient CPU, the Transmeta Crusoe.)”	
“In 2004 HP prototyped a printer with a corn-based plastic case that could biodegrade.”	(Faludi, 2006, pg 11)
“Even simpler methods work as well--sleek aluminum cases are more robust and far more recyclable than plastic ones.”	(Faludi, 2006, pg 11)
“Lease and take-back options (purchaser buys computing “service” rather than a computer “product”).”	(Northwest Product Stewardship Council, 2005, p.2)
“Choose operating systems and software that are readily upgradeable. “	(Northwest Product Stewardship Council, 2005, p.2)
“Ask for readily upgradeable hardware. Toshiba is developing a modular computer with a rewritable cartridge that can be upgraded electronically at low cost.”	(Northwest Product Stewardship Council, 2005, p.2)
“Make sure spare parts and service will be available (defined in years available after production).”	(Northwest Product Stewardship Council, 2005, p.2)
“Check to see that memory is easily expandable.”	(Northwest Product Stewardship Council, 2005, p.2)
“Demand “spare tire” software and licensing can be pre-loaded to allow for simple reuse of hardware.”	(Northwest Product Stewardship Council, 2005, p.2)
"To have a truly corporate policy, it's got to come from the top down," Sullivan said. "If the CIO doesn't care about efficiency in the data center, do you think anybody working for him is going to?"	(Parkinson, 2007, p.3)
“She could not find a refurbished model to fit her needs, so she consulted the Electronic Product Environmental Assessment Tool, or Epeat, an electronics rating system available free at www.epeat.net.”	(Rehfeld, 2006, p.1)
“Seeking new environmentally sound computers may also want to consider keeping their existing ones just a while longer. There will be a much broader selection of greener computers and other electronics by 2008 because all manufacturers are under pressure to make their products meet hazardous-substance standards that are as high or higher than those of Epeat.”	(Rehfeld, 2006, p.2)
“Section 2-h) ensure that the agency (i) when acquiring an electronic product to meet its requirements, meets at least 95 percent of those requirements with an Electronic Product Environmental Assessment Tool (EPEAT)-registered electronic product, unless there is no EPEAT standard for such product.”	(Bush, 2007, par.8)
“Enables the Energy Star feature on agency computers and monitors.”	(Bush, 2007, par.12)
“Establishes and implements policies to extend the useful life of agency electronic equipment.”	(Bush, 2007, par.12)
“Uses environmentally sound practices with respect to disposition of agency electronic equipment that has reached the end of its useful	(Bush, 2007, par.12)

life."	
". . .replacing its blade servers with virtual machines that use more server capacity and consume less power."	(Varon, 2007b, p.34)
"Select servers with power conscious chips/processors."	(Overby, 2007a, p.40)
"Select better cooling and power supplies. These include systems that use carbon dioxide for cooling, direct-current power supplies, and more efficient in-chassis, in-rack, in-row cooling products."	(Overby, 2007a, p.40)
"Manufacturers and retailers also have a major role in educating the public by providing point-of-sale disposal information and product labels indicating which electronics will become hazardous waste."	(California Integrated Waste Management Board, 2004, p.11)
"Energy efficiency can be easily identified through existing eco-labeling programs such as Energy Star."	(Case & Panciera, 2005, p.2)
"Required vendors to provide information on corporate environmental responsibility practices and policies, compliance with Energy Star, third-party certifications, take-back and end-of-life management services, and use of reduced, recycled, and recyclable packaging."	(Case & Panciera, 2005, p.2)
"Preference for computers with environmental features. It included reduction of hazardous substances, design for recycling, upgradeability, Energy Star products, and manufacturer take-back programs."	(Case & Panciera, 2005, p.2)
"The RFP also included a preference for computers that have reduced toxic constituents, take into account user health and safety, are designed to be recyclable, and are manufactured in an environmentally responsible manner. "	(Case & Panciera, 2005, p.2)
"Asked bidders to provide information on their take-back options, third-party certifications, compliance with international directives such as the European Union's Waste Electrical and Electronic Equipment (WEEE) and Restriction of Hazardous Substance (RoHS) Directives, and Energy Star equipment."	(Case & Panciera, 2005, p.2)
"Desktop computers, laptops, and monitors can achieve EPEAT designation at one of three levels—bronze, silver, or gold—depending on their environmental performance."	(Case & Panciera, 2005, p.2)
"Less Toxic Materials— eliminating or reducing hazardous, carcinogenic, and mutagenic substances."	(Case & Panciera, 2005, p.2)
"Upgradeability— extending the life of computers by including features such as expandable memory and modular design."	(Case & Panciera, 2005, p.2)
"Design for Recycling— designing computers so that components can be easily separated for recycling. This includes avoiding glues and welded connections, clearly labeling plastics, and using universal fasteners."	(Case & Panciera, 2005, p.2)
"Energy Star— requiring Energy Star-labeled computers that meet the latest federal energy efficiency standards."	(Case & Panciera, 2005, p.2)
"End-of-Life Management— incorporating provisions that provide for environmentally sound reuse, recycling, and/or disposal of computers."	(Case & Panciera, 2005, p.2)
"Take-Back Requirements— requiring the manufacturer to take back	(Case & Panciera,

computers after their useful life for environmentally sound reuse, recycling, and/or disposal.”	2005, p.2)
“WEEE makes manufacturers financially responsible for the take-back of their electronic products.”	(Case & Panciera, 2005, p.2)
“RoHS calls for the elimination of four metals (cadmium, mercury, lead, and hexavalent chromium) and two brominated flame retardants (PBBs and PBDEs).”	(Case & Panciera, 2005, p.2)
“Energy Star computers enter “sleep” mode after a period of inactivity, which allows them to remain on while saving energy. “	(Case & Panciera, 2005, p.2)
“Ask vendors to activate Energy Star power management features before delivery and provide any necessary technical support. “	(Case & Panciera, 2005, p.2)
“Eliminate or reduce hazardous, carcinogenic, and mutagenic substances in computers including, but not limited to: cadmium, chlorinated plastics, halogenated flame retardants, hexavalent chromium, lead, and mercury (such as those included in RoHS 1).“	(Center for a New American Dream, 2004, p.1)
“Reduce material use and utilize the greatest amount feasible of reused, remanufactured, and/or recycled materials/parts in computers.“	(Center for a New American Dream, 2004, p.1)
“Facilitate the recycling of computer components including, but not limited to: avoiding glues and welded connections, clearly labeling plastics, using universal fasteners (screws, snaps, etc.), using single resin plastics, and ensuring toxic components are easily separable.”	(Center for a New American Dream, 2004, p.1)
“Incorporate upgradeability features into computers including, but not limited to: modular design, expandable memory, owner transferability, and other features that extend the product life and simplify continued use beyond the original owner.”	(Center for a New American Dream, 2004, p.1)
“Use packaging and shipping material that contains reused and/or recycled material; is reusable and/or recyclable in the geographic region where the product is sold; and is collected by the vendor for reuse and/or recycling. Efforts should also be made to minimize the use of packaging and shipping material.”	(Center for a New American Dream, 2004, p.1)
“Meet the most up-to-date Energy Star specifications for computers, ship computers with all specified power management features enabled, and include all necessary information and technical support to ensure that equipment users can easily and simply install and maintain power management features on their equipment.”	(Center for a New American Dream, 2004, p.1)
“Minimize health risk to users including, but not limited to: ergonomic product design and reducing emissions during use (electrostatic fields, electric fields, magnetic fields, noise, etc.).”	(Center for a New American Dream, 2004, p.1)
“Comply with all applicable environmental regulations (e.g. the Montreal Protocol on Substances that Deplete the Ozone Layer), practice pollution prevention techniques that reduce waste and conserve energy and water, and strive for continuous environmental improvement (e.g. ISO 14001 certification).”	(Center for a New American Dream, 2004, p.1)
“Encourage all companies involved in production, distribution, and management of computers (component manufacturers, recyclers,	(Center for a New American Dream,

etc.) To observe environmental management practices such as having a green supply chain program, environmental management system, etc."	2004, p.1)
"Obtain credible eco-labels and third party certifications for products such as, but not limited to: TCO, Blue Angel, etc."	(Center for a New American Dream, 2004, p.1)
"Disclose the use of toxic materials in computers such as those on the OSPAR List of Chemicals for Priority Action 3 and Proposition 65 List."	(Center for a New American Dream, 2004, p.2)
"Provide technical support/training to users including, but not limited to, information on energy management features."	(Center for a New American Dream, 2004, p.1)
"More efficient processors, performance per watt."	(McGee, 2007, p.40)
"EPEAT, Energy Star, energy efficient equipment."	(McGee, 2007, p.40)
"Project Blackbox-a data center in a shipping container-not just portable but also 20% more energy-efficient than today's data center."	(McGee, 2007, p.41)
"Look for ENERGY STAR qualified office equipment, such as computers, copiers, and printers, in addition to more than 50 product categories, including lighting, heating and cooling equipment and commercial appliances. "	(Environmental Protection Agency, 2007a)
"Procuring energy efficient machines."	(L. Williams, 2007, p.1)
"IT hardware purchases are closely evaluated, taking into account the whole life costs, ensuring equipment is deployed to meet the needs of users efficiently,' says Amos. 'We take all factors into consideration when buying IT hardware, such as air conditioning, power consumption, usage patterns and unit life.'"	(L. Williams, 2007, p.1)
"Nationwide recently selected AMD processor-based desktop units over Intel, because of their lower unit power consumption when using standard office applications. 'We are exploring ways to maximize PC hibernation periods,' says Amos."	(L. Williams, 2007, p.1)
"The company has also largely eliminated CRT screens throughout the firm and replaced them with LCD screens, keeping large-size displays – either LCD, data projector and plasma – to a minimum."	(L. Williams, 2007, p.1)

Environmentally Sustainable Use Factors in the Data Center	**Citation**
"Dell, a big PC-maker, recently launched a scheme that allows its customers to plant trees to offset the carbon emissions generated by their computers."	("Going green," 2007, p.1)
"DigiPlex, a Scandinavian data-centre firm, boasts that locating servers in its Oslo facility is greener than elsewhere in Europe, since Norway generates 99% of its electricity from hydropower"	("Going green," 2007, p.1)

“The first is new “multi-core” processor chips, in which performance is improved not by increasing clock speed, but by building several processing engines, or “cores”, into each chip—a far more energy-efficient approach.”	("Going green," 2007, p.1)
“HP, for example, has devised a scheme called Dynamic Smart Cooling, which links temperature sensors installed on servers to air-conditioners so that blasts of cool air can be directed towards particular servers only when needed.”	("Going green," 2007, p.1)
“not making use of power saving strategies such as ‘sleep’ and ‘standby’ mode, and are active 24 hours per day, 7 days per week.”	(Adamson et al., 2005, p.10)
“We have defined the best-case scenario as all computers on campus having LCD energy saving monitors, new CPUs being ENERGY STAR certified, using energy saving techniques, and being active 8 hours per day, 5 days per week.”	(Adamson et al., 2005, p.10)
“To reduce the amount of power consumed by monitors, we recommend that power management options, which are available for the majority of monitors, be activated.”	(Adamson et al., 2005, p.52)
“For extended periods of non-use, such as over night or weekends, computer monitors which will be not be in use for these periods should be turned off completely.”	(Adamson et al., 2005, p.52)
“The implementation of power management.”	
“CPUs can reduce overall power consumption by an additional 40 to 90 W, a savings of about $45 per CPU each year (US EPA, 2005).”	(Adamson et al., 2005, p.52)
“A "thin-client" or "dumb terminal" system is a service that connects you to a big industrial-strength computer somewhere else.”	(Adamson et al., 2005, p.52)
“In facilities of all sizes, from small data centers housed in office buildings to large centers essentially dedicated to computer equipment, effective air distribution has a significant impact on energy efficiency and equipment reliability.”	(Greenberg et al., 1999, p.3)
“Short-circuiting of heated air over the top or around server racks.”	(Greenberg et al., 1999, p.3)
“Cooled air short-circuiting back to air conditioning units through openings in raised floors such as cable openings or misplaced floor tiles with openings.”	(Greenberg et al., 1999, p.3)
“Misplacement of raised floor air discharge tiles.”	(Greenberg et al., 1999, p.3)
“Poor location of computer room air conditioning units.”	(Greenberg et al., 1999, p.3)
“Inadequate ceiling height or undersized hot air return plenum.”	(Greenberg et al., 1999, p.3)
“Air blockages such as often happens with piping or large quantities of cabling under raised floors.”	(Greenberg et al., 1999, p.3)
“Openings in racks allowing air bypass (“short-circuit”) from hot areas to cold areas.”	(Greenberg et al., 1999, p.3)
“Poor airflow through racks containing IT equipment due to restrictions in the rack structure.”	(Greenberg et al., 1999, p.3)

"IT equipment with side or top-air-discharge adjacent to front-to-rear discharge configurations."	(Greenberg et al., 1999, p.3)
"Inappropriate under-floor pressurization - either too high or too low	(Greenberg et al., 1999, p.3)
Use of "hot aisle and cold aisle" arrangements where racks of computers are stacked with the cold inlet sides facing each other and similarly the hot discharge sides facing each other."	(Greenberg et al., 1999, p.4)
"Sealing cable or other openings in under-floor distribution systems."	(Greenberg et al., 1999, p.4)
"Blanking unused spaces in and between equipment racks."	(Greenberg et al., 1999, p.4)
"Careful placement of computer room air conditioners and floor tile openings, often through the use of computational fluid dynamics (CFD) modeling."	(Greenberg et al., 1999, p.4)
"Collection of heated air through high overhead plenums or ductwork to efficiently return it to the air handler(s)."	(Greenberg et al., 1999, p.4)
"Minimizing obstructions to proper airflow."	(Greenberg et al., 1999, p.4)
"Given that projections of IT equipment electrical requirements will remain an inexact science, it is nonetheless important to size electrical and mechanical systems such that they will operate efficiently while overall loading is well below design, yet be scalable to accommodate larger loads should they develop."	(Greenberg et al., 1999, p.4)
"Design for medium temperature chilled water (50-55°F) in order to eliminate uncontrolled dehumidification and reduce plant operating costs. Since the IT cooling load is sensible only, operating the main cooling coils above the dewpoint temperature of the air prevents unwanted dehumidification and also increases the chiller plant efficiency, since the thermodynamic "lift" (temperature difference) between the chilled water and the condenser water is reduced."	(Greenberg et al., 1999, p.5)
"Dehumidification, when required, is best centralized and handled by the ventilation air system, while sensible cooling, the large majority of the load, is served by the medium temperature chilled water system."	(Greenberg et al., 1999, p.5)
"Use aggressive chilled and condenser water temperature resets to maximize plant efficiency. Specify cooling towers for a 5-7°F approach in order to improve chiller economic performance."	(Greenberg et al., 1999, p.5)
"Design hydronic loops to operate chillers near design temperature differential, typically achieved by using a variable flow evaporator design and staging controls."	(Greenberg et al., 1999, p.5)
"Primary-only variable flow pumping systems have fewer single points of failure, have a low first cost (half as many pumps are required), are more efficient, and are more suitable for modern chillers than primary-secondary configurations."	(Greenberg et al., 1999, p.5)
"Thermal storage can offer peak electrical demand savings and improved chilled water system reliability. Thermal storage can be an economical alternative to additional mechanical cooling capacity."	(Greenberg et al., 1999, p.10)

"Use efficient water-cooled chillers in a central chilled water plant. A high efficiency VFD-equipped chiller with an appropriate condenser water reset is typically the most efficient cooling option for large facilities. The VFD optimizes performance as the load on the compressor varies. While data center space load typically does not change over the course of the day, the load on the compressor does change as the condenser water supply temperature varies. Also, as IT equipment is added or swapped for more-intensive equipment, the load will increase over time."	(Greenberg et al., 1999, p.10)
"For peak efficiency and to allow for preventive maintenance, monitor chiller plant efficiency. Monitoring the performance of the chillers and the overall plant is essential as a commissioning tool as well as for everyday plant optimization and diagnosis."	(Greenberg et al., 1999, p.10)
"Direct liquid cooling of components offers the greatest cooling system efficiency by eliminating airflow needs entirely. When direct liquid component systems become available, they should be evaluated on a case-by-case basis."	(Greenberg et al., 1999, p.10)
"Improved air management, emphasizing control and isolation of hot and cold air streams."	(Greenberg et al., 1999, p.11)
"Right-sized central plants and ventilation systems to operate efficiently both at inception and as the data center load increases over time."	(Greenberg et al., 1999, p.11)
"Optimized central chiller plants, designed and controlled to maximize overall cooling plant efficiency, including the chillers, pumps, and towers."	(Greenberg et al., 1999, p.11)
"Central air-handling units with high fan efficiency, in lieu of distributed units."	(Greenberg et al., 1999, p.11)
"Air-side or water-side economizers, operating in series with, or in lieu of, compressorbased cooling, to provide "free cooling" when ambient conditions allow."	(Greenberg et al., 1999, p.11)
"Alternative humidity control, including elimination of simultaneous humidification and dehumidification, and the use of direct evaporative cooling."	(Greenberg et al., 1999, p.11)
"Improved configuration and operation of uninterruptible power supplies."	(Greenberg et al., 1999, p.11)
"High-efficiency computer power supplies to reduce load at the racks."	(Greenberg et al., 1999, p.11)
"Such design principles include a central chilled water plant that utilizes centrifugal VFD chillers, variable speed pumping, VFD cooling tower fans, condenser water temperature reset strategies, central air handlers, no or little humidity control, outside air economizing, gravity damper exhaust (without return fans), high ceiling and return. In addition to the presence of efficient equipment, extensive monitoring is done by the EMCS, and features such as "gateway" from the chiller control panel, and VSD control panels are present. Furthermore, the EMCS software has block programming that is easily accessible from the interface, allowing for real time adjustment of control variables, such as	(Lawrence Berkeley National Laboratory, 2003, p.28)

valve tuning parameters."	
"McNealy has long been championing Sun's "thin-client" strategy, in which individuals log on to a server that contains, in effect, their desktop, including all of their programs and documents, just the way they left them."	(Makower, 2005, p.2)
"Power management can only save energy if it is enabled and working properly."	(Nordman et al., 1997, p.9)
"The energy saving potential from reducing PC power consumption is enormous, from turning off those that don't need to be on, and from power managing PCs when they are on, but idle."	(Nordman et al., 1997, p.10)
"Spend some IT dollars on removing legacy servers,"	(Parkinson, 2007, p.2)
"Proper installation of the hot aisle, cold aisle must take place."	(Parkinson, 2007, p.2)
"Additionally, steps should be taken to seal off cable cutouts and holes in the perimeter walls and the raised floors."	(Parkinson, 2007, p.2)
"A reduction of the bypass airflow - the air not getting to the server - should be reduced to below 10%, and not be as high as that 60% figure from the Uptime survey."	(Parkinson, 2007, p.2)
"Computers used by U.S. businesses and government offices are left humming after hours, and that sleep mode has been disabled or is not functioning on 40 percent of monitors and 75 percent of computers."	(Rutherford, 2001, par.2)
"Also important, a growing body of data shows that efficiency is associated with a healthier and higher quality workplace environment, especially regarding the use of outside make-up air."	(Shamshoian et al., 2005, p.3)
"Institute an energy management program, integrated with other functions (risk management, cost control, quality assurance, employee recognition, training)."	(Shamshoian et al., 2005, p.22)
"Evaluate the potential for energy-efficient on-site power generation, including combined heat and power technologies."	(Shamshoian et al., 2005, p.22)
"Ensure that all facility operations staff are provided with site-specific training that includes identification and proper operation of energy-efficiency features."	(Shamshoian et al., 2005, p.22)
"Environmental Protection Agency's Green Lights Program, which offers companies technical expertise while committing them to a set of energy-efficient lighting improvements."	(S. T. Anderson & Newell, 2004, p.2)
"Power-economizer modes should always be selected to ensure more efficient operation of the server."	(The Green Grid, 2007d, p.5)
"New best-in-class UPS systems have 70% less energy."	(The Green Grid, 2007d, p.5)
"Close-coupling targets specific areas where cooling is needed (such as an individual row,rack, or server) as opposed to a large open."	(The Green Grid, 2007d, p.5)
"Proper location of vented floor tiles."	(The Green Grid, 2007d, p.10)
"Installation of a close-coupled cooling architecture."	(The Green Grid, 2007d, p.10)
"Deployment of server virtualization."	(The Green Grid, 2007d, p.10)

"Installation of energy-efficient lighting."	(The Green Grid, 2007d, p.10)
"Installation of blanking panels."	(The Green Grid, 2007d, p.10)
"Efficient server consolidation practices."	(The Green Grid, 2007d, p.10)
"Utilization of air conditioner economizer modes."	(The Green Grid, 2007d, p.10)
"Coordination of air conditioners."	(The Green Grid, 2007d, p.10)
"Proper configuration of server software."	(The Green Grid, 2007d, p.10)
"This new IT facilities group is a separate group from the traditional "building" facilities group. The IT facilities group acts as a liaison between IT and the facilities building group, but is under the direct control of IT."	(The Green Grid, 2007d, p.10)
"The short-circuiting of cooled air back to air-conditioning units through openings in raised floors, such as cable openings and misplaced floor tiles with openings configurations."	(Tschudi, Mills, Greenberg, & Rumsey, 2006, p.5)
"Misplaced raised-floor air-discharge tiles."	(Tschudi et al., 2006, p.5)
"Poorly located computer-room airconditioning (CRAC) units."	(Tschudi et al., 2006, p.5)
"Inadequate ceiling height or an undersized hot-air-return plenum. Benchmarking Air blockages, which are common with piping and large amounts of cabling under raised floors."	(Tschudi et al., 2006, p.5)
"Openings in racks that allow air bypass ("short-circuiting") from hot areas to cold areas or vice versa."	(Tschudi et al., 2006, p.5)
"Poor airflow through IT-equipment racks caused by restrictions in rack structure."	(Tschudi et al., 2006, p.5)
"Inappropriate—either too high or too low—underfloor pressurization."	(Tschudi et al., 2006, p.6)
"Sealing openings in underfloor systems."	(Tschudi et al., 2006, p.6)
"Blanking unused spaces in equipment racks."	(Tschudi et al., 2006, p.6)
"Collecting heated air through high overhead plenums or ductwork and efficiently returning it to the air handler(s)."	(Tschudi et al., 2006, p.6)
"Water-side economizers utilizing evaporative cooling (usually provided by cooling towers) can be used to indirectly produce chilled water to cool a data center when outdoor conditions are mild or at night."	(Tschudi et al., 2006, p.6)
"A centralized air-handling system can take advantage of surplus and redundant capacity, improving efficiency."	(Tschudi et al., 2006, p.6)
"It is nonetheless important to size electrical and mechanical systems so that they will operate efficiently when overall loading is well below design and yet be scalable to accommodate larger loads."	(Tschudi et al., 2006, p.6)

"Businesses have implemented various types of programs to reduce energy use. The most popular programs include: installing energy-efficient lighting systems (80%)."	(Business Environmental Alliance, 2006), p.9
"Placing thermostats on timers (76%)."	(Business Environmental Alliance, 2006), p.9
"Using energy-efficient computer monitors/office equipment (55%)"	(Business Environmental Alliance, 2006), p.9
"Using energy-efficient HVAC systems (48%)."	(Business Environmental Alliance, 2006), p.9
"Information programs, which seek to encourage energy efficiency by increasing aware-ness of conservation opportunities and offering technical assistance with their implementation, are an important element of this energy-efficiency policy portfolio."	(S. T. Anderson & Newell, 2004, p.2)
"Other practices include: unplugging electronic equipment when not in use."	(Business Environmental Alliance, 2006, p.9)
"Installing solar electric systems."	(Business Environmental Alliance, 2006, p.9)
"Installing motion sensors."	(Business Environmental Alliance, 2006, p.9)
"Installing appliances that automatically shut off when not in use."	(Business Environmental Alliance, 2006, p.9)
"Opening windows to cool/ventilate rather than use A/C."	(Business Environmental Alliance, 2006, p.9)
"By going through the process of writing an environmental policy statement, companies have found ways to reduce their overhead and boost their bottom line."	(Business Environmental Alliance, 2006, p.14)
"Half of the responding companies incorporated environmental criteria in the selection of goods and services."	(Business Environmental Alliance, 2006, p.14)
"Almost two-thirds (65.6%) of responding companies encourage their employees to participate in and suggest improvements in the company's environmental policies and practices."	(Business Environmental Alliance, 2006, p.15)
"Through an open management attitude toward employee suggestions and willingness to implement any policy that will help protect the environment."	(Business Environmental Alliance, 2006, p.15)
"The distribution of articles about resource management as part of the training process."	(Business Environmental Alliance, 2006, p.15)

“Employers encourage employees to share conservation ideas via email.”	(Business Environmental Alliance, 2006, p.15)
“Environmental issues are part of an annual evaluation process that includes meetings and training.”	(Business Environmental Alliance, 2006, p.15)
“Learning about sound environmental practices is apart of the employee training program.”	(Business Environmental Alliance, 2006, p.15)
“Staff meetings and specific environmental forums highlight the advancements in environmental strategies.”	(Business Environmental Alliance, 2006, p.15)
“Committees make recommendations for products or purchases that use recyclable materials and otherwise “green” products.”	(Business Environmental Alliance, 2006, p.15)
“Recycling and energy-saving programs and devices are regularly instituted in response to employees’ suggestions.”	(Business Environmental Alliance, 2006, p.15)
“Currently, waste reduction is an area in which almost all companies have some kind of program in place; followed by energy conservation.”	(Business Environmental Alliance, 2006, p.17)
“. . .using more efficient cooling systems.”	(Varon, 2007b, p.34)
“. . .sealing holes in your data center’s floor.”	(Varon, 2007b, p.34)
“Virtualize projects and consolidate servers.”	(Overby, 2007a, p.40)
“Improve utilization.”	(Overby, 2007a, p.41)
“Deploy virtual machines. Virtual servers save energy by enabling greater utilization of CPU capacity.”	(Overby, 2007a, p.42)
“Use cleaner power. Factor the source of electricity into decisions to site new data centers. For example, hydroelectric power generates fewer emissions- and costs less- than power plants run on fossil fuels.”	(Overby, 2007a, p.42)
“When the computer will not be used for an extended period of time—overnight, for example—it is more energy efficient to turn computers off.”	(Case & Panciera, 2005, par.20)
“To keep servers from overheating, data centers typically have air-conditioning units that push cool air up through holes in floor tiles. That air is sucked in through vents in the front of servers, pushed by fans through the circuitry and out the back of the systems. Ceiling intakes remove the hot air and recirculate it.”	(Clark, 2005, p.3)
“Server virtualization, grid computing, multicore processors, improved cooling, aggressive use of blade servers.”	(McGee, 2007, p.44)
“Power-supply appliances that more efficiently transfer power to servers.”	(McGee, 2007, p.41)
“Building materials such as tiles with air holes that help with cooling.”	(McGee, 2007, p.44)
“Virtualization. . .by dividing each server into multiple virtual machines that run different applications.”	(McGee, 2007, p.44)
“Telecommute.”	(McGee, 2007, p.44)

"Videoconference to cut corporate travel."	(McGee, 2007, p.44)
"Replacement of the building 's humidification systems (with heat recovery in the vivarium wing), stabilization and improvement of the building control system, installation of a Web-based utility metering system, replacement of cooling coils."	(Environmental Protection Agency, 2006a, p.6)
"Resetting of laboratory air flow levels to Agency standards (they had been operating at higher flows) and replacement of the building cooling towers."	(Environmental Protection Agency, 2006a, p.6)
"Top 10 target areas, which included: boilers, air handling units, steam traps, chillers, cooling towers, building automation systems, pumps, fans, air compressors, and lighting."	(Environmental Protection Agency, 2006a, p.9)
"Actions to reduce lighting loads, and adjustment of building automation system (BAS) set points."	(Environmental Protection Agency, 2006a, p.10)
"In addition, a number of facilities reported increasing outreach to employees to raise awareness of energy efficiency and banning the use of personal heaters."	(Environmental Protection Agency, 2006a, p.10)
"EPA recommissioned the office side air handlers, implemented a nighttime setback in the office areas, and recommissioned the BAS. Opportunities identified in the core computing center include rearranging equipment and heat loads and subsequent optimization of cooling."	(Environmental Protection Agency, 2006a, p.10)
"To save energy and reduce greenhouse gas emissions at work, always activate the power management features on your computer and monitor."	(Environmental Protection Agency, 2006a, p.10)
"Unplug laptop power cords when not in use and turn off equipment and lights at the end of the day."	(Environmental Protection Agency, 2007a)
"Consider using a power strip that can be turned off when you're done using your computers, printers, wireless routers and other electronics."	(Environmental Protection Agency, 2007a)
"You cannot fill a rack with servers now, we are only filling them two-thirds full – which is about six or seven kilowatts – because that is all we can traditionally air cool,' he says."	(L. Williams, 2007, p.1)
"Provision for water cooling in case it needs to pack the cabinets more densely – meaning the building had to have a pre-strengthened floor and specialist plumbing system."	(L. Williams, 2007, p.1)
"Each 25-watt screen is now switched off at least 50 per cent of the week."	(L. Williams, 2007, p.1)
"By taking the technology out of the dealing room and putting it into a computer room, with racks, it is a more efficient model because heat and cooling is concentrated in one place,' says Walker."	(L. Williams, 2007, p.1)
"And our computing equipment is being made more energy efficient by exploiting new low-power technologies and enabling power saving features."	(L. Williams, 2007, p.1)
"There is, he says, a role for IT in helping to reduce greenhouse gases	(L. Williams, 2007,

through hardware hibernation, monitoring energy use, asset management and better control of heating systems."	p.1)
"IT departments are examining paper use, data warehouse energy consumption, and cutting down travel by exploring collaborative working technologies like instant messaging – all these technologies cut costs and help the environment. It is a win-win situation."	(L. Williams, 2007, p.1)

Environmentally Sustainable Disposal Factors in the Data Center	Citation
“Reducing the amount of computer waste relies heavily upon the reuse of systems that may be out of date, but fully functional.”	(Adamson et al., 2005, p.26)
“Reselling old computers is another way to extend a working PC’s lifespan, however, many re-sell agents only accept the newest generation of equipment.”	(Adamson et al., 2005, p.26)
“Upgrading a computer in order to suit current technology is a choice often made only by computer specialists or hobbyists, due to the fact that user knowledge is required and full upgrades can be costly.”	(Adamson et al., 2005, p.27)
“Keeping detailed records of working computers, as well as those which have been removed for disposal, and their current locations, would allow IT and office managers to further track their machines and divert them into the on-campus disposal system, rather than allow them to simply “disappear” in storage.”	(Adamson et al., 2005, p.60)
“It is recommended that on-campus computers, which are still fully functional (both CPU and monitor) be donated to such programs as Computers for Schools, so that they may continue to provide service for libraries, school and non-profit organizations.”	(Adamson et al., 2005, p.61)
“The best way to recycle a computer, however, is to keep it and upgrade it.”	(Faludi, 2006, pg 14)
“Reduce the amount of waste generated.”	(Griffin, 2005, p.1)
“Reuse products.”	(Griffin, 2005, p.1)
“Recycle products or components.”	(Griffin, 2005, p.1)
“First, it could be reused. This means that it is somehow used again after becoming obsolete to the purchaser– possibly a result of being resold or reassigned to another user without extensive modification.”	(Matthews et al., 1997, p.3)
“Second, the computer could be stored by the original owner. In this case, it is serving no purpose except to occupy space.”	(Matthews et al., 1997, p.3)
“Third, the computer could be recycled. We define this to mean that the product is taken apart and individual materials or subassemblies are sold for scrap. (Recall our earlier comments about recycling firm activities).”	(Matthews et al., 1997, p.3)
“Product take-back is an emerging international paradigm which requires that firms organize methods to reclaim their products at the end of their useful life.”	(Matthews et al., 1997, p.6)
“Endorsing such a program could be as simple as adding a line in user manuals or attaching stickers to all new computers informing users (a majority of whom are replacing equipment) of the value in recycling obsolete electronics while still valuable.”	(Matthews et al., 1997, p.10)
“Sharing multiple applications on servers.”	(Matthews et al., 1997, p.10)
“The Zurich-based financial services company names specific employees to work with approved e-waste processors, says Urs	(Pratt, 2007, p.1)

Peter Steiger, risk management lead associate.”	
“UBS also tracks its waste, so it knows exactly what has been refurbished for the secondary market and what has been stripped down and recycled.”	(Pratt, 2007, p.1)
“19% said they donate their unwanted PCs to schools or nonprofit organizations. Good intention; bad policy, says O’Brien. Your company could be responsible if the nonprofit improperly disposes of the donated equipment or inadvertently releases sensitive data still residing on the equipment.”	(Pratt, 2007, p.1)
“Other items that need special attention include cell phones and handheld devices, as well as routers and even copiers, which today have memory that can contain sensitive information.”	(Pratt, 2007, p.2)
“Companies that want to protect themselves in this area know they have to have a good asset management strategy.”	(Pratt, 2007, p.3)
“E-waste program implementers expressed a need for a mechanism to ensure that recyclers are handling materials in an environmentally responsible manner.”	(California Integrated Waste Management Board, 2004, p.10)
“Although a certificate does not relieve cradle-to-grave liability, it can help protect your organization. This documentation provides an audit trail that traces e-waste from the collection site to the final processing facilities, including the dates of processing and the management methods utilized.”	(California Integrated Waste Management Board, 2004, p.10)
“Third party environmental audits are a valuable tool for businesses to help minimize liability, avoid compliance costs associated with new projects, and find opportunities for improved operating practices.”	(California Integrated Waste Management Board, 2004, p.11)
“The average life of an IT product in Europe is 10 years. However, its 'first use' life may be as short as two years, and this is likely to decrease even further. This significantly exceeds its shelf life that can be as little as one year. It is also double its viable life without upgrading. Barely 25% of products shipped 10 years ago are finding their way into the waste stream.”	(The Institution of Engineering and Technology, 2006, p.11)
“Electronics retailers now commonly offer bins for the recycling of old cell phones and batteries.”	(N. Anderson, 2006, p.1)
“Certificates of recycling/destruction are not regulated documents and are only as good as the information they contain. Although a certificate does not relieve cradle-to-grave liability, it can help protect your organization. This documentation provides an audit trail that traces e-waste from the collection site to the final processing facilities, including the dates of processing and the management methods utilized.”	(California Integrated Waste Management Board, 2004), 11
“Provide take-back and end-of-life management services that ensure computers are reused (preferable) and/or recycled to the greatest extent feasible in a way that minimizes harm to the environment and human health. Toxic elements should not be sent to municipal solid waste (non-hazardous waste) landfills or incinerators.”	(Center for a New American Dream, 2004, p.1)

"Do not send hazardous waste to developing countries for disposal or recycling in accordance with the Basel Convention. This does not include working equipment, parts, or materials intended for reuse or resale. Equipment, parts, and materials may be sent to developing countries for repair only if assurances can be made that hazardous components will not be disposed of in developing countries as a result."	(Center for a New American Dream, 2004, p.1)
"Disclose how taken-back computers are handled, reused, repaired, recycled, and/or disposed."	(Center for a New American Dream, 2004, p.1)
"Meet high standards of worker protection in both the United States and overseas. This includes employment practices that protect workers from hazardous exposures and that enable employees to take action to protect their own health."	(Center for a New American Dream, 2004, p.1)
"Hire a 3rd party company to erase data from drives and remove asset tags and other forms of corporate ID then refurbish for resale or grind them up to recycle the material."	(McGee, 2007)
"One way to find a place to send or take unwanted televisions or CRT computer monitors is to check DTSC's list of CRT handlers who have submitted notifications. Anyone who accepts more than five CRT devices from off site in a calendar year is required to notify DTSC."	(Department of Toxic Substance Control, 2006)
"Some UWED material handlers who have notified DTSC of their activities have also applied to the California Integrated Waste Management Board (CIWMB) to be Approved Collectors under the Electronic Waste Recycling Act. CIWMB maintains a list of Approved Collectors and Approved Recyclers of CRT materials and Universal Waste Electronic Devices (UWEDs) on its Web site. http://www.ciwmb.ca.gov/Electronics/Reports/ApprovedSearch.aspx"	(Department of Toxic Substance Control, 2006)
"This guideline applies to designated materials that are directed to reuse or refurbishment. However, it is only intended to apply to those shipments of designated materials (such as the following intact equipment: monitors, televisions, CRT bulbs, CPUs, laptops, printers"	(Environmental Protection Agency, 2006b), p.5
"Plug-In partner" means a manufacturer, retailer, government agency, non-profit, or other entity who (1) is not a recycler nor performs recycling activities (other than collection), (2) through contracts or other arrangements, utilizes reuse, refurbishment, recycling or disposal services, and (3) has a Plug-In To eCycling partnership agreement with EPA."	(Environmental Protection Agency, 2006b), p.8
"GreenDisk program to recycle "technotrash,"	(Environmental Protection Agency, 2006a), p.32
"The Recycling Electronics and Asset Disposition Services (READ) and Computers for Learning Program (CFL) continue to be effective methods for EPA to properly recycle electronics."	(Environmental Protection Agency, 2006a), p.33

"For your old electronics, investigate leasing programs to ensure reuse and recycling or donate used equipment to schools or other organizations. "	(Environmental Protection Agency, 2006a), p.33

Appendix C: Definition of Terms

Content analysis: Content analysis is a research tool used to determine the presence of certain words or concepts within texts or sets of texts (Palmquist et al., 2005).

Data center: The computer-equipped, central location within an organization. The data center processes and converts information to a desired form such as report or other types of management information records (Goleniewski, 2003).

Ecological footprint: The inverse of carrying capacity, the ecological footprint quantifies the average amount of land needed per person to provide the resources and ecosystem services used in the data center (Hitchcock & Willard, 2006, p. 92).

Efficiency: effective operation as measured by a comparison of production with cost (as in energy, time, environmental impact and money) (Merriam-Websters, 2007)

Energy efficiency: efficient generation, transmission and use of electricity and natural gas as measured by a comparison of production with cost (as in energy, time, environmental impact and money) (Merriam-Websters, 2007; Nadel, 2006).

Energy Star Program: In 1992 the US Environmental Protection Agency (EPA) introduced ENERGY STAR as a voluntary labeling program designed to identify and promote energy-efficient products to reduce greenhouse gas emissions. Computers and monitors were the first labeled products. Through 1995, EPA expanded the label to additional office equipment products and residential heating and cooling equipment (Environmental Protection Agency, 2007b).

Environmental management system (EMS): A tool used by a company to identify measure and manage the effects of its activities on the environment (Whitehouse, 2005).

Environmentally Sustainable disposal: reuse of electronic equipment and components, recycling equipment and components for material recovery, management for energy recovery, and finally, disposal of materials (California Integrated Waste Management Board, 2004).

Environmentally Sustainable purchasing: a procurement process that has as it's fundamental objective the reduction of total cost of ownership as it relates to your ecological footprint (Case & Panciera, 2005).

Environmentally Sustainable use: improving facility systems' efficiency, improving the interface between building systems and IT equipment, and improving the efficiency of IT equipment (Tschudi, Xu, Sartor, & Stein, 2004).

Environmental sustainability: encompasses a wide range of issues from pollution to natural resource management challenges and institutional capacity. It requires attention to the past, the present, and the future (Esty et al., 2005).

Green: Environmentally friendly or sustainable (Stapleton & Glover, 2001).

Green data center: All of the mechanical, electrical and computer systems were selected for maximum energy efficiency (Parkinson, 2007)

Information technology (IT): Any equipment or interconnected system or subsystem of equipment, that is used in the automatic acquisition, storage, manipulation, management, movement, control, display, switching, interchange, transmission, or reception of data or information. The term information technology includes computers, ancillary equipment, software, firmware and similar procedures (United States Access Board, 2000).

Information technology (IT) managers: Information systems managers plan and coordinate activities such as installation and upgrading of hardware and software, programming and systems design, development of computer networks, and implementation of Internet and intranet sites. They are increasingly involved with the upkeep, maintenance, and security of networks. They analyze the computer and information needs of their organizations from an operational and strategic perspective and determine immediate and long-range personnel and equipment requirements (U.S. Department of Labor, 2006).

ISO 14000: A series of standards emitted or being prepared by the International Standards Organization (ISO), covering a number of environmental topics. ISO 14000 is a system for navigating and controlling environmental impact through reduced waste and resource consumption (Johnson, 1997).

Literature review: From the collected literature, the researcher evaluates, organizes, and synthesizes what others have done related to one's own investigation (Leedy & Ormrod, 2005).

Management information systems (MIS): Manage information systems and computing resources for their organizations. These managers oversee a variety of user services such as an organization's help desk, which employees can call with questions or problems. MIS directors also may make hardware and software upgrade recommendations based on their experience with an organization's technology. Helping ensure the availability, continuity, and security of data and information technology services is the primary responsibility of these workers (U.S. Department of Labor, 2006).

Recycling: Recycling is a series of activities that includes reusing, refurbishing, donating or collecting recyclable materials that would otherwise be considered waste, sorting and processing recyclables into raw materials such as fibers; manufacturing raw materials into new products or (Environmental Protection Agency, 2004, 2007c).

Small to medium size enterprises (SME): The threshold of 500 employees guides the classification of small and medium-size enterprises (SMEs) in Canada, Mexico and the United States (Whitehouse, 2005).

Supply Chain: Whereas marketing channels connect the marketer to the target buyers, the supply chain describes a longer channel stretching from raw materials to components to final products that are carried to final buyers (Kotler & Keller, 2006).

Sustainability: Meeting our needs while not compromising the ability of future generations to meet theirs (Bruntland, 1987).

System: Computer hardware and its associated devices and programs (Goleniewski, 2003).

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