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An Economic Analysis of

Regular vs. Green Data Servers

Team Chester

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1.Introduction

Information Technology has grown at a rapid pace in parallel with the evolution of computer technology and sky-rocketed after the passing of the millennium. The millennium launched the rise of web 2.0, social media, and information that revolutionized communication. According to some, information will become the oil of the 21st Century [1]. Business, organizations, public sectors, and government increasingly rely on computational and network infrastructure for operations, information storage, and retrieval. The widespread usage of IT is not the only trend that exploded after the millennial transition, a new threat emerged and rippled globally as a major international problem - climate change has become global concern. The impact of climate change has gradually been disrupting the way business, organization, and government are operating. The effect of climate change initiated a paradigm shift towards green and sustainable solutions that push organizations to pay attention to corporate responsibility, pollution, waste, toxins, and carbon footprints. The push towards greener, more ecological and sustainable solutions has infiltrated into the field of IT and introduces the growing practice of Green IT [2].

Since the advent of computer systems, performance has been the key purchasing argument for customers. However, high performance often comes in exchange of consuming of more power. In 2005, Information and Communication Technology (ICT) was accountable for 3 percent of global electricity usage. Data centers in particular are a major concern as half of the IT-related electrical costs are generated there [3]. The ever-growing demand for higher performance and increased reliance on the storage, backups, transfer, and processing of digital information caused significant growth in power consumption of data centers and electricity bills became a major expense. Power is not only needed for servers in data centers, it is also needed for technologies such as storage devices, networking controllers, uninterrupted power supplies and air conditioning. In 2005, the power and cooling expenses for data servers was 1.2% of total US electricity consumption, an amount comparable to that for color television [4]. In the same year, the total electricity bill for data servers was about $2.7B in US and $7.2B worldwide.

Reducing electricity consumption has gained a lot of attention by different organizations including hardware vendors, lawmakers, and performance benchmark organizations. In 2006, the

US House of Representatives adopted bill HR 5646 which calls for additional research in reducing power consumption in computer servers and data centers [5]. The bill directs the Environmental Protection Agency (EPA) to identify the potential energy savings to the federal government and includes direction from Congress that buying energy efficient servers is in the United State's interests. Such initiatives from government along with the IT electricity consumption crisis added a new item into many corporations' agenda: to adopt environment friendly IT practices and make their IT "Green". There are many methods to build a Green IT infrastructure that will be discussed in following sections.

The current study is focused on comparing the capitalized worth of a regular data server and an equivalent green one. The study used the capacity of the existing data servers in the Engineering building of Portland State University as the baseline scale.

2.Green IT

The target of Green IT is similar to Green Chemistry. In the production cycle, energy use follows the maximized efficiency, reduced use of hazardous materials, and increased recycling of waste products. However, Green IT wants to follow a solution of reducing electricity, decreasing power consumption, and maintaining IT operations. Green IT is becoming a trend of sustainable development for a variety of companies and organizations in the software development industry. There are several reasons:

1. **Saving money:** Power management software can cut energy costs for each computer. On the other hand, it can save millions of dollars for a company. Green IT can use fewer watts to reach the same efficacy; it also reduces energy on powering devices that are not in use, and thus saves on power bills. When computers are in idle mode, less energy is used.
2. **Energy consumption:** There are two main energy hungry components in IT, servers and cooling systems. With increasing demand in IT-based transactions, the number of servers is increasing and power consumption continues to rise. Energy-efficient servers can spend less energy; they also decrease heat dissipation and carbon emissions, reducing the

extra energy for cooling system which is often the main source of electricity consumption in server rooms.

3. **Risk of energy shortages**: In certain environments, such as the developing world, public utility energy itself is not always available on a reliable basis. This can cause cost of operating a business to rise. Reducing energy consumption minimizes risk and simplifies management of this resource.
4. **Environmental protection:** An ever-growing demand on higher performance also speeds up the replacement rate for technology products. Green products are more environmentally friendly to produce and are often made from recyclable materials.

Green IT is a broad concept and is spread out in various subsections of IT. The main focus of our research is the specified subcategories of data mining, focusing on technological establishment of network server infrastructure of data mining; primarily on the set of server hardware, software, and construction with a green, sustainable focus. Depending on the complexity of the infrastructure, a server can consume a massive amount of power to maintain steady operations. Server equipment also quickly depreciates over time leading to technological obsolescence and forced replacement. Conventional server infrastructure contributes to the existing problem of carbon footprints, excessive waste of physical resources and energy, and equipment that contains hazardous toxic chemicals. Such factors increase carbon footprints and this toxicity can potentially leak into ecosystem when disposed of inappropriately.

The lifecycle in conventional servers can currently be described as unsustainable with “cradle-to-grave” calculations. Green IT introduces strategies, and principles to prevent such catastrophes from deepening the threat of ecological pollution and contributing to climate change.

The main goal behind Green IT server infrastructure is to focus on reducing power consumption as much as possible, which can greatly cut costs for powering servers as well as reduce the carbon footprints of the power grid [6]. Secondary focus with Green IT servers is the end of the lifecycle of the server equipment, finding strategies on reusing or recycling server parts, avoiding filling landfills and eliminating chemical leaks into the ecosystem. Green IT thrives to focus on “cradle-to-cradle” lifespan whereby once server equipment has reached obsolescence and no longer meets the intended needs it can be re-used for another purpose or recycled. Combined with principles from sustainability, Green IT focuses on the strategies to reduce carbon footprints along with the triple bottom line[1] while maintaining steady operations for businesses, government, and organization.

Standards in Green IT – Environmental Regulations

Server computers are composed of multiple components but involve primarily electrical and electronic equipment. When looking into building Green IT servers, there are various components that are considered for selection that meet various international standards. European and the United States have different standards as required by regulations, with a different focus in each country. The United States has implemented several standards where the primary focus is on energy efficiency [6].

EPEAT (Electronic Product Environmental Assessment Tool) form by The Electronic Green Council is a voluntarily standard for organizations unless products are sold to US Government agencies. EPEAT provides requirement criteria of energy efficiency for computers, servers, notebooks, components, and monitors. EPEAT is continually growing with environmental ratings and certification for greater efficiency for greener computer and electronic devices and to promote organizational sustainability and greener performance [7].

Energy Star 4.0 is a set of standards introduced by the U.S Environment Protection Association (US EPA) and the U.S Department of Energy (USDOE) for power supplies in computers and electronic devices to operate on different modes such as standby or sleep modes for computers and notebooks, and idle modes for hard drives and electric devices to reduce energy consumption. The Energy Star label indicates higher efficiency which reduces greenhouse gas emission and pollution that results from inefficient use of energy. The label aids consumers to locate and identify energy efficient products for purchase [16].

RoHS (Restriction of Hazardous Substances) is sponsored by the European Union which focuses on elimination of toxic chemical substances that threatens both people and their environment. The RoHS standard applies regulations and limitations on the use of lead, mercury, cadmium, hexavalent chromium, poly brominated biphenyl (PBB), and polybrominated diphenyl

[1] Triple Bottom Line (TBL) stands for People, Planet, and Profit, is a framework to measure sustainability and performance.

ether (PBDE) flame retardants in electrical and electronic equipment. RoHS establishes regulations in Europe that require compliance for electrical and electronic product to clearly document the tested results. [7]

WEEE (Waste Electrical and Electronic Equipment) is sponsored by the European Union and establishes that a manufacturer collects their product free of charge when a product is at its lifespan or ready to be disposed of. The regulation establishes encouragement for recycling and reduces pollution and waste. Electrical and electronic devices and IT and telecommunication devices are also under the directive of WEEE. [17]

3.Our Approach

As discussed in the previous section there are various methods to make data servers green. Our team looked into the current capacity of data servers in Portland State's Engineering Building and did a cost analysis on the regular data server (similar to current setup in the Engineering building) vs. a theoretical "Green" data server with the same capacity.

PSU CAT Data Servers

PSU's Engineering Server consists of a total capacity of 150 Terabytes (TB) in 6 server computers. 4 SATA (Serial Advance Technology Attached) and 2 SAS (Serial Attached SCSI) drives are shared with 5,000 students. Each student is granted approximately 7 Gigabytes (GB) of space. SATA hard disks are less expensive compared to SAS disks but have lower speeds. SATA hard disks are used for passive storage and backups while SAS disks are used when more real-time access to students' data is required i.e. when students are browsing the Internet and need to save or load bookmarks.

Based on PSU Engineering Department server use as a model, the capacity was converted to 2013 technology and costs. The same process was done with a 126 TB and 24 TB SAS green server version using energy-efficient hardware and green server components.

Table1 shows the current capacity of SAS and SATA had disks at Engineering Building. Figure 1 shows a regular setup based on today's available components to provide the same SATA and SAS capacity. Four servers are needed to provide 126 TB SATA capacity and two servers are required to provide 24 TB SAS capacity.

Table 1 Current Hard Disk Capacity at Engineering Building

Hard Disks	Total Capacity
4 SATA Servers	126 Terabytes (TB)
2 SAS Servers	24 Terabytes (TB)

Heavy Duty SATA Regular Server			
Components	**Specs**	**Prices**	**Comments**
Steel Server Case	2u size, 12 HDD, 4 80mm Fans, OEM	$250.00	Habey ESC02122C 12 Bay 3.5
Server Power Suppy	80Plus, 300W x 2	$94.00	80Plus = Certified Energy Efficiency
Server Motherboard - Supermicro x9SRI-3F	E5-2670 Xeon, onboard Video, fan speed controller, LGA2011	$360.00	12x SATA 3.0Gb/s
Intel E5-2650 x 2	8 Core, 32nm, 2.0GHZ, Hyperthread, virtualization tech, 95W	$2,280.00	Total 190W
1u Server Heatsinkx x 2	Copper Heatsink, 70mm,	$64.00	
Standard ECC DDR3 x 4	4 x 8 = 32 Gigs Ram, 1.5V	$440.00	
SATA Regular HDD x 12	3TB x 12 = 24TB	$1,668.00	10.5W x 12 = 72W, Idle Watt = 0.75 x 6 = 4.5W
Server Total Cost		$5,156.00	
CAT SATA server = 126 TB	# Equivilent Green SATA server of 128TB	4	
		$20,624.00	
Heavy Duty SAS Server			
Steel Server Case	2u size, 12 HDD, 4 80mm Fans, OEM	$70.00	
Server Power Suppy	80Plus Gold, 600W, OEM	$94.00	
Server Motherboard - Supermicro	E5-2670 Xeon, onboard Video, fan speed controller, LGA2011	$340.00	
Intel E5-2650 x 2	8 Core, 32nm, 2.0GHZ, Hyperthread, virtualization tech, 95W	$2,280.00	
1u Server Heatsinkx x 2	Copper Heatsink, 70mm,	$64.00	
ECC Standard DDR3 x 4	4 x 8 = 32 Gigs Ram, 1.5V, 40nm	$440.00	
Seagate SAS 500GB Sata	500GB x 12 = 3TB	$2,256.00	Active = 11.5W x 12 = 9.2W
Server Total Cost		$5,544.00	
CAT SAS Server = 24 TB	# Equivilent Green Servers of 24TB	4	
		$22,176.00	

Figure 1 - Regular server specs for 126TB SATA and 24TB SAS HDDs

Our team compared the costs of a regular data server with the same hard disk specs as above, which is similar to the current servers in the PSU Engineering Building, and using Green IT concepts proposed an equivalent green setup.

4.Designing Green Data Servers

Green IT Server Hardware and Components

Server Case and Heat-sink

Computer technology evolves at a rapid pace through continual innovation. As the server has become a commodity product over time, Green IT practices now involve the implementation of Cradle to Cradle methodologies. Cradle to Cradle implies that once a product is at the end of its operable lifespan, all components can be reused or recycled. Old components can be used with new hardware, or can be recycled to make into new products [8]. For our green server, steel server cases and copper heat sinks were selected with the possibility of the material being reusable and recyclable.

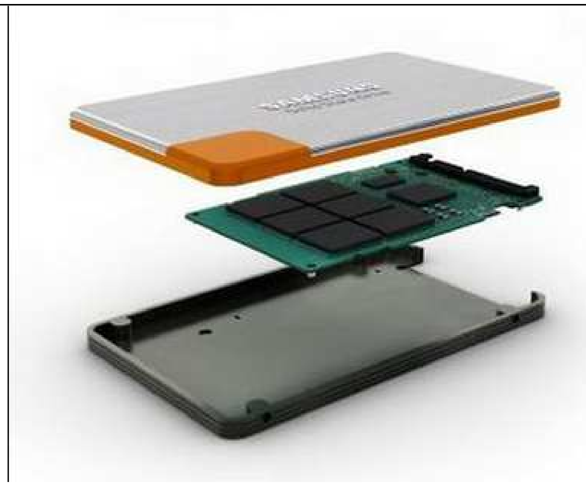
Hard Disk Drive and Solid State Drive

Storage is central to IT and data mining server are constantly running due to constant storage and retrieval of users and applications' information. Our Green IT combines strategies to cut back on energy consumption and energy cost. Various hard drive companies release green Hard Disk Drive (HDD) as part of their product line. The green product indicates that the product is made with recyclable parts, non-toxic to the environment, and is energy efficient. The energy efficient HDDs come at a cost of reduced performance compared to a standard HDD, but in return cuts back on energy consumption costs. However, the lower performance is not really significant [9]. Data server designers can adjust their performance requirements and use green HDDs especially in cases like passive backups and data dumps where higher performance is not essential. The green hard drive in this report is designed with Western Digital Green Caviar HDD with a capacity of 3TB that consumes up to 6 watts when reading and writing data and 0.75 watts when idle [18]. Compared to high performance SATA HDD counterparts, the Green Caviar HDD reduces a yearly energy consumption and energy cost by 42% [18][2].

SSD (Solid State Disk) is a more recent innovation that does not use the traditional mechanical motors and spindles to write and retrieve data. The technology used for SSD is based

[2] See appendix for calculation of the energy consumption and cost.

on integrated circuits (IC) memory and NAND (Negated AND or Not AND) based flash memory. SSD technology increases performance and reduces energy consumption significantly. SSD was selected to replace SAS drives in the green server because of their performance and energy efficiency. Samsung's SSD consumes 0.75 watts for data input and retrieval and 0.15 watts when idle [19]. Compared to Seagate SAS drives consume 11.5 watts for data input and retrieval, a 93% energy consumption and energy cost reduction [20][3].

	
Seagate Cheetah 15k SAS Drive. \	Samsung 470 Series SSD Driver

DDR3 RAM

Random Access Memory (RAM) is another critical component for servers. RAM's evolution has rapidly grown in speed, size, and energy consumption. Transitioning from DDR2 (Double Data Rate) to DDR3, DDR3 has 30% reduction of energy consumption with 2.5 volts (DDR2) to 1.5 volts (DDR3). Similar to CPU's (Central Processing Unit) RAM has evolved with smaller chips from 90 Nanometers to 40 Nanometers. Samsung released Green DDR3 Ram in their recent green product line with cutting edge technology of 30 nanometer class Green RAM operating at 1.35 volts that was selected for the project's Green IT server. Samsung Green DDR3 RAM operates at 14 watts compared to standard ram running at 34 watt with a yearly 59% reduction in energy usage and cost [9][4] .

[3] See appendix for SSD vs SAS calculation
[4] See Appendix for DDR3 RAM energy cost calculation.

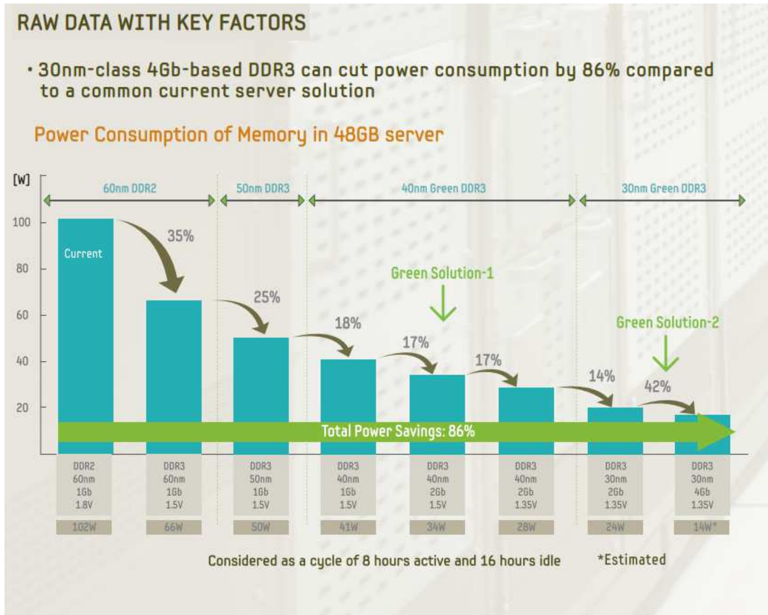


Figure 2 - Samsung Green DDR3 Ram Power Reduction Graph. Picture by Samsung.

Power Supply Unit

Power Supply Units distribute electricity and power the server. The higher the performance of the server component the more power-hungry it will be. Thus, fast servers result in large amounts of wattage to be dispersed from Power Supply Unit which leads to greater energy usage. Like all electronic devices, the Power Supply Unit itself dissipates heat as it is being run and a considerable percentage of wattage is wasted as heat dissipation. In order increase energy efficiency for the Power Supply Unit, 80 Plus introduces energy efficiency standardization for Power Supply Unit in computers. Ranging in different levels from 80Plus, being the least efficient, to 80Plus Platinum with the highest efficiency. 80Plus certifies that Power Supply Unit under the standards has at least 80% efficiency in powering computers [10].

80 plus Gold-Green	20%	50%	100%
power supply in watt	120 Watt	300 Watt	600 watt
Quantity	4	4	4
Server Total to Power HD	480 Watt	1200 Watt	2400 watt
Hours in a day	24	24	24
Daily	1.5 Kilowatt	2.88 Kilowatt	7.49 kilowatt
Weekly	10.5 Kilowatt	20.16 Kilowatt	52.43 kilowatt
Monthly	42 Kilowatt	80.64 Kilowatt	209.72 kilowatt
Yearly	547.5 Kilowatt	1051.2 Kilowatt	2733.85 kilowatt

80 plus-Regular	20%	50%	100%
power supply in watt	120 Watt	300 Watt	600 watt
Quantity	4	4	4
Server Total to Power HD	480 Watt	1200 Watt	2400 watt
Hours in a day	24	24	24
Daily	2.3 Kilowatt	5.76 Kilowatt	11.52 Kilowatt
Weekly	16.1 Kilowatt	40.32 Kilowatt	80.64 Kilowatt
Monthly	64.4 Kilowatt	161.28 Kilowatt	322.56 Kilowatt
Yearly	839.5 Kilowatt	2102.4 Kilowatt	4204.8 Kilowatt

Figure 3 - Power consumption 80-plus Gold vs. 80-plus Regular

An 80Plus Gold standard is selected for our Green Server specifications with 87% efficiency compared to an 80Plus Regular for the conventional server that has only 80% efficiency. This means that 80-Plus Gold will only have 13% waste on heat as its output. Figure 3 compares the power consumption of 80-plus power supply vs. 80-plus gold in one day, one week, one month, and one year and Figure 4 presents the cost differences[5] based on Portland General Electric (PGE) rates. All the calculations are for four servers based on the proposed 126 TB and 24 TB capacities in Figure 1.

[5] Results are based on Portland, Oregon cost per kilowatt. Appendix provides more details.

80 Plus Gold for 4 servers			
Based on Portland Residential Charge - Non-Renewable Energy			
	20%	**50%**	**100%**
Hour	$0.01	$0.02	$0.06
Day	$0.31	$0.59	$1.54
Week	$2.15	$4.16	$10.75
Month	$8.60	$16.62	$42.99
Year	$112.07	$216.67	$560.37

80 Plus Regular for 4 servers			
Based on Portland Residential Charge - Non-Renewable Energy			
	20%	**50%**	**100%**
Hour	$0.02	$0.05	$0.10
Day	$0.47	$1.18	$2.35
Week	$3.30	$8.25	$16.48
Month	$13.18	$33.01	$65.91
Year	$171.85	$430.36	$859.23

Figure 4- 80-Plus Gold vs. 80 Plus Cost Comparison for 4 servers-600 Watts

Central Processing Unit (CPU)

The server running for PSU's Engineering department is currently serving and supporting 5,000 students across various sub-departments. Students access the server dailyin both academic and personal various tasks that involve intensive processing resources. In order to meet the demands for PSU, the project selected Intel Xeon's processor where Xeon is specially designed to run servers and the capability to utilize Intel's QPI (Quick Path Interconnect) with architecture to run dual processors [11].

Intel Xeon E5-2650 was selected and customized with dual processor motherboards to handle intensive processing capability for servers with 8 cores architecture running 16 threads. The server is designed with a total of 16 cores with 32 threads with virtualization technology. The E5-2650 can crunch powerful calculation up to 2.8GHz with 95 watts of power consumption. Another important aspect in utilizing multi-core technology is the implementation of virtualization that has become a common practice to cut back energy consumption, cost, and space by allowing a single hardware platform to be utilized as multiple virtual platforms.

Software Side of Green IT

Virtualization

The innovation of multi-core processing expended the fields of virtualization. Virtualization is a technique that allows the creation of virtual machines or virtual platforms to execute multiple independent functions on one physical machine.

Advanced computer technology now allows a single server to run multiple host computers with multiple operating systems. A traditional server consists of a single processor server computer running on a single operating system (OS), usually powered by a 500 watt power supply unit. In order to run a different OS to do different tasks, eight different servers powered by eight 500 watt power supply units were required. Virtualization can perform the same task of eight traditional servers consolidated into a single server by distributing eight processing cores to each virtual machine with a different OS, all while using a single 500 watt power supply unit. Each core from a multi-core processor can act as a single processor for a virtual machine. Such an efficient setup will significantly reduce space, cost, resources, and energy consumption. Figure 5 illustrates the above concept.

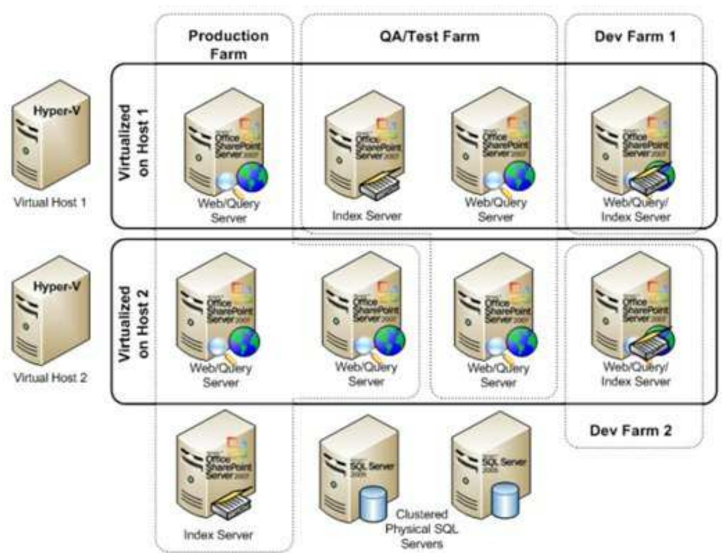


Figure 5 - Representation of Virtualization with virtual machines

Energy and Heat

Powering servers is the primary cost driver in an IT organization that can easily take up 50% of organization energy overall cost [6]. Server computers are running all day long throughout the year and consume massive amount for operation and cooling. The focus of Green IT is to reduce energy consumption and focus on efficiency of server operation and lower energy usage.

Power Management

Data centers and IT departments are dependent on servers for their primary operation. In order for organizations to reduce their cost in power consumption, Green IT solutions can strategize through the use of power management software. Utilizing power management strategies and software decreases energy cost and consumption by implementing automation and adjustments on server workload; the software adjusts the amount of power in wattage of the CPU to match the amount workload at real time [6]. Power management can also monitor temperature control in server rooms to adjust to the heat dissipation and requirement of cooling through the use of smart thermostats, airflow, ventilation, and automated cooling management from workload and thermal load management [10].

Construction and server cooling

When constructing the server room the two primary concerns to think about are size and cooling. Size can be easily mitigated with the use of virtual servers and other sources of green servers that have been discussed previously in this paper. The size of the server room should be big enough to facilitate the amount of servers that will be in use, and also for future servers that are accumulated for business growth.

The construction of the green server room is primarily focused on materials and cooling. Materials used to construct the green server room should contribute the higher efficiency of the room. Materials used for construction are generally used from same building materials that would be used to construct the entire building. Layout and planning design would be the major factor that contributes to the efficiency of the room. Design would include air circulation through ducting coming from the roof side, and cooling from the floor side of the room.

Cooling the server room is the primary focus when constructing the server room. There are several options to contribute to cooling the server room, and there are some options that can be more efficient than other options. The server room can be cooled through existing ducting from the building using portable air conditioners and newer more compact spot coolers. Spot coolers are a more self-contained way of air conditioning using the heat output of the servers to run the cooler [12]. The spot coolers are more centralized to cool localized areas. There is an outlet attached to the servers that suck the heat out from the server itself and utilizes the heat to create the refrigerant needed to output the cool air that is blown directly onto the server. Excess heat can be either sent outside or utilized to heat the other parts of the building which in turn creates more efficiency of a green server room.

There are some construction companies out that specialize in adding green technologies to existing buildings to help businesses create more efficiency and save on their energy costs. One such construction company called PECI has a proven track record of saving businesses money through such efficiencies as recycling the heat output that the servers create, and harvesting the cool air from the outside during the peak cooling times of the night and using that cooler air to cool the entire building along with the server room [13]. Other methods of improving efficiency include server cabinet arrangement near the floor vents, and even using flooring methods as putting grass down below the floor paneling.

The average cooling cost to power one server is estimated to be around $533.48 depending on the datacenter cooling efficiency or power utilization efficiency [14]. The heat output for a server is measured in either the Btu, or the kilowatt. Heat output for green servers have been already previously mentioned in figures 4 and 6 of this paper. For construction purposes heat output would generally be measured in the square foot to maximize efficiency. As previously mentioned the server room should not exceed 300 watts per square foot to maximize the efficiency.

It is not always necessary to keep a server room at refrigerator temperatures to maintain the lifespan of the server room. In today's world with the computer and the server shrinking it is more beneficial to keep the server room at an 85 degree temperature. Some companies are pushing to move toward having a 90 degree ambient temperature for the server room. In today's server room it is not uncommon to have the servers placed into cabinets that can contain and exhaust air. These cabinets are also known as "Chimney Cabinets". They have ducting tubes that suck the heat out and contain it to recycle it, and then in turn use that hot air to feed the air conditioner that blows the cooler air into the cabinet. Figure 6 shows a diagram of the spot cooler that relocates the heat from the server and how this process hurts [12].

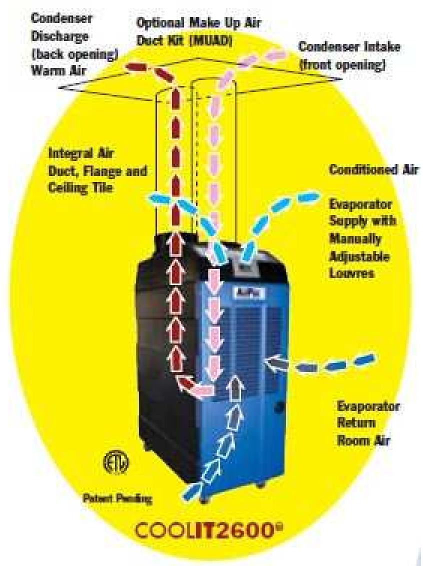


Figure 6- A diagram of the CooLIT 260-spot cooler that relocates heat from the server

The cost of construction on a green server room is greater at start up than a conventional server room but has higher savings than the conventional server room through efficiency and sustainability. The overall savings on construction of a green server room will be a greater amount than the overall cost of start-up building materials and maintenance. Most of the cost comes with the purchase of the building materials and the cost of labor on construction of the green server room. The cost savings is generally measured in the entire building and not just the server room. The technology being used is a very new technology, and measuring the savings created over longer periods of time is problematic. Looking at case studies provided by PECI shows that some businesses using their green technology has created an annual savings of $48,653 [15]. This savings was created through implementation of construction of green technology throughout the entire building with the server room being a part of where that construction was applied. The focus of this paper was centered on the green technology applied to the construction of the server room.

5.Economic Analysis

Initial investment calculation

Section 4 elaborated on various possible methods of making a data server green. Based on the discussions above and the regular data server specifications, our team has come up with the below configuration for an equivalent Green data server using both SATA and SAS hard disk drives. The Server Spec is for a 16 TB server with 32 GB of RAM running 16 Core processors in addition to hyper threading equaling 32 Cores. Using virtualization it can run up to 16 OS system, each using 1 core and 1 virtual core.

Heavy Duty SATA Green Server			
Components	**Specs**	**Prices**	**Comments**
Steel Server Case	2u size, 12 HDD, 4 80mm Fans, OE	$250.00	Habey ESC02122C 12 Bay 3.5
Server Power Supply	80Plus Gold, 600W, OEM	$100.00	80Plus Gold = Certified Energy Efficiency
Server Motherboard - Supermicro x9SRI-3F	E5-2670 Xeon, onboard Video, fan speed controller, LGA2011	$360.00	12x SATA 3.0Gb/s
Intel E5-2650 x 2	8 Core, 32nm, 2.0GHZ, Hyperthread, virtualization tech,	$2,280.00	Total 190W
1u Server Heatsinkx x 2	Copper Heatsink, 70mm,	$64.00	
Samsung Green DDR3 x 4	4 x 8 = 32 Gigs Ram, 1.35V, 30nm	$340.00	
WD Green HDD x 12	3TB x 12 = 36TB	$1,680.00	6W x 12 = 72W, Idle Watt = 0.75 x 6 = 4.5W
Server Total Cost		$5,074.00	
CAT SATA server = 126 TB	# Equivilent Green SATA server of	4	
		$20,296.00	
Heavy Duty SSD Green Server (SAS Equivilent)			
Steel Server Case	2u size, 12 HDD, 4 80mm Fans, OE	$70.00	
Server Power Suppy	80Plus Gold, 600W, OEM	$100.00	
Server Motherboard - Supermicro	E5-2670 Xeon, onboard Video, fan speed controller, LGA2011	$340.00	
Intel E5-2650 x 2	8 Core, 32nm, 2.0GHZ, Hyperthread, virtualization tech, 95W	$2,280.00	
1u Server Heatsinkx x 2	Copper Heatsink, 70mm,	$64.00	
Samsung Green DDR3 x 4	4 x 8 = 32 Gigs Ram, 1.35V, 30nm	$340.00	
SSD Samsung 500GB Sata	500GB x 12 = 3TB	$3,708.00	Active = 0.15W x 12 = 1.8W
Server Total Cost		$6,902.00	
CAT SAS Server = 24 TB	# Equivilent Green Servers of 24TB	4	
		$27,608.00	

Figure 7 - Equivalent SATA and SAS green data servers

The initial investment is based on the prices in today's market as shown in Figure 1 for regular and Figure 3 for green data servers. Costs are calculated in Figure 8.

SATA(126 TB)			
Regular		**Green**	
Component	**Price**	**Component**	**Price**
Steel Server Case	$250.00	Steel Server Case	$250.00
Server Power Suppy	$94.00	Server Power Supply	$100.00
Server Motherboard - Supermicro x9SRI-3F	$360.00	Server Motherboard - Supermicro x9SRI-3F	$360.00
Intel E5-2650 x 2	$2,280.00	Intel E5-2650 x 2	$2,280.00
1u Server Heatsinkx x 2	$64.00	1u Server Heatsinkx x 2	$64.00
Standard ECC DDR3 x 4	$440.00	Samsung Green DDR3 x 4	$340.00
SATA Regular HDD x 12	$1,668.00	WD Green HDD x 12	$1,680.00
Total for 1 Server	**$5,156.00**		**$5,074.00**
Total for 4 Servers	**$20,624.00**		**$20,296.00**

SAS(24 TB)			
Regular		**Green**	
Component	**Price**	**Component**	**Price**
Steel Server Case	$70.00	Steel Server Case	$70.00
Server Power Suppy	$94.00	Server Power Suppy	$100.00
Server Motherboard - Supermicro	$340.00	Server Motherboard - Supermicro	$340.00
Intel E5-2650 x 2	$2,280.00	Intel E5-2650 x 2	$2,280.00
1u Server Heatsinkx x 2	$64.00	1u Server Heatsinkx x 2	$64.00
ECC Standard DDR3 x 4	$440.00	Samsung Green DDR3 x 4	$340.00
Seagate SAS 500GB Sata	$2,256.00	SSD Samsung 500GB Sata	$3,708.00
Total for 1 Server	**$5,544.00**		**$6,902.00**
Total for 4 Servers	**$22,176.00**		**$27,608.00**

	Regular	Green
Initial Investment Total	**$42,800.00**	**$47,904.00**

Figure 8 - Initial Investment- Regular vs. Green

Capitalized Worth

To calculate the Capitalized Worth (CW) of regular vs. green data servers the below formula has been used:

–

This study has assumed a 3% interest rate and the effect of change in interest rate is shown in Sensitivity Analysis section.

The recovery period of computers is 5 years according to the table 7.2 in chapter 7 of the course book [21] and that's why *n=5* in the formula. Computer systems are changing and new technologies are coming to market so fast that older than 5 years in IT can be considered obsolete. Figure 9 compares the electricity consumption of green vs. regular power supplies in one year. Using this information and the initial investment the CW is calculated.

80 plus	**100%**
power supply(w)	600
Quantity	4
Server Total to Power HD(w)	2400
Hours in a day	24
Daily	**11.52**
Weekly	80.64
Monthly	322.56
Yearly	**4204.8**
Cost per kw	**$0.07**
Transmission Charge	**$0.0024**
Distribution Charge	**$0.03**
Total Cost	**$860.72**

80 plus Gold	**100%**
power supply(w)	600
Quantity	4
Server Total to Power HD(w)	2400
Hours in a day	24
Daily(kw)	**7.49**
Weekly(kw)	52.43
Monthly(kw)	209.72
Yearly(kw)	**2733.85**
Cost per kw	**$0.07**
Transmission Charge	**$0.0024**
Distribution Charge	**$0.03**
Total Cost	**$559.62**

Figure 9- Yearly electricity consumption 80 Plus Regular vs. 80 Plus Gold power supply

IT Corporations receive tax incentives to reduce heating, cooling, lighting and energy costs. [22] The actual tax incentive will be applied to the taxable income which was not applicable for our project. We considered a one-time tax credit of 10% on the initial investment to incorporate the green incentives in reducing total cost. The sensitivity of the CW to tax credit changes are shown in the sensitivity analysis section.

Figure 10 shows the CW of the regular vs. green data servers for a total of 150 TB capacity.

	Regular	Green
Interest rate	3%	3%
Number of years	5	5
Initial investment	$42,800.00	$47,904.00
Yearly server power consumption cost	$860.72	$559.62
Coefficient	4.5797	
PW of yearly costs	$3,941.84	$2,562.89
Tax credit		10%
Total	**$46,741.84**	**$45,676.49**

Figure 10 - CW of regular vs. green data server

Sensitivity analysis

Figure 11 shows the change in total electricity bill as the price of electricity increases. The difference in yearly costs for power consumption of regular vs. green servers is not significant because of the low price of electricity. Figure 11 shows as the electricity price increase the cost saving of green data servers become more and more significant.

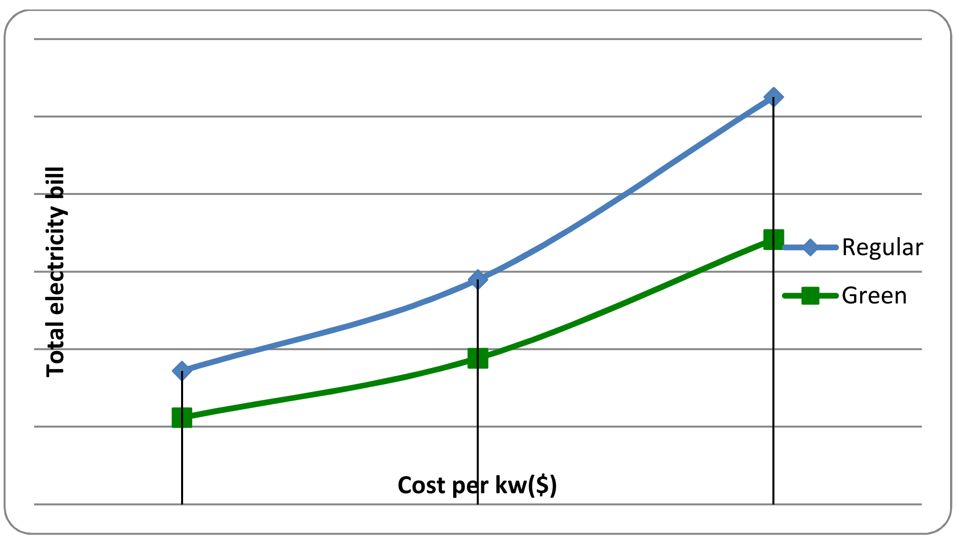


Figure 11-Sensitivity of total electricity bill with increase in cost per kw

Figure 12 shows the change in capitalized worth of green vs. regular servers for different interest rates. As discussed a 3% interest rate was assumed for the capitalized worth calculation. Figure 12 shows the CW for interest rates 2% to 7%. Both CWs decrease as the interest rate increases. Therefore the change in interest rate will favor their CW equally and the analysis remains similar. Figure 13 shows the CW sensitivity to tax credit values.

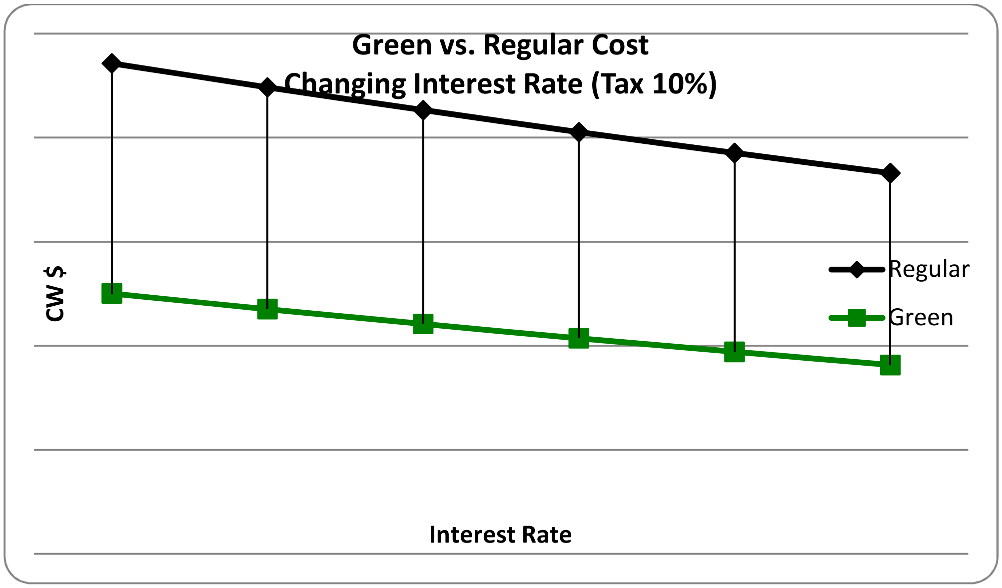


Figure 12-CW sensitivity to interest rate change

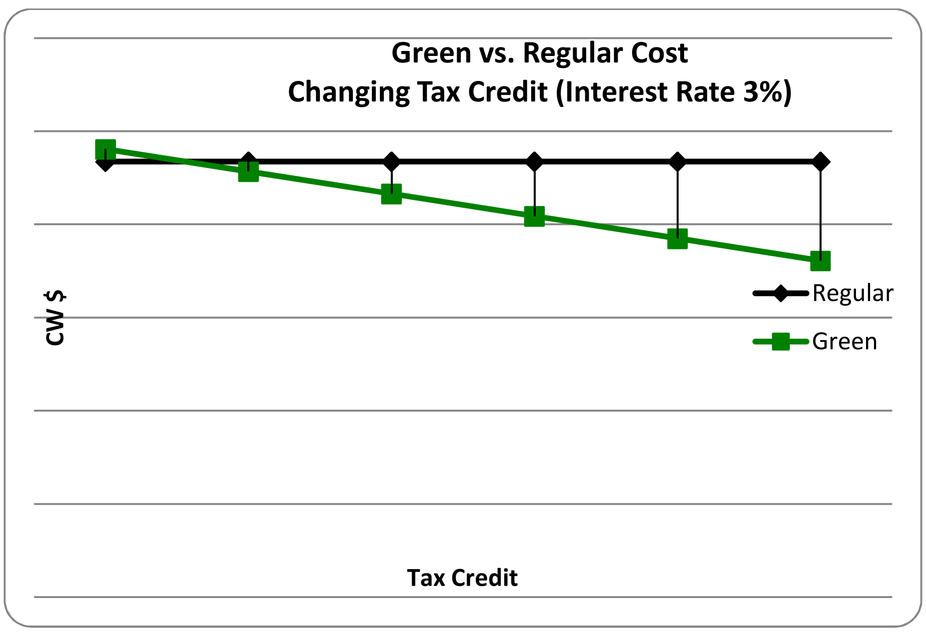


Figure 13 - CW Sensitivity to tax credit

6.Discussion of Results

Based on the results of the research that has been discussed in this paper, the implementation of the use of green servers will have a greater startup cost but the difference will be minor. This greater startup cost will be largely recovered in the energy savings that are seen during normal use. The greatest amount of startup cost difference will be created in construction labor and materials of the server room to create sustainable cooling of the servers. The sustainability of the server room will include limiting cooling costs by recycling the heat output created by the servers, and harvesting outside cool air to use for air flow. Energy savings created by the sustainability of cooling will recover all startup cost within the first 5 years, assuming a 10% tax credit is in place. As Figure 13 shows, reducing this credit to 5% will not pay off the green technology within the 5 year study period.

The use of green servers and a green server room will create enough savings to make implementation of green servers beneficial. The serviceability and sustainability of green servers have been proven to meet whatever requirements that are needed for server room use. Looking at the use of the servers, without the startup cost of construction, the savings are created within the initial investment, again assuming a 10% tax credit applied for businesses using green server technology. The other startup costs coming from construction labor and materials of the server room, are not part of the current study, but are estimated to also increase the amount of recovery.

After reviewing the research and the cost calculations, a business implementing this technology would benefit right away and should seriously consider a way of implementing this technology into their business plan. Green server technology should be implemented into all business plans for sustainability, cost savings, and overall good for the environment.

7.Conclusion

The effect of climate change has brought a global concern for sustainability. Sustainability has grown into technologies that lead to many organizations and standards such as the WEEE, RoHS, Energy Efficiency 4.0, 80Plus, and EPEAT into the Electronic and Electrical market. As the issues of climate change and sustainability grow in concern, companies, organizations, and governments have gradually embraced corporate responsibility and are participating into the trend of being more sustainable.

Green IT is a response to the growing trend of sustainability that contributes to corporate responsibility by innovating products into the green market. This establishes the new economics of a green product market, which as our research shows can result in higher startup costs, but will also result in cost savings over the long term. Green products encourage alternatives that aid organizations and companies to participate in sustainability. Applying the practices to operate an IT department in green fashion will give the benefits of cutting energy consumption and cost while maintaining an efficiently operating business environment.

Our research shows that implementing green servers and a green server room is a great potential way of making business sustainable, and beneficial. Utilizing Green IT can reduce consumption, contribute to a healthier environment, and ultimately save on operation costs.

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