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Acknowledgements

Dedico meus sinceros agradecimentos para:

"It's the only home we know. Yet everyday, we take the earth for granted.
Everytime we leave the lights on, we are doing the earth harm.
When we forget to turn off our computers, energy is also wasted.
But together we can help make the world a greener place, one simple act at a time.
Because when it comes to the environment, small changes can make a world of difference.", ***The "Power To Change" manifest***

Glossary of Abrevitations

x	x
CPU	Central Processing Unit
DDR	Double-Data Rate
HVAC	
HDD	Harddisk Drive
ICT	Information and Communcation Technology
LTO	Linear Tape-Open
MFD	Multi Function Devices
MPN	Manufacturer Part Number
OS	Operational System
PC	Personal Computer
PDU	
PSU	Power Supply Unit
RAID	
ROI	Return on Investment
SaaS	Software as a Service
SAN	Storage-Area Networks
TOC	Total Cost of Ownership
VM	Virtual Machine
x	x

Abstract

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Motivation

O greenict tem sido muito importatne para o mundo, as empresas, depois da crise economica, comecaram a ver que Ã© importante, pois, reduz muitos custos, alÃ©m de contribuirem apra o meio ambiente. . . bla bla bla

1 Introduction

Purpose of the study.

1.1 Definition of the problem

1.2 Solution Strategy

1.3 Structure

2 State of the Art

In terms of hardware and equipment, the main measures to be taken towards a Green ICT environment can be grouped in the following categories:

- Workstation Configuration;
- Policies / Tools / Labels;
- Thin client architectures;
- Servers and Virtualization;
- Data Storage;
- Power Architectures;
- Data Center Infrastructure.

For each of those categories there are several types of information that are relevant to the evaluation of the intervention and their consequent energy savings. For each one a list of possible interventions will be made, and after that analyzed if they are either purely conceptual or available in the market. Moreover, it is important to know exactly where the power is going and where the energy is being wasted. In hands with that information, it is possible to redirect it to the places with more necessity and ameliorate the computers with more idle time, by applying one of the above categories before. Therefore, it is feasible to draw a more realistic figure of what is going on with the energy consumed in the place.

It is possible to compare how much energy is spent by three types of components, Computers on Table 1, Monitors on Table 2 and an Apple on Table 3.

Computers	
Desktop Computer	60-250 watts
On screen Saver[a]	60-250 watts
Sleep / Standby	1-6 watts
Laptop	15-45 watts

[a] no difference

Table 1: Energy used by a standard computer

Monitors	
Typical 17" CRT	80 watts
Typical 17" LCD	35 watts
Apple MS 17" CRT[a]	63 watts
Apple MS 17" CRT[b]	54 watts
Screen saver[c]	same as above
Sleeping monitor[d]	0-15 watts
Monitor turned off at switch	0-10 watts

[a] mostly white (blank IE window)
[b] mostly black (black Windows desktop with just a few icons)
[c] any image on screen
[d] dark screen

Table 2: Energy used by Monitors

Apple iMac G5 with built in 20" LCD screen	
Idle	97 watts
Monitor dimmed	84 watts
Monitor sleep	62 watts
Copying files	110 watts
Watching a DVD	110 watts
Opening a lot of pictures	120 watts
Computer sleep	3.5 watts

Table 3: Energy used by Apple iMac G5 with built in 20" LCD screen

2.1 Computer Energy Management Categories

2.1.1 Workstation Configuration

This category represents the components used in a certain machine configuration. All the information about each component performance and power consumption can be obtained from several sources, such as the manufacturer specifications, benchmarks or direct measurements in the case of energy consumption Listed below are the necessary information to evaluate interventions and their energy savings:

Single-core / Multi-core processors

CPU Type

Type and dimension of RAM memory

Type and dimension of cache memory

Chassis (power supply, fan)

Monitor type It is important to say that using flat panel liquid crystal display (LCD) monitors and not conventional CRT monitors can reduce energy consumption by a third. LCD monitors also run cooler, which helps save on air conditioning costs. In addition to that, selecting the right-sized monitor to meet the needsof the user helps, because the bigger the monitor, the more energy it uses.

Hard drives (number and type)

Auto-sleep, remote sleep and screen saver Enabling the energy saving settings on PCs and peripherals is also valuable act, due to the fat that a computer in idle mode uses 20 to 50 times the power of a computer in standby mode. For example, when the computer is in standby mode the computer uses 0 to 6 watts. Reducing the time delay in which the computer will enter in the power saving mode is also a good thing to be done. Another thing to be done, is to disable the screen saver. Studies shown that a monitor in screen saving mode uses significantly more energy than in standby mode.

Efficiency benchmarks fat/thin

Performance benchmarks

Overall and single components power consumption benchmarks, in several load conditions (idle, SO, main applications)

Trade off between performance and consumption

2.1.2 Policies / Tools / Labels

The amount of saved energy depends also on technology acquisition and managerial policies. There are a number of specialized tools that may be used in order to help enforcing these policies and tools.

These policies can be made as acquisition of new computers or components labeled as green by the manufacturer, purchase of dual or multi-core processors, or even the discourage of purchasing or use of other parts, such as dual or large monitors. Likewise, other kinds of policies are a good idea to be defined, and they concern in the use of the workstation, for instance, to turn off the computer if they are going to be unused for a long time, shutdown over nights, and others. These policies, or rules, are important either to enforce the company's position through the green idea either to keep track of the list of thing yet to be prepared in order to convert the computers and workers as green as possible.

Furthermore, the use of tools that automates these methods is always welcome in the enterprise. There are many tools, which let the computer in standby mode, or even turn off after a long period of no utilization. In addition, the use of networked pieces of hardware can be an effective way to achieve the green. Additionally, networked systems allow several nearby users to share a single (faster) printer generally save time, cost, and energy compared with each computer having a dedicated printer, it will decrease their idle time and provide for more cost-effective use of the equipment. Above that, choosing multifunction devices (MFD) that do the work that used to require several machines. In addition to saving space and materials, these All-in-Ones save energy compared to several products working in parallel. Select printers or multifunction products that offer two-sided printing to reduce paper and energy usage. The Table 4[1] describes the characteristics that am energy-efficient networked printer should have, in relation to the number of pages per minute it prints.

Besides these facts, it is also a choice to buy only eco-labeled products. Eco-label is a category given to products, which comply some of the energy efficiency specifications provided by the owner companies of these labels. The most famous of these labels is the ENERGY STAR®, which is a voluntary energy efficiency program sponsored by the

[1] `http://www1.eere.energy.gov/femp/procurement/eep_printer.html`

Efficiency Recommendation		
Printer Speed	Recommended "Sleep" Mode[a]	
	Laser B/W + All Ink jet[b]	Laser Color[c]
$\geq$10 pages/min	10 watts or less	35 watts or less
11-20 pages/min	20 watts or less	45 watts or less
21-30 pages/min	30 watts or less	70 watts or less
31-44 pages/min	40 watts or less	70 watts or less
>44 pages/min	75 watts or less	70 watts or less

[a] "Sleep" mode is a low-power standby condition, it restores automatically with a print request.

[b] Includes both black-ink and color ink jets, and printer/fax combinations.

[c] Also includes LED and thermal transfer color printers.

Table 4: Energy Recommendation to an Energy-Efficient Printer

U.S. Environmental Protection Agency. For example, An ENERGY STAR® qualified computer is possible to use up to 70% less electricity than computers without enabled power management features.

2.1.3 Thin Clients Architectures

According to *Wikipedia*, in 2009, "a thin client is a client computer or client software in client-server architecture networks which depends primarily on the central server for processing activities, and mainly focuses on conveying input and output between the user and the remote server". This is very well connected to both ideas of cloud computing and Green ICT and it is possible to subdivide in three categories for comparison against standard PC architecture: Performance, Power Consumption and Hardware Savings and they are going to be exploited in the following subsections.

PC vs. Thin Client: Performance

In order to analyze and give a base for a comparison of the performance between standard PCs and two types of thin clients, a set of tests were executed, on networks varying the number of active clients, each running the same typical office applications tasks. The following client platforms participated in this study:

- PC: OptiPlex 210L PCs, basic managed PC desktops running Windows XP Professional;
- Sun thin client: Sun Ray 2 running Sun Ray proprietary software;

- Wyse thin client: Wyse Winterm 5150SE, Linux-based thin clients running Wyse Linux V6.

Each network used a standard file server, an HP ProLiant DL360 3.4MHz with and Intel Xeon processor and Microsoft Server 2003 Enterprise Edition. For test reasons, all files were manipulated by the PC were stored at the server. The tests are listed below:

- Calculating subtotal in Microsoft Office Excel 2003 (Figure 1 and Table 5)
- Compressing a PDF within Adobe Acrobat 7.0 Standard (Figure 2 and Table 6)

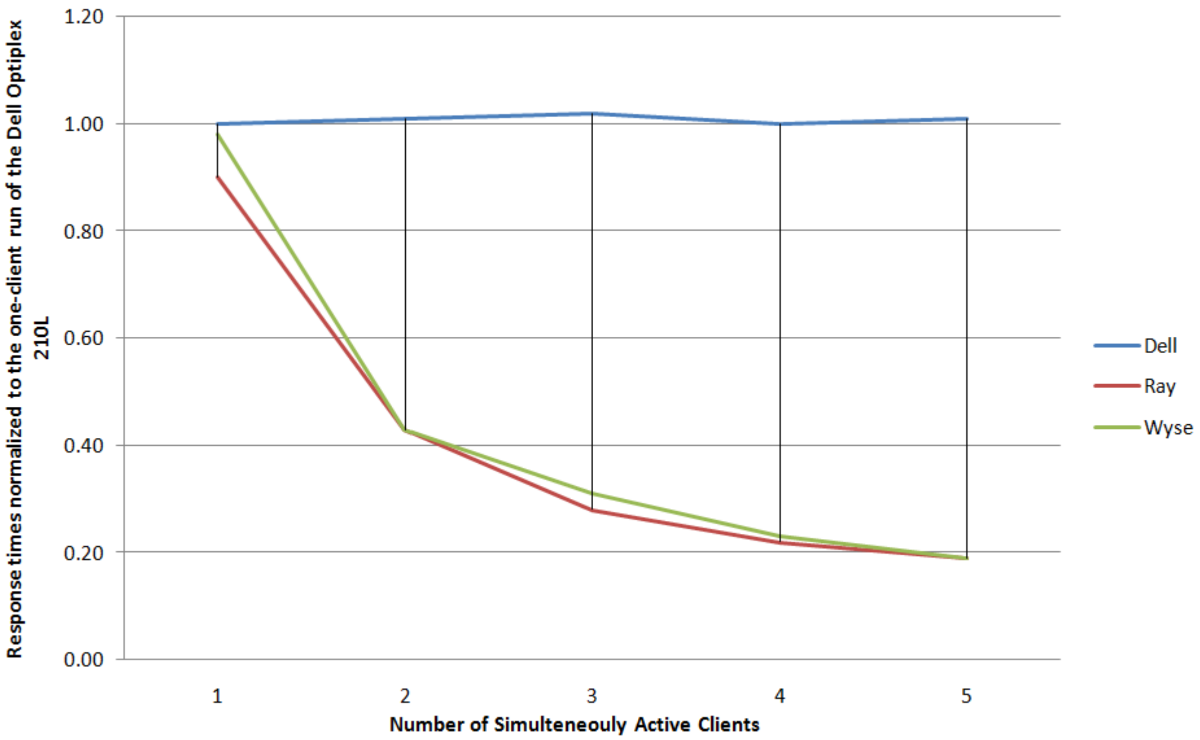

Figure 1: Normalized Excel Subtotals Task Response Times

Performance Results				Comparative Rating		
PC solution	Thin-client solutions		Number of	PC solution	Thin-client solutions	
Dell OptiPlex 210L	Sun Ray 2	Wyse Winterm 5150SE	concurrent active clients	Dell OptiPlex 210L	Sun Ray 2	Wyse Winterm 5150SE
12.9	13.2	13.1	1	1.00	0.90	0.98
12.8	30.2	29.7	2	1.01	0.43	0.43
12.7	45.5	41.9	3	1.02	0.28	0.31
12.9	58.3	57.3	4	1.00	0.22	0.23
12.8	68.1	67.9	5	1.01	0.19	0.19

Table 5: Performance Results for Excel Subtotals Calculation

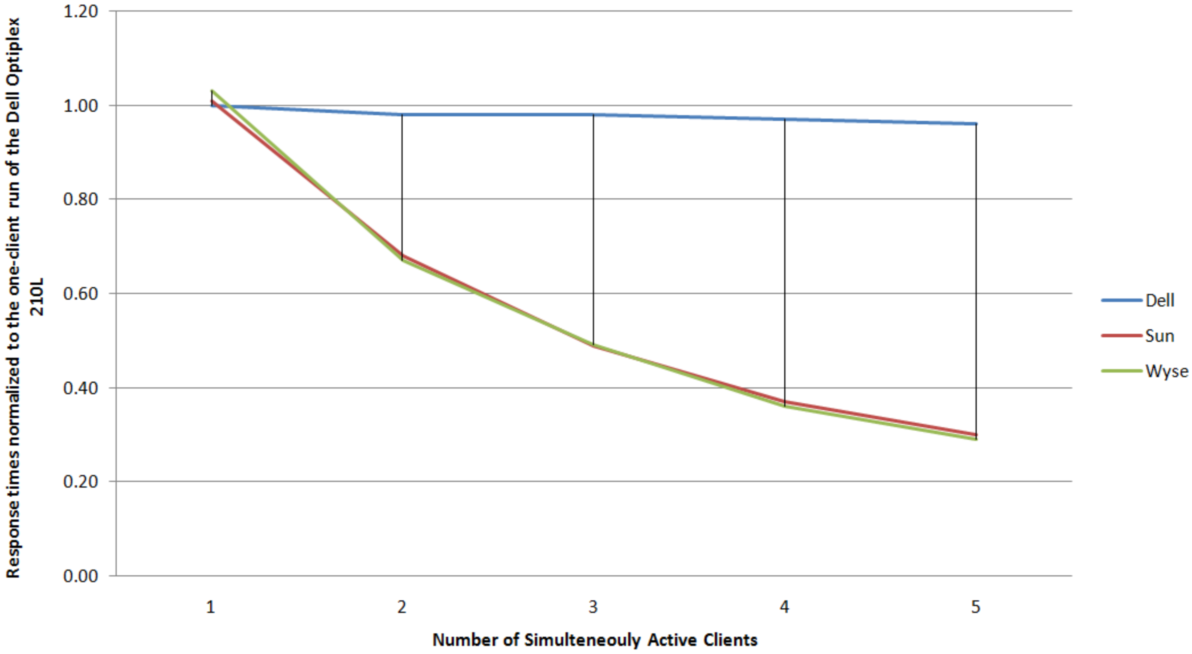

Figure 2: Normalized PDF Subtotals Task Response Times

Performance Results				Comparative Rating		
PC solution	Thin-client solutions		Number of	PC solution	Thin-client solutions	
Dell OptiPlex 210L	Sun Ray 2	Wyse Winterm 5150SE	concurrent active clients	Dell OptiPlex 210L	Sun Ray 2	Wyse Winterm 5150SE
16.1	16.0	15.6	1	1.00	1.01	1.03
16.4	23.8	24	2	0.98	0.68	0.67
16.5	33.0	33.1	3	0.98	0.49	0.49
16.6	43.7	44.3	4	0.97	0.37	0.36
16.7	54.0	55.1	5	0.96	0.30	0.29

Table 6: Performance Results for PDF Compression Subtotals Calculation

PC vs. Thin Client: Power Consumption

Supposing 30 thin users share a 400W server, the total power consumption will be 1300W - a yearly cost of €640.00. 30 PCs would consume 10000W instead - a yearly cost of €4900.00 (assuming the MWh cost is €80.00). The Table 7 shows the power consumption of thin-client and PC.

	Thin Client	PC
Weight	2.2 - 7.7 lbs	22 - 33 lbs
Volume	1.5 - 3 dm^3	30 - 35 dm^3
Packing material	2.2 - 4.4 lbs	3 - 5 kg
Power consumption(including monitor)	20 - 50 watt	300 - 400 watt
Heat rejection	5 - 35 watt	85 - 115 watt
Noise level	0 dbA	50 - 60 dbA

Table 7: PC and thin client power consumption

Hardware Savings

Savings on client hardware The economy brought by the substitution of PCs with thin clients was estimated around US$ 208 per PC per year. The estimative considered the average prices of a PC, an adequate thin client and the PC upgrade costs every 3 years. If energy consumption is considered, the savings will be even greater.

The following considerations were taken:

- Thin client cost: US$250.00 x PC cost: US$750.00;
- PC needs to be upgraded every 3 years and thin clients need to be replaced every 6 years.

Therefore, in a 6-year period US$1500.00 will be spent on a PC against $250.00 that will be spent on a thin client.

Extra server hardware costs Considering that:

- On average 30 users will need a dual processor server with 4 GB of RAM and SCSI hard disks;
- A brand new server should cost around US$4,500.00 and will depreciate on average in 3 years.

For 60 users, the thin client solution should out-price the PC one by US$11,300.00 per year, excluding the administration costs of both solutions.

2.1.4 Servers and Virtualization

Rack vs. Blade

According to Goldworm(GOLDWORM, 2007), Blade servers are a package of "ultra-high density components including servers, storage, and communications interfaces in a pre-wired chassis with shared components such as power, cooling, and networking. In contrast to the conventional *horizontal* positioning within a rack (rack mounted servers), blades are typically (though not always) installed *vertically* in a blade chassis, like books in a bookshelf". This disposition of the servers provide a high density of the components and thus performance, for example, 60 blade servers can fit in the same physical space as 42 rack-mounted servers. Another improvement reached with this type of server is the integration of a remote system management, differently form the ordinary (rack or standalone), where it is an add-on. An example of this type of server can be seen on Figure 3. Moreover, Blade servers[2] are computer servers designed to minimize the use of physical space. A blade enclosure, which can hold from 8 to 24 (REHN, 2008) blade servers, provides common services such as power supply, cooling and networking thus eliminating redundancies in each individual blade server. More than 250 blade servers can be easily accommodated in a single rack. On the other hand approximately 42 servers can be accommodated to a standard rack when it comes to the other lower end servers available in the market. Whereas, rack-mounted servers are those arrange in industrial rack. A single rack is capable of holding 10 to 20 servers. Therefore, this type of servers come with rails or slides to ease inserting and removing of the components(BAILEY, 2009). In the Table 8, a comparison is made between IBM HS21 blades and x3550 rack servers. The blades and rack servers have comparable performance.

- 2.0 GHz intel quad core;
- 8 GB DDR2 memory;
- Both in standard configuration, with no HDDs.

Thus, a possible conclusion to this comparison is that with Blade servers the gain with space, performance and, more importantly, power consumption is much smaller than with Rack-mounted devices.

- Space saving and efficiency - packaging more computer power in a significantly smaller area;

[2] `http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?tp=&arnumber=1362591&isnumber=29851`

(a) IBM LS20 **(b)** Sun 6000 Series Blade Enclosure **(c)** HP Intros Rack

Figure 3: Examples of Blade Servers

(a) Chenbro 5U RM51924 **(b)** Rack Server

Figure 4: Examples of Rack Servers

- Consolidation of servers to improve and centralize management as well as utilization;
- Return on investment (ROI) and improved total cost of ownership (TOC) through increased hardware utilization and reduced operating expenses;
- More energy efficient, due to existence of centralized power supply, cooling and networking.

IBM server model	**Base Power Consumption**	**kWh consumed over 5 years**	**Total cost ($0.03/kWh) over 5 years**
BC-H Chassis, no blades	0.510 kWh	22,350	$670.50
BC-H HS21 blade	0.318 kWh	13,936	$418.08
x3550 server	0.373 kWh	16,346	$490.39
x3650 server	0.455 kWh	19,940	$598.20
BC-H chassis with 14 HS21 blades	4.962 kWh	217,455	$6,523.65
14 x3550 servers	5.222 kWh	228,849	$6,865.46
14 x3650 servers	6.370 kWh	279,259	$8,374.80

Table 8: Power consumption for several servers, excluding cooling and redundancy

According to the figures, the choice of using a blade server provides roughly 5% power saving over a similar rack-mount configuration. The main benefit brought by the use of blade servers, however, is the processing density, as a rack filled with blade servers may carry up to 50% more servers than one with rackable servers. Other benefits are that blade servers are easier to service and reduce the number of power cables needed from as many as 80% (HENDERSON, 2007).

However, the high power density might prove to be a problem to server farms in terms of overheating[3].

Virtualization

The overall goal of virtualization is to create a logical abstraction of physical assets. It allows to multiple "virtual" servers to run on one physical server, thereby consolidating many physical servers onto one. *Wikipedia*, in 2009, defines virtualization as the following: "Virtualization is the process of presenting a logical grouping or subset of computing resources so that they can be accessed in ways that give benefits over the original configuration. This new virtual *view* of the resources is not restricted by the implementation, geographic location or the physical configuration of underlying resources. Commonly virtualized resources include computing power and data storage". Moreover, virtualization improves efficiency and availability of resources and applications in the organization. According to *Vmware*, it is possible to save 50-70% overall IT costs. Overall benefits from virtualization includes: reduction of costs, free up IT resources, provide better infrastructure optimization and utilization, increase availability and improve desktop management.

[3]—- falar disso na parte de cooling

Regarding the energy consumption, it is a critical issue for IT organizations now a days, either the objective is the reduction of costs, environmental issues or keeping the data center running. In the United States alone, data centers consumed $4.5 billion worth of electricity in 2006. Industry analyst Gartner (KUMAR, February 2007) estimates that over the next 5 years, most enterprise will spend as much energy as they spend on hardware infrastructure, power and air conditioning. Besides that, virtualization has made positive improvements to the environment issue. Gartner (STAMFORD, October 2007) estimates that 1.2 million workloads run in virtual machines, which represents an aggregate power savings of about 8.5 billion kWh - more electricity than is consumed annually in all of New England for heating, ventilation and cooling. While this is a good start, there are plenty of opportunities for saving even more energy and money. Analyst firm IDC (IDC, February 2007) states that the un-utilized server capacity equates to approximately:

- $140 billion
- 3 years supply of hardware
- More than 20 million servers

At 4 tons of carbon dioxide (CO_2) annually per server, these un-utilized servers produce a total of more than 80 million tons of CO_2 per year. This is more than is emitted from the country of Thailand and more than half of all countries in South America. In conclusion to all of these exploited data, all of these data shows that virtualization is a good improvement to the data center, saving not only space provided to the servers, but also saving energy by reducing the idle time of the server by augmenting the workload and the up-time. It is also important to state that, by providing a virtualized solution, the number and variety of applications running can be increased.

There are two kinds of virtualization that may be used in a data center: storage and computing virtualization. Storage-area networks (SAN) may be implemented to present several different physical storage racks as a single virtual storage pool (ANTONOPOULOS, September 2005). On the other hand, computing virtualization It can be implemented in two ways. The first case is when single physical server can offer multiple virtual servers, each with its own OS. Another option is to consolidate multiple physical servers into a cluster that acts as a single server. There are cross-platform server virtualization software available which allows data center managers to cluster and partition servers.

According to the Figure 5 there is a trend indicating an increasing number of virtualized units over time along a forecast that by the end of 2009 the number of virtualized

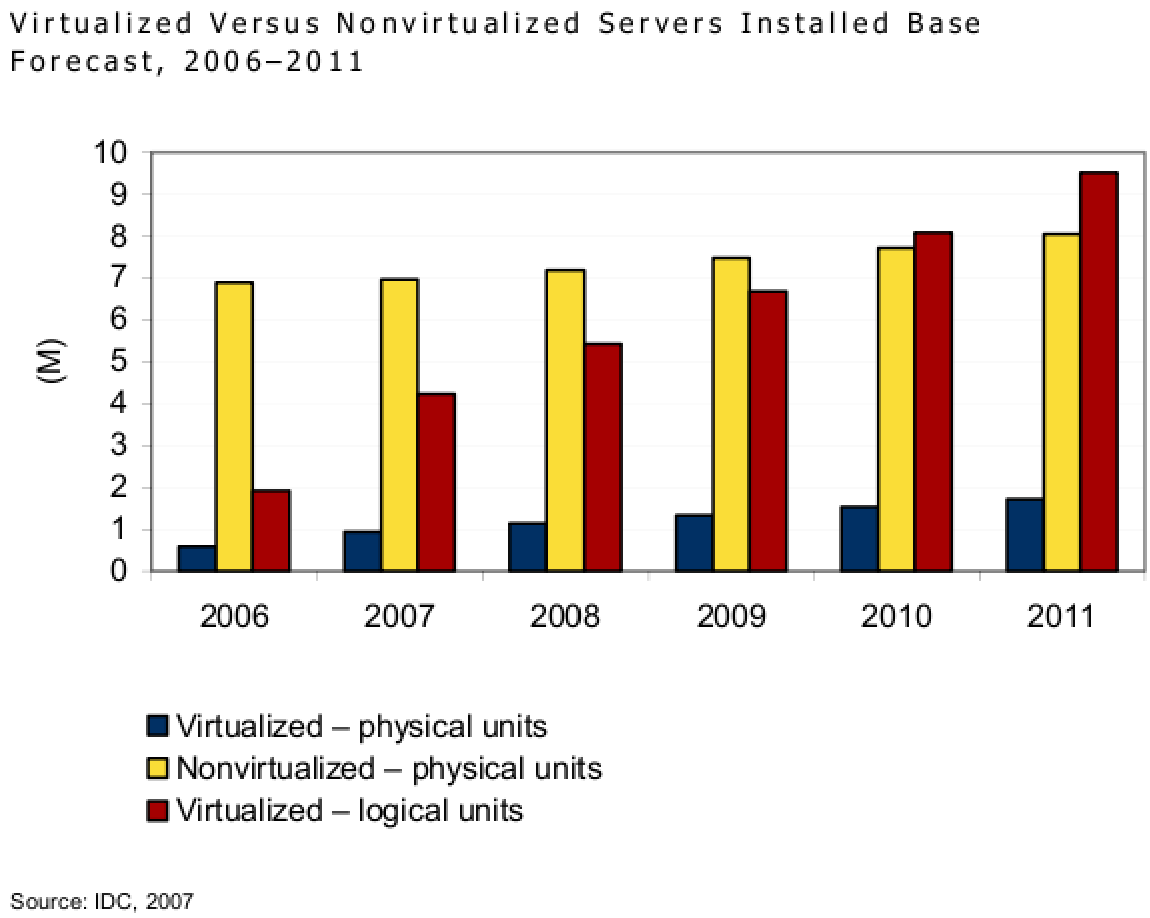

Figure 5: Installed Base of Virtualized and Non-Virtualized Servers

servers will be greater than non-virtualized ones. Logical units represent virtualized storage while physical units represent the use of non-virtualized storage. As shown in the Figure 6, virtualization tools such as VMware allow one physical server to act as a number of logical servers. VMware also provides a benchmark tool called VMmark[4] along with a set of test results in (MAKHIJA, September 2006) for a configuration that includes a mail server, a java server, a standby server, a web server, a database server and a file server.

Coming along with the virtualization trend are high-throughput and eco-responsible processors such as the Sun's UltraSPARC T1 processor (HETHERINGTON, December 2005), which support up to 128 virtualized systems in a single server and gives one of the best performance per watt of the available processors. As shown in the Table 9[5], with relation to the UltraSPARC CPU the only comparable performance was met by the POWER5+ processor, which in average dissipates 4.5 times as much as the earlier.

[4] `http://www.vmware.com/products/vmmark/`
[5] `http://www.anandtech.com/cpuchipsets/showdoc.aspx?i=2657&p=4`

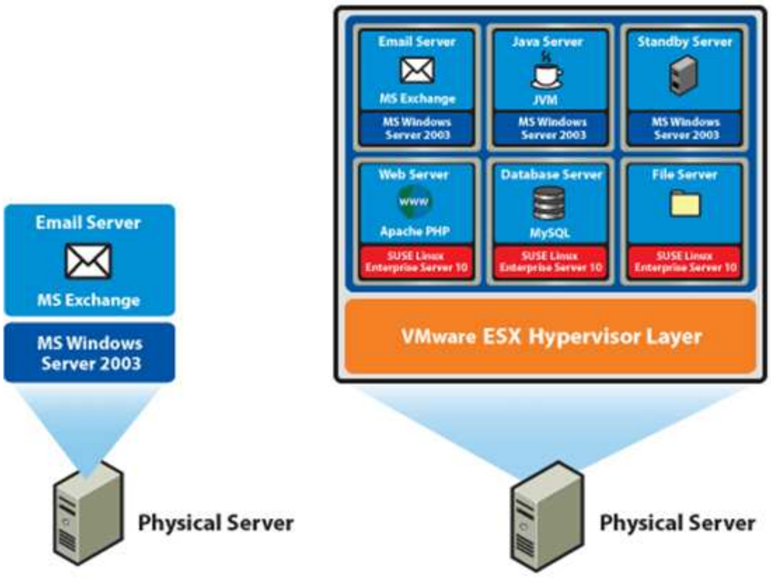

Figure 6: Illustration of Virtualization Applied to a Physical Server

System	CPU	Power Dissipation CPUs (Estimated)	Number of cores	Number of Active Threads	Score (bops)	Score (%)
Sun Fire T2000	1x 1.2GHz UltraSPARC T1	72-79 W	8	32	63.378	160%
Sun Fire X4200	2x 2.4GHz DC Opteron	150-180 W	4	4	45.124	114%
IBM p5 550	2x 1.9GHz POWER5+	320-360 W	4	8	61.789	156%
IBM 346 xSeries	2x 2.8GHz DC Xeon	270-300 W	4	8	39.585	100%

Table 9: Performance and Power Dissipation for Several Processors by the Specjbb2005 Java Benchmark

2.1.5 Data Storage

Data Storage . . .

Tape Drives

A tape drive is a data storage device that reads and writes data stored on a magnetic tape. Its main use is as archival storage of data stored in hard drives. It is typically used for archival storage of data stored on hard drives. Tape media generally has a favorable unit cost; long archival stability and low energy consumption per MB of data stored to compensate for their slow seek times. Despite the slow seek time, tape drives can stream data to tape as quickly as hard drives. For example, modern LTO drives can reach continuous data transfer rates of up to 80MB/s, which is as fast as most 10,000rpm hard disks, according to *Wikipedia, 2008*. Tape drives can range in capacity from a few megabytes to hundreds of gigabytes. Data can be compressed as to maximize the capacity usage. The compression rate is of usually 2:1. A set of tables related to tape drives can be found in Appendix B

Disk Arrays

Disk array refers to a linked group of one or more physical independent hard disk constituting a larger, high-performance system. They are usually implemented using RAID technology, which can provide component redundancy and high throughputs.

Comparison between Tape Drives and Disk Arrays

Supposing a 995 TB database consisting of:

- Storage base (frequently used data)
- Backup cache (13 weeks)
- Backup archive (1 year backup)

A solution consisting exclusively of disk arrays would require four 32-drawer disk array systems of 245 TB each would be necessary. In order to ensure reliability and recoverability, a RAID5 format with two RAID5 arrays assigned to each drawer has been assumed. The total equipment cost is estimated on US$10.57M (REINE, October 2008) and according to the following table the disk array solution consumes 98KWh per TB per year. With a native capacity of 800GB and throughput of 120 MB/sec, an LTO 4

Power	Processor Chassis	Standby Power Supply	Per SATA Drawer	Number of SATA Drawers	Total Array Power	Power Per Day	Annual Power	Annual Cost US$0.12/kWh
Typical	430 W/h	34 W/h	325 W/h	32	11 kW/h	264 kWh	96,360 kWh	11,563
Maximum	800 W/h	300 W/h	425 W/h	32	15 kW/h	360 kWh	131,400 kWh	15,768

Table 10: Disk Array Power Costs

drive has a compressed capability to write at 240 MB/sec, or 864 GB/hour. Supposing the same database is to be entirely stored at this drive, the equipment cost would be of

US$233,878.00 with an annual energy cost of US$599.00.The tape solution will consume 1150 kWh in 1 year or 1,16kWh per TB per year. In overall, for the 995 TB database the

Nº of frames acquired	Nº of drives acquired	Library acquisition cost	Frame acquisition cost	Cartridge cost	Drive acquisition cost	Space cost	Energy cost	Total cost
1	2	76,000	30,000	82,278	45,600	68,850	599	303,327

Table 11: Disk Array Power Costs

following conclusions can be drawn:

- Disk arrays consume 84 times as much as tape drives, per TB stored
- The disk array solution costs 35 times as much as the tape drive solution

Although the cost difference between of both solutions may be high, performance should be also considered in the comparison. In that case, an adequate proportion between disk array and tape storage must be drawn according to the frequency of backup access.

2.1.6 Power Architectures

Conventional AC Architecture

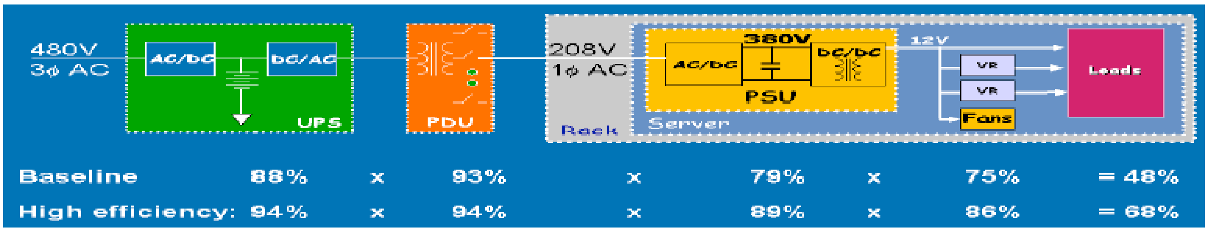

Figure 7: Conventional AC architecture efficiency

In this configuration (Figure 7)the following transformations take place:

- PDU steps down the voltage from 480VAC to 208VAC;
- Power Supply Unit (PSU) converts 208VAC to 380VDC;
- Final component distribution at 12VDC.

The efficiency is measured for both conventional (baseline) and high efficiency (best-in-class) equipments. The difference in efficiency between the two equipment choices is of 20%.

Rack-Level DC Architecture

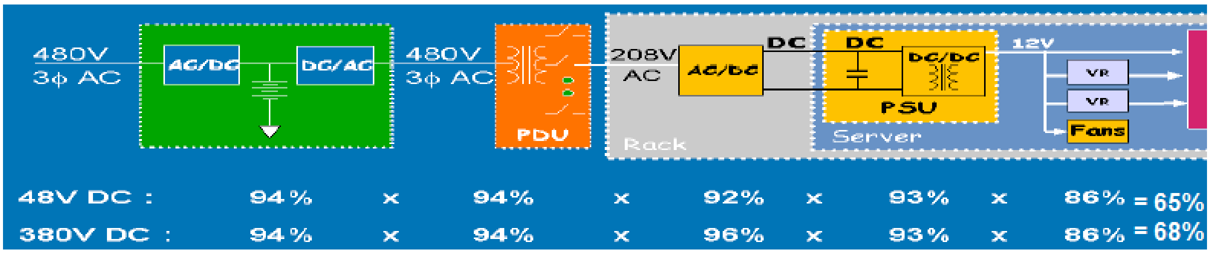

Figure 8: Rack-level DC architecture efficiency

On Figure 8, it is possible to see that, after the PDU, an 208VAC to 48VDC/380VDC conversion is made in the rack. PSU and PDU are considered to be best-in-class, with high efficiency.

Facility-level DC Architecture

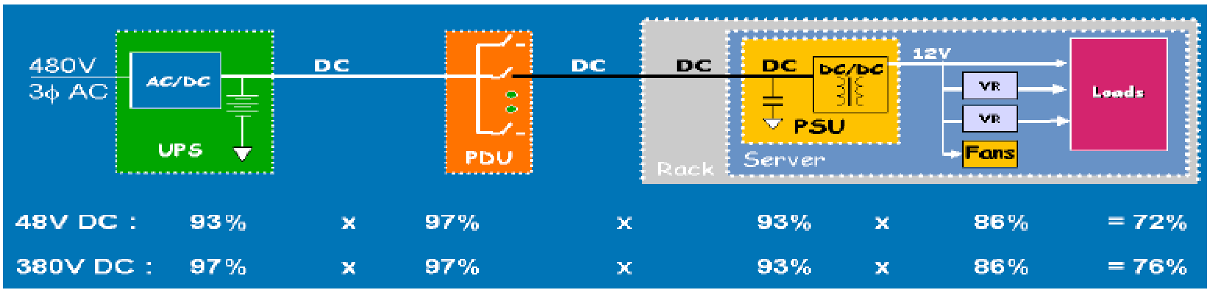

Figure 9: Facility-level DC architecture efficiency

In this configuration (Figure 9), the DC-AC conversion in the UPS and the AC-DC conversion in the power supply are removed. It can be noted that the 480VAC-380VDC conversion in the UPS is more efficient than the 480VAC-48VDC conversion.

2.1.7 Data Center Infrastructure

Water Cooling

The reasonable limit of rack power and cooling capacity for a conventional forced-air (HVAC) cooled data center is 8 kW per rack. For power densities approaching 15 kW per rack, the layout of the computing rooms and cooling facilities must be determined using specialized software (such as HP Static Smart Cooling). For racks requiring more than 15 kW, the latest cooling techniques use water (Figure 10) (HP, April 2007). As shown in the following figure, the use of water cooling reduces in 50% the equipment footprint, allowing

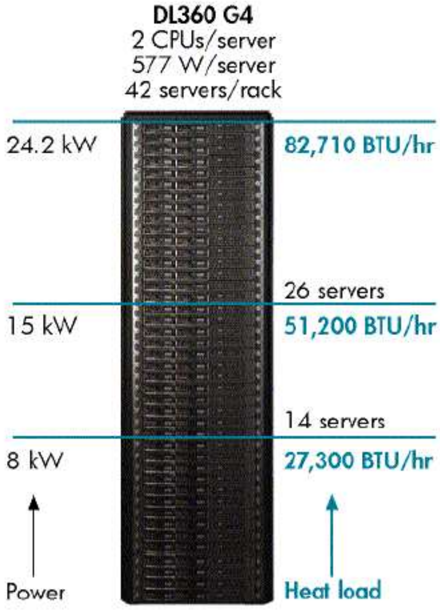

Figure 10: Power Consumption per Number of Servers in the Rack

greater server density. A 35 kW heat load dispersed among 4 racks could be concentrated in one single rack. With relation to maintenance costs, Figure 12 () The annual costs for water cooling and air cooling (including charges, maintenance, equipment) do not differ by a large amount. The main benefit from water cooling is the footprint reduction which can increase the server density in a datacenter[6]

[6]need revision

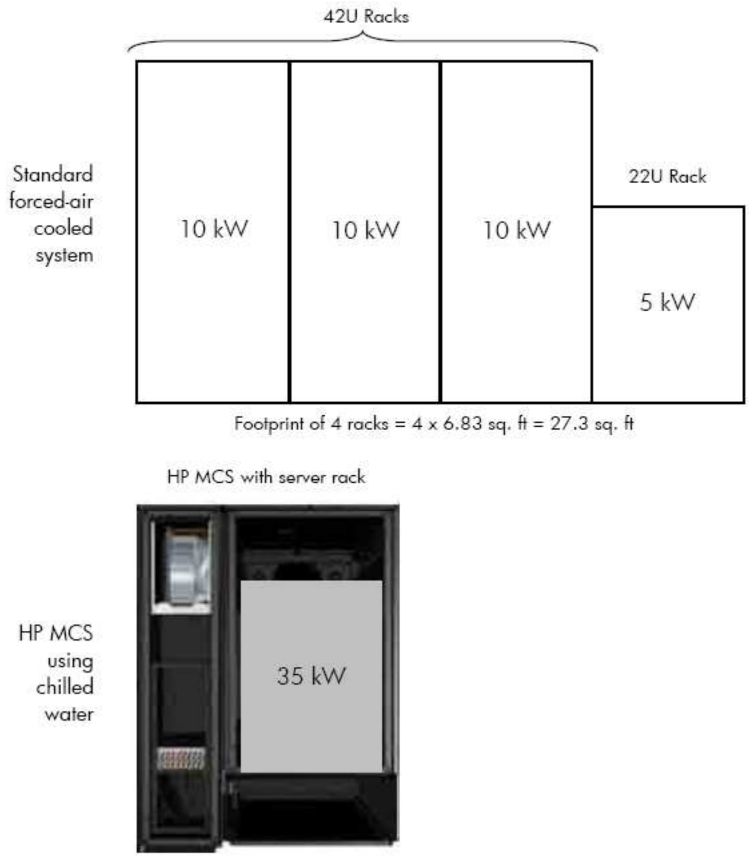

Figure 11: Footprint Reduction for a 35 kW Heat Load

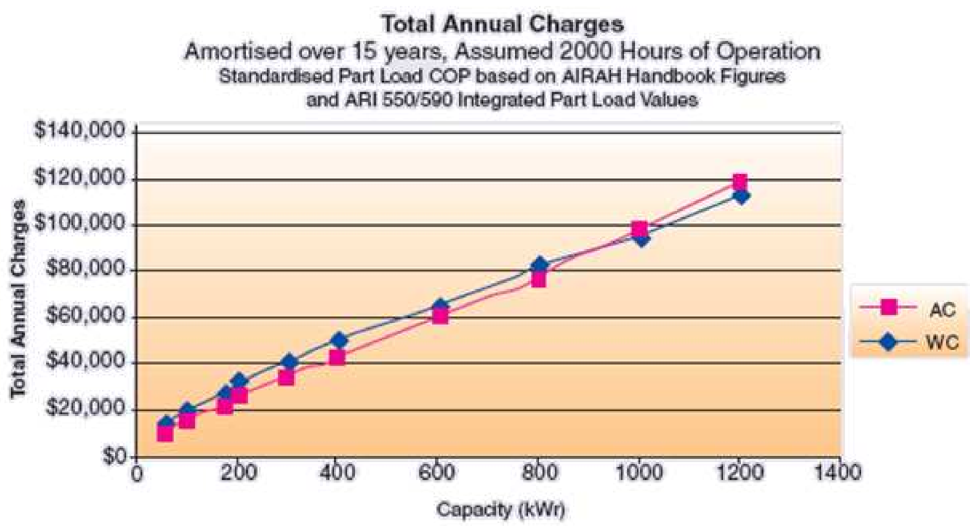

Figure 12: Economic Cross-over of Annualized Charges Air-cooled to Water-cooled for 2000 Hours of Operations (in US $)

2.2 Green ICT

2.3 Devices Consumption

2.4 Measurement Tools

LIFE CYCLE COSTING - TOTAL ANNUAL CHARGES METHOD - TI AE 140									
Generic Comparison 600 kWr @ 3000 hrs		**Option A - Water Cooled With Cooling Tower**				**Option B - Packaged Air Cooled Plant**			
ITEM	**Design Years = n**	**Full Life Cost**	**Annual Charge Factor**	**Present Value (1)**	**Equiv. Annual Charge**	**Full Life Cost**	**Annual Charge Factor**	**Present Value (1)**	**Equiv. Annual Charge**
CAPITAL COSTS									
A - Provision of New Water Cooled Chiller	15	$189,750	0.15		$29,362		0.15		
B - Cost of Air Cooled Packaged Plant.	15		0.15			$159,500	0.15		$24,681
Dosing Set c/w dual biocide and inhibitor pumps	15	$2,750	0.15		$426		0.15		
Water Meter Monitoring	15	$250	0.15		$39		0.15		
Chemical Spill control	15	$50	0.15		$8		0.15		
Cleaning Access to cooling Tower to facility RMP and OH&S requirements	15	$10,000	0.15		$1,547		0.15		
			0.15				0.15		
SUB TOTAL					$31,382				$24,681
RUNNING COSTS		Cost/a				Cost/a			
Water Supply Cost for Options A	15	$2,479	0.15	7.28	$2,792		0.15	7.28	
Water Sewerage Discharge Cost for Options A.	15	$150	0.15	7.28	$169		0.15	7.28	
Annual maintenance Chemical Dosing and Cleaning for Option A	15	$2,022	0.15	7.28	$2,277		0.15	7.28	
Annual Registration Charge and RMP Review for Option A	15	$500	0.15	7.28	$563		0.15	7.28	
A - Estimated Power Cost - for Options A.	15	$36,264	0.15	7.28	$40,837		0.15	7.28	
B - Power Cost - Air Cooled Chiller.	15		0.15	7.28		$45,664	0.15	7.28	$51,423
	15		0.15	7.28			0.15	7.28	
SUB TOTAL					$46,638				$51,423
MAINTENANCE AND REPLACMENT COSTS		Cost.				Cost.			
Option A Compressor and Chiller Component Replacement.	7.5		0.22				0.22		
Option B Fan Motor Replacement	7.5		0.22			$5,000	0.22		$1,083
		Cost/a				Cost/a			
A - General Maintenance Costs for Option A.	15	$1,500	0.15	7.28	$1,689		0.15	7.28	
B - General Maintenance Costs for Option B.	15		0.15	7.28		$500	0.15	7.28	$563
	15		0.15	7.28			0.15	7.28	
	15		0.15	7.28			0.15	7.28	
SUB TOTAL					$1,689				$1,646
SALVAGE VALUE									
A - Scrap Value of Cooling Tower System	15	-$500	0.15	0.16	-$12		0.15	0.16	
B - Scrap Value of Air Cooled Packaged Plant	15		0.15	0.16		-$500	0.15	0.16	-$12
	15		0.15	0.16			0.15	0.16	
SUB TOTAL					-$12				-$12
TOTAL ANNUAL CHARGES					$79,696				$77,738

ASSUMPTIONS
Escalation = e 2.0%
Discount Rate = r 13.0%

NOTES
(1) Present Value (Escalating Annuity) for Running Costs and Maintenance.
Present Value (Single Sum) for Salvage Value and Replacement Costs.

Figure 13: Life Cycle Costs of Water-cooled and Air-cooled Solutions

3 Methodology

Write a review point of the problem and the solution we want to achieve. . . . Describe the general and specific objective . . .

Phase 0: Thesis - In this part the work subject was defined, along with its hypothesis and goals.

Phase 1: Examination - This was the first step taken to begin the research, in which, many components were analyzed and cataloged to later use;

Phase 2: Analysis of Benchmarking Softwares - A number of existing softwares were analyzed and those that met the requirements and specifications previously made were chosen. A list of these other softwares can be found in Appendix C;

Phase 3: Catalog - The tools provided information about computer components that were used to create a component database.

Phase 4: Build Database -

Phase 5: Analysis -

Phase 6: -

3.1 Overview

This research was conducted in order to determine how much energy a computer's components, for instance, CPU[1], Memory and Hard Drives spend and also how much it would affect the cost of acquisition of new workstations as a whole. Above that, the advantages and disadvantages as well as the reliability of these measures and benchmarks played also an important role in the requirements of this thesis work. With regard to

[1]Central Processing Unit

the topic in hand, the analysis was carried out with the help of specialized softwares, which will be described in the following sections and also analytical measures using an energy measurement device to counterbalance and compare the benchmarking measures obtained from these softwares. Concretely, more than 1000 components were analyzed and categorized in a database, whose schema can be further analyzed on Figure 16. Firstly, it was used the Sandra's database 3.3.1 to collect the components and separate them by categories, along with their benchmark related data. Secondly, WebSPHINX 3.3.3 was used to create a collection of components and their respective MPNs. Thirdly, an energy measurement device 3.3.2 was used for the comparison and validation of the results given by the other benchmarks and acquisition of new data.

Finally, these data were all linked in a database for later comparison and choice.

3.2 Research Design

The experimental method of research was used in this study. Figure 14 draws the steps of the method used. To define the experimental type of research, Bryman (BRYMAN, 1989) stated that "the experimental design (...) allows the causal hypothesis that underpins the question to be examined", which means that this method is a systematic and scientific approach to research in which the researcher manipulates one or more variables, controlling and measuring any changes in other variables. The emphasis given is on the results and analysis of the benchmarks provided and theirs measures. It allows to verify the thesis in which this work is based on, by making use of empirical methods changing the benchmark used and the purpose of it.

/********* Os proximos paragraphs foram criados para direcionar o pensamento e deve ser mantidos como comentario, ou retirados do texto Ã© preciso que sejam melhor desenvolvidos*******/

Universe o Study In this study, the empirical method was employed so as to identify which parts of the computer manage energy more efficiently with the reason of building the most green data center.

Subject of Study The choice of analyzing each component separately was made in order to have a better control of the energy consumed and the ability to compare the different combination

Relationship Between certain variables The benchmarks were executed to obtain

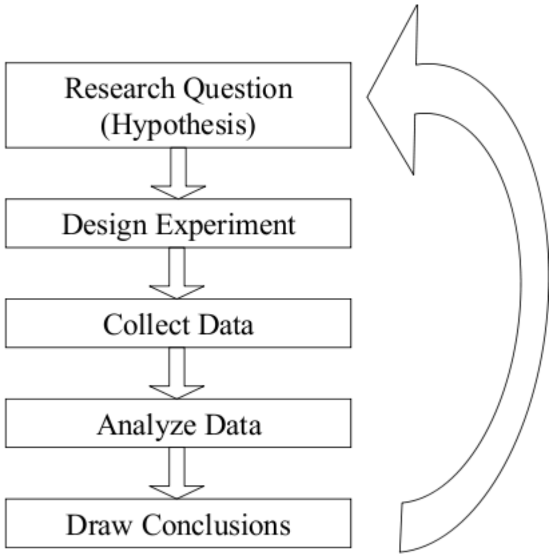

Figure 14: The Experimental Design Process

information about the components, such as speed(MHz), energy consumed (Watts), size(GB, MB),

Set of selected methods for obtain data In order to obtain relevant data, it was chosen two analysis' methods: empirical and benchmarking. In the empirical method, it was used an energy measurement device (section 3.3.2) that connected the electrical plug to the computer, and the measure was taken down in a spreadsheet. While doing this, the benchmarking tool (section 3.3.1) was performed in the host computer

Analytical Categories In a later stage, all the data acquired by the measurement approaches were separated by categories and components

3.3 Energy Management and Benchmarking Tools

In order to obtain relevant information about the data required for making the comparison between the components, it was needed to use some energy management and benchmarking tools.

The softwares used, were selected from many of existents softwares in the area for the following reasons: There exists many softwares

Size of Database The database of components, in order to get a good result should be considerably big;

Characteristics of Benchmarks The benchmarks provided by the software should provide information about the energy consumed for each component;

Number of Benchmarks The software should have a good database of benchmarks;

Quality of Benchmarks Although, the number of benchmarks should be sufficiently, the quality, precision and relevancy were, also, important in the decision method;

Ease of Use In the sense that, the software should provide an ambient of work that is intuitively and comfortable;

something1 explain ;

something2 explain ;

something3 explain ;

The acquisition of data was made analyzing the results of these benchmarks, making use of their database

3.3.1 SiSoftware SANDRA

SiSoftware Sandra[2] is an information and diagnostic utility. It provides most of the information (including undocumented) one need to know about their hardware, software and other devices whether hardware or software. SANDRA was the main software utilized to benchmark the data in this thesis work. It contains a huge database of components to make sure the benchmarks provided have the best results and accurate comparisons.

The software goes beyond the point of other Windows Utilities, by giving the user, the possibility of benchmarking and comparing at both high and low level the computer devices. Moreover, it is a tool for monitoring the performance on systems and even benchmarking many parts of the computer, this includes, CPU[3], memory, hard disks, CD/DVD ROM, network, PSU[4], etc. For that reason, it is considered one of the most complete benchmarking tools available. Besides the benchmarking, Sandra also provides access to information about the Hardware, including the Motherboard, processor, disks, printers, etc; and Software, such as, key softwares (web browsers, e-mail program, etc.), OS information, processes, memory usage and more.

[2] The **S**ystem **AN**alyser, **D**iagnostic and **R**eporting **A**ssistant
[3] Central Processing Unit
[4] Power Supply Unit

The detailed list of modules utilized by SiSoftware Sandra can be found in Appendix A.

Furthermore, the Sandra has a great functionality that is a catalog of pricing, which, in addition to the power consumption and other important characteristics, the best combination (which means the most green) of devices can be chosen to the server.

3.3.2 Energy Measurement Instrument

Figure 15: Energy Measurement Instrument

The device, which can be seen on Figure 15, was used for comparing and validating with the results of the benchmarks given by Sandra.

After the result of the benchmark was obtained from the SiSoftware Sandra, this equipment that was connected to the computer read how much energy it was consumed and it was inserted in the database.

3.3.3 WebSPHINX - A Personal, Customized Web Crawler

WebSPHINX[5] is a Java class library used for web crawling. It provides a way to browse and process web pages automatically.

This piece of software was used to establish the pricing, linking it with the MPN[6], and, afterwards, composing the database explained in 4.1.

[5]Website-Specific Processors for HTML Information Extraction

[6]Manufacturer's Part Number

3.3.4 CPU-Z

CPU-Z detects information about the CPU, RAM Memory, motherboard, chip-set and more. That program was used to complete the database with missing information about the components.

3.4 Data Processing and Analysis

4 Analysis and Results

4.1 Analysis

here it is explained the database, how it was built, the database schema and etc...

4.1.1 Overview

4.2 Results

4.2.1 Benchmark Results

Conclusions

Perspectives and Future Developments

Suggestions for future developments, there are

- Link this research with SaaS
-
-
-
-

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APPENDIX A – List of SiSoftware Sandra Modules

Here is the list of principal modules used in this research work.

•System Summary

•Mainboard/Chipset/System Monitors Info

•CPU/BIOS Info

•APM & ACPI (Advanced Power Management) Info

•PCI(e), AGP, CardBus, PCMCIA bus and devices Info

•Video Information (monitor, card, video bios, caps, etc.)

•OpenGL Information

•Keyboard Info

•Windows Memory Info

•Windows Info

•Font (Raster, Vector, TrueType, OpenType) Information

•Modem/ISDN TA Information

•Network Information*

•IP Network Information*

•WinSock & Internet Security Information

•Drives Information (Removable Hard Disks, CD-ROM/DVD, RamDrives, etc.)

•Ports (Serial/Parallel) Info

•Remote Access Service Connections (Dial-Up, Internet)*

•OLE objects/servers Info*

•Processes (Tasks) & Threads Info

•Modules (DLL, DRV) Info

•Services & Device Drivers (SYS) Info*

•SCSI, SAS Information*

•ATA, ATAPI, SATA, RAID Information

•Data Sources Information*

•CMOS/RTC Information*

•Smart Card & SIM Card Information*

List of Benchmarks

•Arithmetic Benchmark (including SSE2, SSSE3)

•Multi-Media Benchmark

•Multi-Core Efficiency Benchmark

•Power Management Efficiency Benchmark

•File System (Removable, Hard Disks, Network, RamDrives) Benchmark

•Removable Storage/Flash Benchmark

•CD-ROM/DVD Benchmark

•Memory Bandwidth Benchmark

•Cache & Memory Bandwidth Benchmark

•Network/LAN Bandwidth Benchmark

•Internet/ISP Connection Benchmark

•Internet/ISP Peerage Benchmark

Applications and Usage

•Hardware Interrupts Usage*

•DMA Channel Usage*

•I/O Ports Usage*

•Memory Range Usage*

•Plug & Play Enumerator*

•Hardware registry settings

•Environment settings

•Registered File Types

•Key Applications* (web-browser, e-mail, news, anti-virus, firewall, etc.)

•Installed Applications*

•Installed Programs*

•Start Menu Applications*

•Installed Web Packages* (ActiveX, Java classes)

•System Event Logs*

* Commercial version only

APPENDIX B – Comparison Tape Drives

SDLT & DLT Tape Drives	Native Capacity & Transfer Rate	Compressed Capacity & Transfer Rate
DLT-S4	800GB at 60MB/s	1600GB at 320MB/s
SDLT 600	300GB at 36MB/s	600GB at 72MB/s
SDLT 320	160GB at 16MB/s	320GB at 32MB/s
SDLT 220	110GB at 11MB/s	220GB at 22MB/s
DLT 8000	40GB at 6MB/s	80GB at 12MB/s
DLT V4	160GB at 10MB/s	320GB at 20MB/s
DLT1	40GB at 3MB/s	80GB at 12MB/s
DLT-VS160	80GB at 8MB/s	160GB at 16MB/s
DLT-VS80	40GB at 3MB/s	80GB at 6MB/s
DLT 7000	35GB at 5MB/s	70GB at 10MB/s
DLT 4000	20GB at 1.5MB/s	40GB at 3MB/s
DLT 2000XT	15GB at 1.25MB/s	30GB at 2.5MB/s

Table 12: Comparison Between SDLT and DLT Tape Drives Capacities and Transfer Rates

Product	Capacity, native (uncompressed)	Average file access time (first file)	Data transfer rate, native (uncompressed)
T-Series			
T9840A	20 GB	8 sec	10 MB/sec
T9840B	20 GB	8 sec	19 MB/sec
T9840C	40 GB	8 sec	30 MB/sec
T9940A	60 GB	41 sec	10 MB/sec
T9940B	200 GB	41 sec	30 MB/sec
LTO Ultrium			
LTO Gen 1	100 GB	86-96 sec	15-16 MB/sec
LTO Gen 2	200 GB	64-75 sec	32-35 MB/sec
LTO Gen 3	400 GB	72 sec	80 MB/sec
SDLT			
SDLT 320	160 GB	82 sec	16 MB/sec
SDLT 600	300 GB	79 sec	36 MB/sec

Table 13: Access times for several tape drives

SDLT & DLT Tape Drives	**Native Capacity & Transfer Rate**	**Compressed Capacity & Transfer Rate**
LTO-4	800GB at 120MB/s (864GB per hour)	1.6TB at 240MB/s
HP Ultrium 1760	800GB	1.6TB at 576GB/hr
HP Ultrium 1840	800GB at 120MB/s	1.6TB at 240MB/s
HP Ultrium 960	400GB at 80MB/s	800GB at 160MB/s
HP Ultrium 460	200GB at 30MB/s	400GB at 60MB/s
HP Ultrium 230	100GB at 15MB/s	200GB at 30MB/s
IBM LTO-4	800GB at 120MB/s	1.6TB at 240MB/s
IBM LTO-3	400GB at 80MB/s	800GB at 160MB/s
IBM LTO-2	200GB at 35MB/s	400GB at 70MB/s
IBM LTO-1	100GB at 15MB/s	200GB at 30MB/s
Quantum LTO3	400GB at 245GB/hr	800GB at 490GB/hr
Quantum LTO3 HH	400GB at 68MB/s	800GB at 90MB/s
Quantum LTO2	200GB at 123GB/hr	400GB at 245GB/hr
Quantum LTO2HH	200GB at 94GB/hr	400GB at 144GB/hr
Tandberg Data LTO4 FH	800GB at 120MB/s	1.6TB at 240MB/s
Tandberg Data LTO3 FH	400GB at 80MB/s	800GB at 160MB/s
Tandberg Data LTO3 HH	400GB at 60MB/s	800GB at 120MB/s
Tandberg Data LTO2 HH	200GB at 24MB/s	400GB at 48MB/s
Tandberg Data LTO1 HH	100GB at 16MB/s	200GB at 32MB/s
Certance LTO-1	100GB at 960MB/min	200GB at 1920MB/min

Table 14: Comparison Between LTO Tape Drives Capacities and Transfer Rates

APPENDIX C – List of Other Energy Management Tools

C.1 Power To Change

Power To Change is a widget for desktops that measures how much energy was saved when the computer is turned-off. With this application installed, when the machine is turned on, the user can receive information about how much energy and carbon footprint it was saved while it was turned off, and also, compare with global results and others. The widget can be downloaded from `http://www.hp.com/powertochange`.

C.2 PlateSpin - Recon

This software did not compose the ones used for doing this thesis. Yet, it is important to notice this, because it is almost the same of Sandra, but it provides a more incisive work on Data Centers in general. It provides workload profiling, analysis and planning of complex server consolidation, disaster recovery, capacity planning, asset management and green data center initiatives. It also provides forecasting for optimizing the data center by collecting hardware, software and services inventory for all server workloads. Furthermore, it results an statistics work for the server workloads running on data center and how their resources are being used.

C.3 APC Virtualization Energy Cost Calculation

`http://www.techworld.com/green-it/news/index.cfm?RSS&NewsID=116650`

APPENDIX D – Database Schema

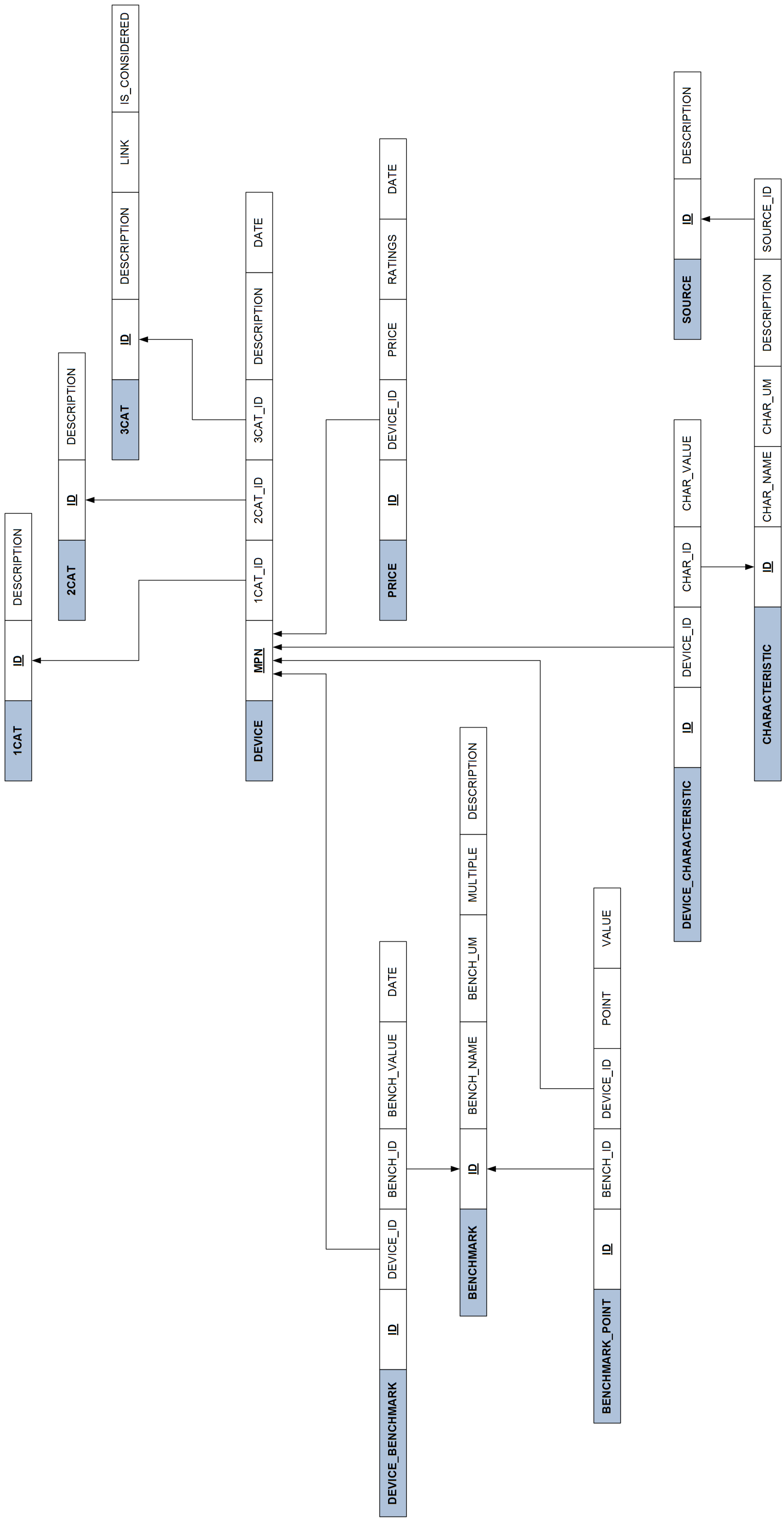

Figure 16: Database Schema