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Data Center Energy Efficiency: Analysis and Test of Energy Consumption Benchmark Tools

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Efficienza Energetica dei Data Center: Analisi e Verifica dei Tool di Benchmark dei Consumi

Tesi di Laurea

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Acknowledgements

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"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***

Questions and Doubts

In order not to have any text not related to the thesis in the middle of the text and maybe, in the final version nobody sees it, I created this file, like that, we can put some information here and delete it in the last version. Of course, these are not the only issues related to the thesis, but it is better to have a centralized way to do that.

The questions are:

Section ?? or Appendix ?? Do we need to insert all tables here, in appendix, or where do we need to insert the tables? Or just the database schema? These tables were taken from the SANDRA Access file.

Section ?? special attention to the schema of the database with measures with the measurement tool provided.

Figure ?? Can we insert a picture with the Toms hardware logo, or do we need to port it and provide the source?

Figure ?? same as above.

Computer Model	***Idle* with monitor on (W)**	***Idle* with monitor off (W)**	**Estimated Monitor Power (W)**	**Processor fully stressed**
HPdv3500el	28.57	25.19	3.38	35.64
HPdv6580el	62.18	57.14	5.04	85.27
Compaq-nx9420	78.89	74.65	4.24	79.64
Acer Aspire 6935g	38.67	33.76	4.91	55.39
Acer Aspire 4720z	44.57	39.88	4.69	67.28
Acer Aspire 5930G	44.48	39.56	4.92	62.83
HP dv6000	43.65	39.12	4.53	58.95
Toshiba	54.80	46.03	8.77	65.73
Fujistu AMILO Pa2548	60.28	55.40	4.88	87.40
Samsung Q310	33.60	26.60	7.00	48.55
Acer Aspire 5930G	39.33	32.52	6.81	62.40
HP Pavilion dv6000	34.06	29.38	4.68	48.20
Sony Vaio SZ650N	52.44	45.67	6.77	81.65
HP Pavilion ze2000	37.48	31.48	6.00	58.34
Sony Vaio v6nfw11e	34.84	29.57	5.27	44.14
Asus F3 Series	47.63	38.98	8.65	50.33
HP 550	41.31	33.60	7.71	48.11

Table 1: Measures made with the Energy Measurement Device

Computer Model	Processor Benchmark (W)	Cache & Memory Benchmark[a] (W)	Physical Disks Benchmark (W)
HPdv3500el	19.69	26.69	N/A
HPdv6580el	32.01	40.06	2.00
Compaq-nx9420	26.93	36.16	N/A
Acer Aspire 6935g	28.03	35.03	N/A
Acer Aspire 4720z	19.78	34.57	N/A
Acer Aspire 5930G	25.13	32.13	N/A
HP dv6000	25.00	34.23	N/A
Toshiba	22.50	31.24	N/A
Fujistu AMILO Pa2548	N/A	N/A	N/A
Samsung Q310	26.28	33.28	N/A
Acer Aspire 5930G	38.60	47.63	N/A
HP Pavilion dv6000	12.95	31.84	N/A
Sony Vaio SZ650N	28.99	49.68	N/A
HP Pavilion ze2000	14.62	17.86	N/A
Sony Vaio v6nfw11e	35.08	42.08	N/A
Asus F3 Series	12.44	28.53	N/A
HP 550	29.63	44.42	N/A

[a] chipset + processor + memory
N/A Not Returned a Valuable Result

Table 2: Measures Resulted from Benchmark with SANDRA

Computer Model	Processor Model
HPdv3500el	Intel Core Duo P8400 @ 2.26GHz
HPdv6580el	Intel Core Duo T7300 @ 2.00GHz
Compaq-nx9420	Intel Core Duo T2400 @ 1.83 GHz
Acer Aspire 6935g	Intel Core Duo T6400 @ 2.00GHz
Acer Aspire 4720z	Intel Core Duo T2310 @ 1.66 GHz
Acer Aspire 5930G	Intel Core 2 P7350 @ 2.0GHz
HP dv6000	Intel Core Duo T5600 @ 1.83GHz
Toshiba	Intel Core Duo T2300 @ 1.66 GHz
Fujistu AMILO Pa2548	AMD Turion 64 X2 TL-58 @ 1.9GHz
Samsung Q310	Intel Core Duo P7350 @ 2.00GHz
Acer Aspire 5930G	Intel Core Duo T9400 @ 2.53GHz
HP Pavilion dv6000	Intel Core Duo T5450 @ 1.66GHz
Sony Vaio SZ650N	Intel Core Duo T7500 @ 2.20 GHz
HP Pavilion ze2000	Intel Pentium M 1.60 GHz
Sony Vaio v6nfw11e	Intel Core Duo P8400 @ 2.26 GHz
Asus F3 Series	Intel Core Duo T7300 @ 2.00GHz
HP 550	Intel Celeron 530 @ 1.73 GHz

Table 3: Processor Contained in each Measured Computer

Processor Model	Processor nominal power (W)
Intel Core Duo P8400 @ 2.26GHz	25
Intel Core Duo T7300 @ 2.00GHz	35
Intel Core Duo T2400 @ 1.83 GHz	31
Intel Core Duo T6400 @ 2.00GHz	35
Intel Core Duo T2310 @ 1.66 GHz	35
Intel Core 2 P7350 @ 2.0GHz	25
Intel Core Duo T5600 @ 1.83GHz	34
Intel Core Duo T2300 @ 1.66 GHz	31
AMD Turion 64 X2 TL-58 @ 1.9GHz	31
Intel Core Duo P7350 @ 2.00GHz	25
Intel Core Duo T9400 @ 2.53GHz	35
Intel Core Duo T5450 @ 1.66GHz	35
Intel Core Duo T7500 @ 2.20 GHz	35
Intel Pentium M 1.60 GHz	35
Intel Core Duo P8400 @ 2.26 GHz	25
Intel Core Duo T7300 @ 2.00GHz	35
Intel Celeron 530 @ 1.73 GHz	27

Table 4: Manufacturer Specification

Computer Model	Benchmark Processor Power (W)	Nominal Processor Power (W)	Incompatible Results
HPdv3500el	19.69	25	
HPdv6580el	32.01	35	
Compaq-nx9420	26.93	31	
Acer Aspire 6935g	28.03	35	
Acer Aspire 4720z	19.78	35	
Acer Aspire 5930G	25.13	25	**x**
HP dv6000	25	34	
Toshiba	22.5	31	
Fujistu AMILO Pa2548	N/A	31	
Samsung Q310	26.28	25	**x**
Acer Aspire 5930G	38.6	35	**x**
HP Pavilion dv6000	12.95	35	
Sony Vaio SZ650N	28.99	35	
HP Pavilion ze2000	14.62	35	
Sony Vaio v6nfw11e	35.08	25	**x**
Asus F3 Series	12.44	35	
HP 550	29.63	27	**x**

N/A Not Returned a Valuable Result

Table 5: Processor Specifications' Results

Computer Model	Measurement Result: *Idle* With Monitor Off (W)	Estimated PSU Power[a] (W)	Measured Power[b] (W)
HPdv3500el	25.19	6.30	18.89
HPdv6580el	57.14	14.29	42.86
Compaq-nx9420	74.65	18.66	55.99
Acer Aspire 6935g	33.76	8.44	25.32
Acer Aspire 4720z	39.88	9.97	29.91
Acer Aspire 5930G	39.56	9.89	29.67
HP dv6000	39.12	9.78	29.34
Toshiba	46.03	11.51	34.52
Fujistu AMILO Pa2548	55.40	13.85	41.55
Samsung Q310	26.60	6.65	19.95
Acer Aspire 5930G	32.52	8.13	24.39
HP Pavilion dv6000	29.38	7.35	22.04
Sony Vaio SZ650N	45.67	11.42	34.25
HP Pavilion ze2000	31.48	7.87	23.61
Sony Vaio v6nfw11e	29.57	7.39	22.18
Asus F3 Series	38.98	9.75	29.24
HP 550	33.60	8.40	25.20

[a] at 75% Efficiency

[b] processor/chipset/memory

Table 6: Measures with Processor in *idle* state

Computer Model	**Measurement result: *Fully Stressed*[a] (W)**	**Estimated PSU Power[b] (W)**	**Measured power[c] (W)**
HPdv3500el	32.26	8.07	24.20
HPdv6580el	80.23	20.06	60.17
Compaq-nx9420	75.40	18.85	56.55
Acer Aspire 6935g	50.48	12.62	37.86
Acer Aspire 4720z	62.59	15.65	46.94
Acer Aspire 5930G	57.91	14.48	43.43
HP dv6000	54.42	13.61	40.82
Toshiba	56.96	14.24	42.72
Fujistu AMILO Pa2548	82.52	20.63	61.89
Samsung Q310	41.55	10.39	31.16
Acer Aspire 5930G	55.59	13.90	41.69
HP Pavilion dv6000	43.52	10.88	32.64
Sony Vaio SZ650N	74.88	18.72	56.16
HP Pavilion ze2000	52.34	13.09	39.26
Sony Vaio v6nfw11e	38.87	9.72	29.15
Asus F3 Series	41.68	10.42	31.26
HP 550	40.40	10.10	30.30

[a] estimated monitor power [b] at 75% efficiency
[c]processor/chipset/memory

Table 7: Measures with Processor *Fully Stressed*

Computer Model	Sandra Benchmark: Measurement of Consumption[a]	Measured Consumption[a]	Percentual delta over the measured values
HPdv3500el	26.69	18.89	41%
HPdv6580el	40.06	42.86	7%
Compaq-nx9420	36.16	55.99	35%
Acer Aspire 6935g	35.03	25.32	38%
Acer Aspire 4720z	34.57	29.91	16%
Acer Aspire 5930G	32.13	29.67	8%
HP dv6000	34.23	29.34	17%
Toshiba	31.24	34.52	10%
Samsung Q310	33.28	19.95	67%
Acer Aspire 5930G	47.63	24.39	95%
HP Pavilion dv6000	31.84	22.04	44%
Sony Vaio SZ650N	49.68	34.25	45%
HP Pavilion ze2000	17.86	23.61	24%
Sony Vaio v6nfw11e	42.08	22.18	90%
Asus F3 Series	28.53	29.24	2%
HP 550	44.42	25.20	76%
		Average delta:	**39%**

[a] chipset+processor+memory

Table 8: Results for Processor in *Idle* State

Computer Model	Sandra Benchmark: measurement of Consumption[a]	Measured Consumption[a]	Percentual delta over the measured values
HPdv3500el	26.69	24.20	10%
HPdv6580el	40.06	60.17	33%
Compaq-nx9420	36.16	56.55	36%
Acer Aspire 6935g	35.03	37.86	7%
Acer Aspire 4720z	34.57	46.94	26%
Acer Aspire 5930G	32.13	43.43	26%
HP dv6000	34.23	40.82	16%
Toshiba	31.24	42.72	27%
Samsung Q310	33.28	31.16	7%
Acer Aspire 5930G	47.63	41.69	14%
HP Pavilion dv6000	31.84	32.64	2%
Sony Vaio SZ650N	49.68	56.16	12%
HP Pavilion ze2000	17.86	39.26	55%
Sony Vaio v6nfw11e	42.08	29.15	44%
Asus F3 Series	28.53	31.26	9%
HP 550	44.42	30.30	47%
		Average delta:	**23%**

[a] chipset+processor+memory

Table 9: Results for Processor *Fully Stressed*

Glossary of Abrevitations

x	x
ALU	Arithmetic Logic Unit
CIO	Chief Information Officer
CPU	Central Processing Unit
DDR	Double-Data Rate
FPU	Floating Point Unit
HVAC	
HDD	Hard-disk 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
ROM	Read-Only Memory
SaaS	Software as a Service
SDRAM	Synchronous Dynamic Random Access Memory
SAN	Storage-Area Networks
TCO	Total Cost of Ownership
VM	Virtual Machine
VPN	Virtual Private Network
x	x

Abstract

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1 Conclusions

This chapter summarizes the main findings of this study and draws out their support for applying a green solution. It thereby aims to enrich the understanding of the method and of the valuable information that can be extracted from the created database.

The use of *green ict* applied to data centers can be a very useful strategy in different scenarios. The database of components resulted from this thesis work can be very effective for what it is proposed to be: offering a way to compare the energy consumption of the computer components in one single place. Retrieving information about how much components spend in terms of power consumption will help the development of the green project in the *Assessment* phase by comparing components already existent in the market with the ones present in the data center. That is important firstly because the analysis and research of power consumption of critical spots can be made with ease. The database can also provide assessment when renewing or expanding the data center by permitting the choice of the most adequate and power-efficient machine configurations.

In the test conducted with a series of notebooks, the results of the power consumption data analysis proved that the power consumption estimated by the Sandra benchmarks is inaccurate. Although its estimates were incompatible with respect to the direct measurements, the usefulness of the component database should be no lesser. It provides a great number of other useful information, mainly regarding component performance benchmarks and price which are essential when analyzing datacenter equipment.

In this way, for the component database to provide support for a green ICT methodology a new source of power-related data should be found. This could be a systematic measurement of components with an adequate aggregation level or a function of the nominal power found in component specifications.

1.1 Perspectives and Future Developments

As part of the initial phase of the development of a green methodology, there are some possible functionalities and information that could still be added. These are as follows:

- This first version of the component's database is not automatically updated, so it could be made a back-end robot which would crawl for new components as they are released in the market and automatically populate the database;
- As stated before, the use of a new source of power-related information was suggested. This information should then be inserted in the component database as to make efficiency (performance/power) comparison between components.
- To create a front-end software for a interactive and effective way of comparing the components.

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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 10: 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 11: 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 12: Comparison Between LTO Tape Drives Capacities and Transfer Rates