Topten Technology Paper on

energy-efficient servers and data storage equipment (Guidelines for Procurement)

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The Project in brief

Topten is part of the international Euro-Topten-Max initiative supported by the European programme Intelligent Energy Europe and several national institutions (energy agencies, WWF, consumer associations, research institutes). On global level, Topten is coordinated by TIG, the Topten International Group. This association promotes to the Topten Charter, TIG statutes and Rules of Procedure (www.topten.eu).

Topten is a service that supports the market for energy efficient products. It aims at making energy efficient products the first choice for consumers, by offering them a user-friendly tool for product comparison and selection. The key element is an online information platform for consumers presenting the most energy efficient appliances currently available in various product categories, including household appliances, office equipment, consumer electronics and cars. Information on energy consumption and performance of products as well as several other characteristics (i.e. brand, model, price, picture) is provided. Product data is based on labels and standardized declarations as well as tests from accepted well-known institutions. The service is independent of manufacturers and retailers.

Consortium

The project is co-ordinated by the Agence de l'Environnement et de la Maitrise de l'Energie (ADEME). The other 19 project partners are:

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Topten Technology Paper
on energy-efficient servers and data storage equipment

Contents

1 Introduction

Technology papers provide detailed information for product categories that offer high energy saving potential and are not yet covered by regulations or products behaving as systems as opposed to plug-in products. Technology papers are for products that cannot easily be addressed in the form of a Topten recommended product list. They present expert recommendations on how to choose an efficient product and what has to be considered for a well-sized and efficient installation.

This technology paper contains guidelines for procurement of server equipment, information about legislation and labels and best practice advices.

Technology papers support the Euro-Topten-Max partners with detailed information about technologies in order to develop potential recommendations, articles or procurement guidelines for national Topten websites.

According to international studies, the energy consumption in server rooms and data centres has increased in the US and EU by 60 %[1] from 2005 to 2010. This rising trend still continues due to more powerful equipment and more complex IT services. Furthermore the number of servers in the world will increase from 18 million in 2007 to 122 million in 2020. This will create many adverse environmental effects. Aspects to consider are the generation of electronic waste and the consumption of energy and materials.The energy consumption in server rooms (including IT equipment, the cooling system, the lighting) is the most significant environmental impact. Due to the relatively short lifespan of data centre equipment (servers: 3-5 years, network equipment: 5-7 years and infrastructure: 10-15 years) consumption of materials and generation of electronic waste is also an aspect to consider.

New technologies such as innovative hardware and power management options have been developed to improve efficiency. So far there is no mandatory regulation addressing energy consumption. First voluntary efficiency criteria have been developed by ENERGY STAR in 2009. Moreover, the energy efficiency benchmark SPECpower for servers is available since 2008. A more comprehensive benchmark suite for servers also to be used in the Energy Star framework will become available in late 2012 (SPEC SERT). The information in this technology paper is mainly based on ENERGY STAR requirements and sources from the IEE project PrimeEnergyIT.

[1] Procurement guidance for energy efficient server room and data centre equipment, http://www.efficient-datacenter.eu/ (Website of the IEE project PrimeEnergyIT)

2 Overview Legislations and Labels

Energy efficiency criteria for servers are still in their early stages. Criteria for other IT products such as PCs, printers and monitors are available for a longer time, whereas the development of server benchmarks and standards only began in late 2007.

To date there is no mandatory energy label or Eco-Design measure for servers and server equipment in place in the EU, though there is a draft regulation being discussed (see below).

This chapter gives a short overview of the relevant legislation and labels. More information about the labels can be found in Chapter 5 “Guidelines for procurement”.

2.1 International standards and benchmarks for energy-efficient servers

There are voluntary labels developed in Europe and outside, with specifications highlighting energy efficient and environmental friendly products. These labels are often used by manufacturers.

2.1.1 Ecodesign requirements for computers and computers servers (in preparation)

Currently the Commission Regulation implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to eco-design requirements for computers (desktop computers, workstations) and computer servers is under preparation and shall be finished in the following months. In the draft regulation (August 2012) there are criteria’s for computer servers (which have less than four processor four processor sockets) and small scale servers covering internal power supply efficiency and information requirements for manufacturers. The regulation doesn’t apply to blade system and components, server appliances, multi-node servers and computer servers with more than four processor sockets.

The technical specifications of the regulation have been specified similar to the ENERGY STAR and the 80 PLUS certification scheme.

2.1.2 ENERGY STAR[2]

Energy Star is a voluntary label developed by the US that identifies the most energy efficient products on the market. To be eligible for Energy Star, products must meet specified criteria including energy efficiency minimum standards. Since 2000, the EU has an agreement with the US to use the label for office ICT equipment (computers, monitors, printers, etc).

The US-EU agreement expired at the end of 2011 and is currently renewed. Due to the temporary expiration of the agreement Energy Star compliant products are currently only listed on the US ENERGY STAR website:[3] http://www.energystar.gov/ia/partners/product_specs/program_reqs/computer_server_prog_req.pdf

In the ENERGY STAR program requirements for Computer Servers criteria are defined for power supply efficiency, idle power, standard information reporting, data measurement and output requirements.

Currently Version 2 of the ENERGY STAR specification for computer servers is available (Effective December 16, 2013; note: as of March 15, 2013, manufacturers may have products certified to V2) and can be downloaded at http://www.energystar.gov/ia/partners/prod_development/revisions/downloads/computer_servers/Program_Requirements_V2.0.pdf?c327-16f0

Currently EPA is developing a new ENERGY STAR product specification for data center storage (https://energystar.gov/products/specs/node/144).

The ENERGY STAR requirements are described in detail in Chapter 5 “Guidelines for procurement”.

[2] http://www.energystar.org
[3] If the EU programme continues the products for the EU will be listed at http://www.eu-energystar.org

2.1.3 The Standard Performance Evaluation Corporation (SPEC)[4]

The Standard Performance Evaluation Corporation (SPEC) is a non-profit corporation formed to establish, maintain and endorse a standardized set of relevant benchmarks that can be applied to the newest generation of high-performance computers and servers. The corporation with its headquarter in the USA was founded in 1988 by a small number of workstation vendors. SPEC develops benchmark suites and also reviews and publishes submitted results from their member organizations and other benchmark licensees.

SPECpower_ssj2008 was the first standard benchmark supporting energy efficiency assessment of volume class servers. It addresses mainly CPU related efficiency and thus provides a good assessment regarding CPU intensive workloads. At the moment a Server Efficiency Rating Tool (SERT) for supporting IT managers in selecting energy efficient hardware is being developed. The tool will consider server efficiency based on partial benchmarks for CPU, memory, storage and system and is designed to satisfy the needs of the ENERGY STAR program as well as other energy efficiency programs around the globe. In ENERGY STAR version 2 for servers SERT shall be included as an assessment tool.

Usually, the data needed for the SPEC Benchmarks are not published by manufacturers. So it is necessary to ask the manufacturers for the required data. More information about SPEC can be found in Chapter 5 “Guidelines for procurement”.

2.1.4 80 PLUS initiative[5]

80 PLUS™ is an electric utility-funded incentive programme founded in the USA supporting the integration of more energy-efficient power supplies into desktop computers and servers. There are also power supplies in Europe available with the 80 PLUS label. The 80 PLUS™ performance specification for power supplies in computers and servers requires at minimum 80 % efficiency. This makes an 80 PLUS certified power supply substantially more efficient than typical power supplies.

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[4] http://www.spec.org/sert/

[5] http://www.plugloadsolutions.com/ or http://www.80plus.org

2.1.5 European Code of Conduct for data centers

The aim is to inform and stimulate data centre operators and owners to reduce energy consumption in a cost-effective manner without hampering the mission critical function of data centres. The Code of Conduct aims to achieve this by improving understanding of energy demand within the data centre, raising awareness, and recommending energy efficient best practice and targets. (Best practice guidelines: http://iet.jrc.ec.europa.eu/energyefficiency/sites/energyefficiency/files/best_practices_v3_0_8_2_final_release_dec_2011.pdf)[6]

2.1.6 The Green Grid

As a global consortium comprised of end-users, policy-makers, technology providers, facility architects, and utility companies, The Green Grid aims to improve data center resource efficiency. (http://www.thegreengrid.org/)

2.2 Other general regulations covering server equipment

2.2.1 WEEE Directive on waste electrical and electronic equipment 2012/19/EU (July 2012)[7]

The new WEEE Directive 2012/19/EU has been published in issue L197 of the Official Journal on 24 July 2012.

The purpose of the Directive 2012/19/EU is to contribute to sustainable production and consumption by, as a first priority, the prevention of WEEE and, in addition, by the re-use, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste and to contribute to the efficient use of resources and the retrieval of valuable secondary raw materials.

It also seeks to improve the environmental performance of all operators involved in the life cycle of EEE, e.g. producers, distributors and consumers and, in particular, those operators directly involved in the collection and treatment of WEEE. In particular, different national applications of the ‘producer responsibility’ principle may lead to substantial disparities in the financial burden on economic operators.

The provisions of this Directive should apply to products and producers irrespective of selling technique, including distance and electronic selling. In this connection, the obligations of producers and distributors using distance and electronic selling channels should, as far as is practicable, take the same form, and should be enforced in the

[6] http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/data-centres-energy-efficiency
[7] http://ec.europa.eu/environment/waste/weee_index.tm

same way, as for other distribution channels, in order to avoid those other distribution channels having to bear the costs resulting from this Directive arising from WEEE for which the equipment was sold by distance or electronic selling.

2.2.2 Directive 2011/65/EU on the restriction of the use of certain hazardous substances (RoHs) in electrical and electronic equipment (June 2011)[8]

The directive restricts the use of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) for electronic products. In annex I of the directive where the covered product categories are listed also IT equipment is mentioned.

2.2.3 EMC – Electromagnetic compatibility[9]

The Electromagnetic compatibility - EMC directive, 89/336/EEC (replaced by 2004/108/EC) sets restrictions on the emission of electromagnetic radiation and on the immunity against electromagnetic radiation for electronic products. Countries outside the EU have similar regulations although the detailed requirements differ. In some countries there are, for instance, no restrictions on immunity.

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[8] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:174:0088:0110:EN:PDF

[9] http://ec.europa.eu/enterprise/sectors/electrical/emc/

3 Product Definition

Servers and server equipment are available in a lot of configurations and product ranges. The definitions mentioned below come from the ENERGY STAR Program Requirements for Computer Servers (Version 1).

The full definition and specifications in order to qualify for ENERGY STAR as well as test methods can be found in "ENERGY STAR® Program Requirements for Computer Servers Version 1.0", at
http://www.energystar.gov/ia/partners/product_specs/program_reqs/computer_server_prog_req.pdf

3.1 Definitions[10]

A **computer server** provides services and manages networked resources for client devices, e.g., desktop computers, notebook computers, thin clients, wireless devices, Personal Digital Assistants (PDAs), Internet Protocol (IP) telephones, other computer servers and other networked devices. Computer servers are used in data centres and office/corporate environments. Computer servers are primarily accessed via network connections, and not through direct user input devices such as a keyboard, mouse, etc.

3.1.1 Computer Server Types

Blade Server: A Computer Server consisting of, at minimum, a processor and system memory that relies on shared resources (e.g., power supplies, cooling, etc.) for operation. Blade Servers are designed to be installed in a Blade Chassis, are hot-swappable (replacement of a device with a similar device while the computer system remains in operation) and are incapable of operating independent of the chassis.

In the last few years the blade servers have been the fastest growing market segment. It is therefore important to make this technology very energy efficient.

Blade chassis typically contain 7, 14 or more blade server modules. Chassis support server-, storage- and network modules and can be optimised for specific applications and user types. Compared to standard rack servers, with the blade technology a reduction of some hardware components like power supplies, network Input/Output (I/O) and wiring which are shared by several servers in the common enclosure is possible.

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[10] ENERGY STAR® Program Requirements for Computer Servers, (Version 1)
http://www.energystar.gov/ia/partners/product_specs/program_reqs/computer_server_prog_req.pdf

The key benefits of blade systems are:

- High computing density and low space demand
- Reduced time for maintenance and upgrade of the system due to hot-plug replacement of modules and integrated management features
- Slightly higher energy efficiency as compared to rack servers if power management and cooling is optimised

However, if high blade densities are implemented, requirements regarding infrastructure and cooling strongly increase. High computing density increases power densities to 10–25 kW/rack. Therefore, the standard cooling in data centres and server rooms is mostly not sufficient and specific cooling concepts are necessary. Consequently, energy efficiency of a blade concept also strongly depends on the overall system design.

Figure 3.1: Blade chassis (Source: maxi-pedia.com)

Blade chassis and blade components: Fewer and more efficient power supplies, more efficient fans and extended energy management options in the blade chassis provide higher energy efficiency as compared to standard rack servers in principal. However, efficiency in practice strongly depends on the configuration of the chassis as well as on the use of the power management options. Chassis configured with only a few blades will clearly be less efficient, due to over-provisioning of cooling, power and network capacity

Dual-node and multi-node concepts are based on a similar philosophy as blade servers. In the multi-node concept, a fixed number of server units (commonly 2 or 4) is combined in one rack-mounted chassis. Similar to blades, the servers share power supplies and fans, however there are few expansion options. Dual-node and multi-node servers are designed and built as a single enclosure and are not hot-swappable. Thus, multi-node technology is an approach to implement higher computing density at comparably low cost, often designed for purposes of small and medium enterprises.

However, there are also special high performance dual-node servers available for example for blade systems, which combine two server nodes in one blade.

Figure 3.2 Standard dual node server (Source: stealth.com)

The main benefits of standard dual and multi-node systems are:

- Lower cost and space demand as compared to standard rack servers
- Slightly lower energy consumption due to shared power supplies and fans

3.1.2 Other Data Centre Equipment

Storage Equipment: A system composed of integrated storage controllers, storage devices (e.g., hard drives or solid-state storage) and software that provides data storage services to one or more computer servers. While storage equipment may contain one or more embedded processors, these processors do not execute user-supplied software applications. They may execute data-specific applications (e.g., data replication, backup utilities, data compression, install agents, etc.).

Network Equipment: Equipment whose primary function is to provide data connectivity among devices connected to its several ports. Data connectivity is achieved via the routing of data packets encapsulated according to the Internet Protocol, Fibre Channel, InfiniBand or similar protocols. Examples of network equipment commonly found in data centres are routers and switches.

4 Monitoring of energy consumption in server rooms[11]

Monitoring of the energy consumption in server rooms and data centres is essential to identify energy saving potentials and to evaluate the effectiveness of efficiency measures. It also provides a good basis for energy efficient hardware renewal. Monitoring concepts should be designed with care to ensure that right data is collected.

The following aspects have to be considered:

- Required accuracy and resolution of data
- Breakdown of data collection, ability to collect data from all desired devices
- User friendliness
- Adaptability to new measurement needs
- Data analysis options and integration with control systems
- Ability to detect problems and notify data centre operators
- Investement costs and pay-back

Depending on the size of the server room or data centre the complexity of monitoring methods can be quite different:

The **minimum monitoring** for very small facilities includes periodic spot measurements with portable equipment and the use of the manufacturer's information (power input etc.).

Figure 4.1: Example of a portable single phase and three phase power meter (Source: Chauvin Arnoux)

[11] Energy efficient IT and infrastructure for data centres and server rooms, http://www.efficient-datacenter.eu/

For **advanced monitoring,** the data is recorded in real time by using permanently installed equipment that is not necessarily supported by online tools. For the necessary small modifications to the infrastructure a technical staff is required.

State-of-the-Art monitoring is done with online software with extensive capability for analysis. The data is collected in real time with permanent recording systems. Infra-structure modifications and expert technical staff are usually necessary.

Examples of useful software tools for energy consumption data collection, processing and evaluation:

Data Centre Profiler (DC Pro) Software Tool Suite (for free):
http://www1.eere.energy.gov/industry/datacenters/software.html

Power usage tool:
http://estimator.thegreengrid.org/puee

Power Usage Effectiveness PUE reporting tool
http://www.thegreengrid.org/en/Global/Content/Tools/PUEReporting

PUE Scalability Metric and Statistics Spreadsheet
http://www.thegreengrid.org/library-and-tools.aspx?category=MetricsAndMeasurements&range= Entire%20Archive&type=Tool&lang=en&paging=All#TB_inline?&inlineId=sign_in

PUE and Data Centre Efficiency Measurement DCiE
http://www.42u.com/measurement/pue-dcie.htm

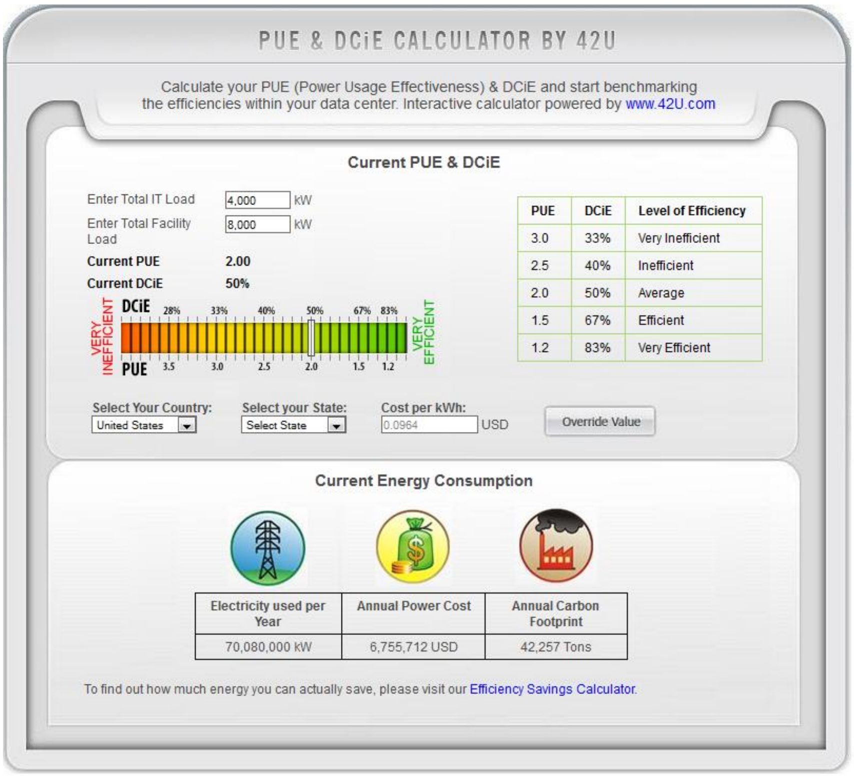

Figure 4.2: PUE and DCiE Data Centre Efficiency Measurement (Source: 42u.com)

5 Guidelines for procurement

The following chapter provides guidelines for the procurement of IT and infrastructure equipment for server rooms and data centres.

5.1 Procurement costs[12]

Over the lifetime (servers: 3 – 5 years, network equipment 5 – 7 years, infrastructure equipment 10 – 15 years) of a typical server room or data centre, the purchasing price of the IT, the cooling and the monitoring equipment only accounts for part of the costs. The total operating costs over the lifetime can be up to four times higher than the capital costs of the equipment.

Private data centre operators (for example internet service providers) typically base investment decisions on the Total Cost of Ownership (TCO) of the facility. Many procurers will be more familiar with the terms life cycle costing (LCC) or whole life costing (WLC) which are largely compareable. The TCO approach can also be used for the procurement of equipment, where competing bids are compared based on their TCO rather than the purchase and installation. This includes the consideration of energy consumption and other aspects such as product lifetime and software costs. When applying this approach, it is crucial to ensure that suppliers are using the same methodology to determine the TCO.

TCO is being increasingly used for procurement decision making across the EU, and a number of tools have been developed for TCO calculation. The following two tools where especially developed for the field of IT[13]:

- VMware Return On Investment (ROI) TCO tool allows a comparison of TCO savings, required investments and the business benefits of virtualisation solutions: http://roitco.vmware.com/vmw/

- The Microsoft Assessment and Planning (MAP) Toolkit supports planning for migration (Migration is the process of moving from the use of one operating environment to another operating environment that is thought to be a better one.) including TCO and ROI calculation: http://www.microsoft.com/en-us/download/details.aspx?id=7826

[12] Procurement guidance for energy efficient server room and data centre equipment, http://www.efficient-datacenter.eu/

[13] Further information and general tools for LCC: http://www.msr.se/en/green_procurement/LCC/; http://www.smart-spp.eu/guidance; http://ec.europa.eu/environment/gpp/lcc.htm

5.2 Energy efficient server hardware[14]

The server equipment (for example Central Processing Unit (CPU)), storage and network equipment is responsible for 60% of the total energy consumption in data centres and server rooms. The remaining 40% were consumed by the infrastructure (especially cooling and power distribution).

To improve energy and cost efficiency the following approaches should be considered:

- selection of efficient hardware and system design
- power management
- hardware consolidation and virtualisation

The selection of energy-efficient server hardware includes the selection of energy-efficient components like power supplies, CPUs, hard disks, etc.

Power management involves powering down servers and/or server components when workloads are low. Power management is possible if applications allow slightly delayed response times and hardware-component performance and if power management features are supported by hardware and software.

Virtualisation allows a significant improvement of server utilisation and therefore substantial efficiency gains. Consolidation of workloads onto a few larger servers can strongly improve energy efficiency and should be checked as an option before buying new server equipment.

In the following, power saving technologies and possible energy efficiency measures are described.

5.2.1 Server equipment and components[15]

To support energy efficient procurement of servers the efficiency criteria from ENERGY STAR may be used. The current ENERGY STAR requirements (Version 1, 2009) for enterprise servers include energy efficiency criteria for rack and pedestal servers containing up to four processor sockets. The requirements define maximum levels for power consumption in *On Idle Mode* for 1- and 2-CPU socket servers as well as criteria

[14] Energy efficient IT and infrastructure for data centres and server rooms, http://www.efficient-datacenter.eu/

[15] Energy efficient IT and infrastructure for data centres and server rooms, http://www.efficient-datacenter.eu/

for power supply efficiency and power management features. The following table shows the base configuration idle power requirements.

Table 5.1: Idle power requirements (Source: ENERGY STAR, Computer Servers Vers. 1)

Computer Server Type	Idle Power Limit
Category A: Standard Single Installed Processor (1P) Servers	55.0 watts
Category B: Managed Single Installed Processor (1P) Servers	65.0 watts
Category C: Standard Dual Installed Processor (2P) Servers	100.0 watts
Category D: Managed Dual Installed Processor (2P) Servers	150.0 watts

The ENERGY STAR requirements for servers (Version 1) where specified in 2009. An update of the requirements (Version 2) is now available. The table below shows the lower idle power criteria of this version which are good reference values for energy efficient servers. Depending on the server type these values can be reduced by 10 – 20 watts for the most efficient products on the market.

Table 5.2: Idle power requirements (Source: ENERGY STAR, Computer Servers Ver. 2.0)

Category	Maximum Possible Number of Installed Processors (# P)	Managed Server	Base Idle State Power Allowance, P_{BASE} (watts)
A	1	No	47.0
B	1	Yes	57.0
C	2	No	92.0
D	2	Yes	142.0
Resilient	2	Yes	205.0

System Characteristic	Applies To:	Additional Idle Power Allowance
Additional Power Supplies	Power supplies installed explicitly for power redundancy(v)	20 watts per Power Supply
Hard Drives (including solid state drives)	Per installed hard drive	8.0 watts per Hard Drive
Additional Memory	Installed memory greater than 4 GB(vi)	0.75 watts per GB(vi)
Additional Buffered DDR Channel	Installed buffered DDR Channels greater than 8 channels (Resilient Servers only)	4.0 watts per Buffered DDR Channel
Additional I/O Devices(vii), (viii), (ix)	Installed Devices greater than two ports of ≥ 1 Gbit, onboard Ethernet	< 1Gbit: No Allowance = 1 Gbit: 2.0 watts / Active Port > 1 Gbit and < 10 Gbit: 4.0 watts / Active Port ≥ 10 Gbit: 8.0 watts / Active Port

Energy Star[16] requirements for idle mode are reasonable efficiency indicators for servers operated at low loads. However, for servers with higher workloads and for consolidated systems the SPECpower-benchmark presented below should be considered.

SPECpower_ssj2008[17] was the first benchmark supporting energy efficiency assessment of volume class servers. It addresses mainly CPU related efficiency and thus provides a good assessment regarding CPU intensive workloads. However, the benchmark is published by manufacturers only for selected hardware. At the moment a Server Efficiency Rating Tool (SERT) for supporting IT managers in selecting energy efficient hardware is developed. The tool will consider server efficiency based on partial benchmarks for CPU, memory, storage and system. SERT allows a more comprehensive assessment/benchmarking of servers and will be included in Energy Star version 2 for servers.

SPECpower_ssj2008 values (and SPEC-SERT evaluation as soon as available) can be requested from manufacturers. For correct interpretation of SPECpower information the following issues must be regarded:

- It is a CPU focussed benchmark, thus most representative for CPU intense workloads.
- Servers may have been tested at rather low configuration (configuration should be checked).
- To arrive a robust interpretation, not only the overall score should be considered (overall operations per watt) but also the detailed benchmarking data including operations/watt for all load levels (10-100%).

[16] http://www.energystar.org
[17] http://www.spec.org/sert/

CPU efficiency

The most energy consuming components in servers are CPUs. Therefore, energy efficient CPU models with effective power management can strongly support efficiency. CPU energy consumption depends on the specific voltage and the clock frequency. Manufacturers provide specific low power CPU versions that allow significant energy savings in practice.

Energy efficiency of CPUs strongly depends on the effective implementation of power management. Common operating systems support power management based on the Advanced Configuration and Power Interface (ACPI[18]) specifications for processor performance states and power consumption (P-States) and thermal management states (C-States).

For hardware configuration in procurement, it is generally essential to check for the concrete performance requirements to be met by the hardware components. Different types of server workloads set different requirements regarding hardware performance. This should be considered for efficient hardware configuration.The table below shows the performance requirements of different server applications.

Table 5.3: Requirements of different server applications (Source: PrimeEnergyIT)

Category	CPU	RAM	Hard disks	I/O
File/print server	0	+	++	+
Mail server	+	+	++	0
Virtualisation server	++	+++	++	++
Web server	+	+	0	+
Database server	++	++	+++	+
Application server	++	++	0	+
Terminal server	++	++	+	+

[18] http://www.acpi.info/

Power supply efficiency

In the ENERGY STAR program requirements for servers minimum requirements are set for the power supply efficiency at 10%, 20%, 50% and 100% load. The 80 PLUS Certification Scheme[19] also offers energy efficiency requirements for server power supplies however excluding the 10%-load level.

It is recommended to choose power supplies that meet at least the 80 PLUS Gold level, which corresponds to 88% efficiency at 20% load and 92% efficiency at 50% load.

Standard rack servers commonly operated at low loads are often equipped with over-provisioned redundant power supplies. This results in high energy losses due to a very low operating point of the equipment. Therefore, right sizing of power supplies is essential. It is supported for example by online power configuration tools offered by manufacturers and by tools for power capping assessment.[20]

Table 5.4: **Efficiency requirements for power supplies (Source: Energy Star programme Version 1)**

Power Supply Type	Rated Output Power	10% Load	20% Load	50% Load	100% Load
Multi-Output (AC-DC & DC-DC)	All Output Levels	N/A	82%	85%	82%
Single-Output (AC-DC & DC-DC)	≤ 500 watts	70%	82%	89%	85%
	> 500 - 1,000 watts	75%	85%	89%	85%
	> 1,000 watts	80%	88%	92%	88%

Table 5.5: **Efficiency requirements for power supplies (Source: Energy Star programme Version 2, Draft 3)**

Power Supply Type	Rated Output Power	10% Load	20% Load	50% Load	100% Load
Multi-output (Ac-Dc & Dc-Dc)	All Output Levels	N/A	85%	88%	85%
Single-output (Ac-Dc & Dc-Dc)	All Output Levels	80%	88%	92%	88%

[19] http://www.plugloadsolutions.com/
20 For example: HP Power Advisor, http://h18004.www1.hp.com/products/solutions/power/index.html

Table 5.6: **Efficiency requirements for power supplies (Source: 80 PLUS initiative)**

80 PLUS Certification	230V Internal Redundant			
% of Rated Load	10%	20%	50%	100%
80 PLUS	N/A			
80 PLUS Bronze	---	81%	85%	81%
80 PLUS Silver	---	85%	89%	85%
80 PLUS Gold	---	88%	92%	88%
80 PLUS Platinum	---	90%	94%	91%
80 PLUS Titanium	90%	94%	96%	91%

5.2.2 Server virtualisation[21]

Server virtualisation provides great potential for energy savings. Through this technology the consolidation of workloads on less physical hardware is possible. This strongly reduces the power and cooling demand. Overall virtualisation offers a number of advantages for the effective design of IT systems in server rooms and data centres. Examples:

- Reduction of hardware and space requirements via deployment of virtual machines (VMs) that can be run safely on shared hardware, this increases server utilisation from 5–15% to 60–80%.
- Test and Development Optimisation – rapidly provisioning test and development servers by reusing pre-configured systems enhancing developer collaboration and standardizing development environments.
- Reducing the cost and complexity of business continuity (high availability and disaster recovery solutions) by encapsulating entire systems into single files that can be replicated and restored on any target server.

VMWare, Microsoft Hyper-V and Citrix XEN are established virtualisation platforms that offer many features like high availability, failover, distributed resource scheduling, load balancing, automated backup functions, distributed power management, server-, storage- and network VMotion etc.

[21] Energy efficient IT and infrastructure for data centres and server rooms, http://www.efficient-datacenter.eu/

The main technology options for server virtualisation involve:

- Physical partitioning
- Virtualisation based on an underlying operating system
- Application virtualisation e.g. Microsoft Terminalserver, Citrix XenApp
- Hypervisor-based virtualisation:
    - VMware ESX
    - Citrix /Open-Source: XENServer 5
    - Microsoft Hyper-V

If virtualisation in data centres is planned it should be based on a virtualisation strategy that includes an evaluation and identification of appropriate server candidates.

For such an evaluation, data on performance (system utilisation, end-of-service timelines, business area and application specification) is needed. When the candidates for virtualisation have been found, application specifications and machine load must be analysed. A performance evaluation should be done and as a basis for hardware selection the following points should be considered to choose a suitable configuration:

- CPU performance
- Required memory
- Disk I/O intensity
- Network requirements
- OS configuration

5.3 Data storage equipment[22]

In the last years efficient management of data storage has become more and more important for companies. It is expected that the storage needs of organisations will grow by a factor of 44 between 2010 and 2020[23]. The prices per MB of storage were constantly falling and so it was less costly to add extra capacity than to avoid data duplicates and other inefficiencies. However, this trend has changed and no further reduction of storage costs are to be expected in the near future.

As nowadays the costs of powering and cooling storage resources are increasing, inefficiencies must be avoided. Data storage equipment is responsible for a large part of the energy consumption in sever rooms and therefore it is necessary to make storage systems more energy efficient and to procure the appropriate solutions.

The following devices and elements belong to data storage equipment:

Data storage services: Solid state drives (SSDs), Hard Disk drives (HDDs) Tape based systems

Date storage elements: disk arrays, massive arrays of idle disks (MAIDs)

Storage solutions: direct attached storage (DAS), network attached storage (NAS), storage area networks (SANs)

Power management options, depending on the number and type of idle and low-power states provided, can significantly improve energy efficiency.

High energy savings can be achieved with a number of widely available consolidation and management features (also called capacity optimisation measures or COM). However, the savings vary with the characteristics of the workload. Some examples are:

- Data deduplication
- Data compression
- Storage tiering
- Thin provisioning

[22] Procurement guidance for energy efficient server room and data centre equipment, http://www.efficient-datacenter.eu/

[23] IDC (2010): The Digital Universe Decade – Are you ready? IDC, May, 2010.

- Delta snapshots
- RAID groups

For procurement issues it is recommended to identify a data storage architecture that is optimised for the companies' usage and application requirements.

Tapes offer the best energy efficiency for long-term storage and have good data retaining characteristics. However, tapes should be used for storing data that is not frequently accessed, but needs to be maintained over long periods.

SSDs have better performance than most HDDs and are more energy efficient. Nevertheless this does not apply for long-term storage. SSDs can also be used as a high performance storage layer.

Small Form Factor (SFF), with 2.5-inch drives use less power, produce less heat, and use less floor space for the same storage capacity and should therefore be preferred.

For backup-to-disk solution for large capacity drives should be considered.

The temperature requirements for server rooms must be considered when procuring new storage equipment. For tape drives a maximum rate of change is 5 °C/hr is recommended, and 20 °C/hr for disk drives.[24]

[24] ASHRAE Thermal guidelines for data processing environments, 2011

6 Summary of best practice advices for procurement[25]

The following summary gives best practice recommendations for procurement for the different types of equipment.

6.1.1 Server equipment and components

Energy efficiency criteria and benchmarks for hardware selection:

- Options for server consolidation and virtualisation should be checked with IT experts. If specific expertise is not available in house, external consultancy services should be considered.
- Especially for servers operated at low loads, Energy Star Version 2.0, requirements for idle mode should be considered. (For the most efficient servers on the market the values of the requirements can be reduced by 10-20 watts.) The requirements for power supplies should be used for any type of equipment.
- SPECpower_ssj2008 (and SPEC-SERT as soon as available) benchmarking results should be requested from manufacturers.
- The workloads and expected workload levels to be run on the servers should be defined.
- The required capacity and performance level of hardware should be defined.
- Costs and energy efficiency of systems from different suppliers should be compared.
- Other product information to be requested from suppliers:
    - Total Cost of Ownership (TCO)
    - Energy efficient hardware components, e.g. efficiency and right sizing of power supplies
    - Management tools especially addressing power management and optimization of system design.

[25] Energy efficient IT and infrastructure for data centres and server rooms, http://www.efficient-datacenter.eu/

- Equipment should be chosen according the highest energy efficiency for the workload types and levels addressed and adequate power management options.

Energy efficiency criteria for blade technology:

- The main reasons for implementing blade technology in the data centre should be defined (e.g. space restrictions).
- The benefits that are expected in comparison to rack technology should be considered and verified if expectations are realistic.
- Check if virtualisation can be an alternative solution.
- The expected Total Cost of Ownership (TCO) and energy efficiency compared to other options (based on information provided by suppliers) should be considered.
- Management tools, intelligent network and power devices for the monitoring of power consumption should be used.

Selecting virtualisation solutions:

- A virtualisation strategy should be developed and servers be assessed to select good candidates for virtualisation.
- Requirements regarding CPU performance, memory, Disk I/O intensity, Network requirements, OS configuration should be determined.
- Products from different suppliers should be compared regarding necessary features for company specific purposes. Licensing policies, power management features and price should be considered. Different main products on the market have different advantages depending on the specific application needs.
- TCO and ROI calculations should be done to identify the benefits of reduced costs for power supply and cooling.

6.1.2 Data storage equipment

Energy efficiency and different storage technologies

- For long-term storage tapes have the best energy efficiency
- SSDs (Solid state drives) are much more efficient than HDDs (Hard disk drives), however also more expensive.
- SSDs should be considered as a high performance storage layer.
- The multiple idle states implemented by HDDs allow considerable energy savings when used in composite storage solutions such as disk arrays and massive arrays of idle disks.

7 Selection criteria

It is currently not possible to recommend fully relevant criteria for a Topten selection of servers and data storage equipment because these products are very complex as opposed to plug-in products and should be selected according to their range of application. The most important points to consider are the selection of efficient hardware, workload consolidation and the use of power management.

Nevertheless the Energy Star requirements are reasonable energy efficiency indicators for servers (Version 2.0 is already available).

The US Energy Star website already lists qualified ENERGY STAR[26] models available for sale in the U.S. and Canada. It is expected that servers will also be listed for the European market as soon as the new Energy Star agreement is fully implemented. This will be followed by criteria and lists for data storage equipment.

For the moment, Topten websites can provide information about severs and server equipment on a generic information page or through procurement guidelines for professional buyers.

[26] http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=DC

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