ELFORSK

Development of Test Definition and Energy Labelling Criteria for Electricity Consumption of Computers in all Modes

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viegand maagøe

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1 Summary

1.1 Objectives

Prior to initiation of this project, there were no generally accepted energy labelling schemes that included the total electricity consumption of a computer and not only the consumption in off and sleep. On this background, the project team designed the project.

The overall long-run objectives were:

- to make it easier for the consumers and especially the organisational purchasers to select the most energy efficient computers when the energy requirements will be based on the total electricity consumption and

- to influence the industry to, in a higher degree than now, develop computers with low electricity consumption, which include the electricity consumption in the active state.

The short-run objectives to be achieved during the project were:

- to create a well founded basis for establishing a test definition for computers' electricity consumption in the active mode and energy labelling criteria or similar measures, which include the electricity consumption in the active state, and which can be established during the project period or immediately afterwards and

- to develop a calculation tool based on the measurements from the project for calculating the energy consumption of typical computers and typical usage scenarios. This objective was added during the project after a request from the supporting organisation ELFORSK.

The focus was to establish a measurement definition and energy label requirements that are realisable in consideration of what is possible and what could be agreed on. Therefore, the definitions and the label requirement should not necessarily be the theoretical optimal solution, but instead a solution that in a simple way can be implemented aiming at reaching the long-run objectives.

1.2 Approach and Project Implementation

The project has been carried out by Viegand & Maagøe in collaboration with Danish Technological Institute and with financial support from Danish Electricity Sector's PSO research and development scheme called ELFORSK (project no. 336-40, financial support 398.571 DKK.

The project phases were:

- Electricity consumption of computers and improvement opportunities: An overall assessment of computers' electricity consumption based on existing data and assessment of development tendencies and impact on the electricity consumption were carried out.

- Measurement definition for the electricity consumption in active mode: For different types of computers, various types of measurement definitions of active modes have been analysed, including the usage of electricity consumption measurements.

- Establishment of qualification levels: Based on electricity measurements for a large range of computers, proposal for qualification levels has been provided.

- Dialogue with the industry and the energy authorities: The project had an on-going dialogue with the manufacturers and the energy authorities through the Energy Star process for new computer specifications.

- Development of a spreadsheet calculation tool for calculating energy savings when purchasing or replacing computers: A user-friendly tool has been developed that can be used to calculate the energy and financial impact of replacement of computers.

1.3 Results

The main project results include:

- Recommendation on how to include the active mode in energy requirements on the short and long run and on how to set energy label requirements
- Input to Energy Star specification revision
- A freeware calculation tool for calculating the impact on energy consumption of two computer scenarios
- Suggestion for further research and development

The target group of the results are primarily energy authorities and research institutions, which are involved in energy labelling schemes or similar activities. The results will eventually influence the industry to design computers with the highest energy efficiency taking into account the users' real needs.

Furthermore, the calculation tool can be used by energy consultants and advisers for calculating the energy and financial impact of replacement of computers.

The results are detailed in the following.

Recommendation on How to Include the Active Mode in Energy Requirements on the Short and Long Run and on How to Set Energy Label Requirements

Simple Modes Approach

The recommendation is to use a simple mode approach using requirements for off, sleep and idle, where idle is representing the active mode.

For typical office and home use, the idle mode measurements will give sufficiently precise approximation of the power consumption in active use. The reason is that typical office and home use (writing of documents and e-mails, web browsing, use of simple spreadsheets etc.) does not put much more load on the computer than the idle mode does.

For most labelling schemes, this will be a simple and yet effective design that will cover the needs, especially if combined with power management requirements.

Simple Annual Electricity Consumption Approach

If there is a desire for providing more design freedom for the manufacturers when they design their computers and for informing the consumers about annual electricity consumption, a requirement for simple annual electricity consumption can be established.

The power consumption in off, sleep and idle will be multiplied by a fixed set of number of hours on the modes.

Advanced Approaches

The advanced approaches use workloads for measuring the active mode or all the modes corresponding to a typical full usage model.

Especially the latter approach by using a full usage model will be theoretically the best way of measuring the energy efficiency of a computer because it includes power management capabilities by using a piece of software that simulates the computer use over a full period e.g. a working day. The reason is that it will show how capable the computer and the components are to decrease and increase their services and to go into low-power modes.

It is however very difficult to simulate the active mode or full usage model, because very few data exist about use of computers that can be used for simulating the usage models. Furthermore, the tool should be used at a global level, where there can be differences in usage models between the countries.

Therefore, it is not recommended to use the advanced approaches unless such workloads or usage models combined with a software tool are available.

Energy Label Requirements

The project provides assessments of different ways of designing energy label requirements related to the computer capacity. The recommendation is to relate the requirements to the functionality of the computers aiming at allowing additional electricity consumption for functionalities that are useful for the user. This can be done either in the form of configuration categories or an electricity consumption adder per function.

The proposed levels for desktops and notebooks depending on the configuration category are shown in Table 1.1 and Table 1.2. The definitions of the categories are provided in Chapter 5.

Desktops	A	B	C	D
Off, W	2	2	2	2
Sleep, W	3	3	3	3
Idle, W	42	46	62	68

Table 1.1: Proposed power levels for off, sleep and idle for each configuration category for desktops.

Notebooks	A	B	C
Off, W	2	2	2
Sleep, W	3	3	3
Idle, W	12	17	37

Table 1.2: Proposed power levels for off, sleep and idle for each configuration category for notebooks.

Input to Energy Star Specification Revision

The results and the material from the project were background material for the revision of the Energy Star specification for computers. Both for the development of Energy Star specifications version 4.0 (effective data 20 July 2007) (Annex A), which was the first version of computer specifications that included the on mode and for version 5.0 (effective data 1 July 2009) (Annex B).

It is not possible to estimate achieved energy savings, however, the Energy Star specifications will globally have an impact on the production of many millions computers and the impact may be very high.

USA and EU are management entities of the Energy Star office programme. In addition, the Energy Star office programme is used by several other countries.

A Freeware Calculation Tool for Calculating the Impact on Energy Consumption of Two Computer Scenarios

The project has developed a freeware spreadsheet calculation tool where combinations of computer types, configurations and usage models can be calculated and two scenarios can be compared, e.g. a current situation and a new situation. The results of the comparison are reported as both energy (kWh per year) and money (Danish DKK per year). The basis was the data measured and collected for computers.

Furthermore, average electricity consumption values for a number of typical computer types, configurations and usage models have been reported.

Suggestion for Further Research and Development

On the long run, it is recommended to further develop typical workloads, where the computer during the test automatically changes between the various work modes, because it gives the best test of how capable the computer and the components are to decrease and increase the output and to go into low-power modes. This however requires more research on consumer behaviour and workloads.

There is a need for further research on how different users use the computers. E.g. what kind of software programmes they use and how much; how they use the computer during a workday, on holiday, and at home etc.

The research should be based on representative types of users in various countries.

2 Danish Summary - Sammenfatning

2.1 Formål

Før starten af projektet fandtes der ikke generelt accepterede energimærkeordninger, der inkluderede det totale elforbrug for computere og ikke bare forbruget i slukket tilstand og dvale. På den baggrund designede projektteamet projektet.

Det langsigtede formål var:

- at gøre det lettere for forbrugere og specielt organisatoriske indkøbere at vælge de mest energieffektive computere, når energikravene er baseret på det totale elforbrug.

- at påvirke industrien til i højere grad end nu at udvikle computere med lavt elforbrug, som inkluderer elforbruget i den aktive tilstand.

Det kortsigtede formål, som skulle opnås under projektperioden, var:

- at skabe en velfunderet basis for at etablere en test-definition af computeres elforbrug i den aktive tilstand og energimærkekrav eller tilsvarende virkemidler, som inkluderer elforbrug i den aktive tilstand og som kan etableres under projektperioden eller umiddelbart herefter.

- at udvikle et beregningsværktøj baseret på projektets målinger for at beregne elforbruget for typiske computere og brugssituationer. Dette formål blev tilføjet i løbet af projektet efter ønske fra tilskudsgiveren ELFORSK.

Fokus var, at test-definitionen og energimærkekravene skulle være realiserbare under hensyntagen til, hvad der er muligt, og hvad der kan skabes enighed om. Derfor skulle definitioner og mærkekrav ikke nødvendigvis være den teoretiske optimale løsning, men derimod være en løsning, der på en simpel måde kan blive implementeret for at nå det langsigtede formål.

2.2 Metode og gennemførelse

Projektet blev gennemført af Viegand & Maagøe i samarbejde med Teknologisk Institut og med finansiel støtte fra den danske elsektors PSO-F&U-ordning, ELFORSK (projektnummer 336-40, støtte 398.571 DKK)

Projektfaserne var:

- Elforbrug for computere og muligheder for forbedring: En overordnet vurdering af computeres elforbrug baseret på eksisterende data og vurdering af udviklingstendenser og påvirkning af elforbruget blev gennemført.

- Måledefinition for elforbrug i aktiv tilstand: For forskellige typer computere blev analyseret mulige måledefinitioner for aktiv tilstand og herunder gennemført elforbrugsmålinger af computere.

- Fastsættelse af energikrav: Baseret på elmålinger for et stort antal computere blev udformet forslag til energikravsniveauer.

- Dialog med producenter og med energimyndigheder: Projektet havde en løbende dialog med producenter og med energimyndigheder gennem Energy Star-processen for udformning af nye energikrav til computere.

- Udvikling af et regnearksværktøj for beregning af elbesparelser ved køb eller udskiftning af computere: Et brugervenligt værktøj blev udviklet, som kan bruges til at beregne effekten af køb eller udskiftning af computere.

2.3 Resultater

De vigtigste projektresultater er:

- Anbefaling af hvordan man kan inkludere den aktive tilstand i energikrav på kort og langt sigt, og af hvordan man kan sætte energimærkekrav.
- Input til Energy Star-processen for opdatering af kravene.
- Et gratis beregningsværktøj for beregning af effekten på elforbruget af to computersituationer.
- Forslag til videre forskning og udvikling.

Resultaterne er målrettet energimyndigheder og forskningsinstitutioner, som er involveret i energimærkeordninger og tilsvarende aktiviteter. Resultaterne forventes desuden i sidste ende at påvirke producenterne til at designe computere med højere energieffektivitet sat i forhold til brugernes reelle behov.

Derudover kan beregningsværktøjet bruges af energikonsulenter og -rådgivere ved beregning af effekten af udskiftning af computere.

Resultaterne er uddybet i det følgende.

Anbefaling af hvordan man kan inkludere den aktive tilstand i energikrav på kort og langt sigt, og af hvordan man kan sætte energimærkekrav

Simpel tilstands-metode

Anbefalingen er at bruge en simpel tilstands-metode, hvor der er krav til elforbruget i slukket, dvale og tomgang, hvor tomgang repræsenterer den aktive tilstand.

For typisk kontor- og hjemmebrug vil målinger i tomgangstilstanden give en tilstrækkelig præcis tilnærmelse af elforbruget i aktiv tilstand. Grunden er, at typisk kontor- og hjemmebrug (skrivning af dokumenter og e-mails, webbrowsing, brug af simple regneark mv.) ikke belaster computeren meget mere end tomgangstilstanden gør.

For de fleste mærkeordninger vil det være en simpel og alligevel effektiv metode, som vil dække behovet, især hvis det bliver kombineret med krav til spareindstillinger (power management).

Simpel årsforbrugs-metode

Hvis der er et ønske om at give mere designfrihed til producenterne, når de designer computere, og om at give forbrugerne oplysninger om årsforbruget kan en simpel årsforbrugs-metode anbefales.

I metoden bliver elforbruget i slukket, dvale og tomgang ganget med et fast antal timer i hver tilstand.

Avancerede metoder

I de avancerede metoder bliver der brugt belastninger, som svarer til en typisk komplet brugsmodel, når den aktive tilstand, eller alle tilstandene bliver målt.

Især vil metoden med at bruge en komplet brugsmodel med måling af alle tilstande være den teoretisk bedste måde at måle energieffektiviteten af en computer på, fordi den inkluderer strømstyringsevnen ved at simulere computerens brug over en periode fx en arbejdsdag ved brug af et software. Grunden er, at metoden vil vise, hvor god computeren og komponenterne er til at skrue op og ned for ydelserne og til at gå ind i sparetilstande.

Det er imidlertid meget svært at simulere den aktive tilstand eller den komplette brugsmodel, fordi meget få data om brug af computeren til brug for simulering af brugsmodellen eksisterer. Desuden skal simuleringsværktøjet bruges på globalt niveau, hvor der kan være forskelle i brugsmodellerne mellem landene.

Derfor er det anbefalet ikke at bruge de avancerede metoder, medmindre sådanne arbejdsbelastninger eller brugsmodeller kombineret med et software er tilgængelig.

Energimærkekrav

Projektet giver vurderinger af forskellige måder at designe energimærkekrav på i forhold til computerkapaciteten. Anbefalingen er at knytte kravene til computerens funktionalitet med målet at tillade ekstra elforbrug for funktioner, som er brugbare for brugeren. Det kan enten være i form af konfigurationskategorier eller et elforbrugstillæg pr. funktion.

De foreslåede niveauer for stationære og bærbare computere for konfigurationskategorierne er vist i tabel 1.1 og tabel 1.2. Kategorierne er defineret i kapitel 5.

Stationær	A	B	C	D
Slukket, W	2	2	2	2
Dvale, W	3	3	3	3
Tomgang, W	42	46	62	68

Tabel 1.1: Foreslåede elforbrugsniveauer for slukket, dvale og tomgang for hver konfigurationskategori for stationære computere.

Bærbar	A	B	C
Slukket, W	2	2	2
Dvale, W	3	3	3
Tomgang, W	12	17	37

Tabel 1.2: Foreslåede elforbrugsniveauer for slukket, dvale og tomgang for hver konfigurationskategori for bærbare computere.

Input til Energy Star-processen for opdatering af kravene

Resultaterne og materialerne fra projektet har udgjort en del af baggrundsmaterialerne for revision af Energy Star-kravene for computere. Både for udvikling af Energy Star-kravene version 4.0 (ikrafttrædelsesdato 20. juli 2007) (bilag A), som var den første version af computerkravene, der inkluderede den aktive tilstand, og for version 5.0 (ikrafttrædelsesdato 1. juli 2009) (bilag B).

Det er ikke muligt at vurdere opnåede elbesparelser, men Energy Star-kravene påvirker designet af mange millioner computere globalt set og elbesparelseseffekten kan være meget høj.

USA og EU har sammen ansvaret for opdatering af Energy Star-kravene til kontorudstyr, mens kravene bruges af mange andre lande.

Et gratis beregningsværktøj for beregning af effekten på elforbruget af to computersituationer

Projektet har udviklet et gratis beregningsværktøj i form af et regneark, hvor kombinationer af computertyper, konfigurationer og brugsmodeller kan beregnes, og to scenarier kan sammenlignes fx den nuværende og en ny situation. Resultaterne af beregningerne bliver rapporteret i årligt elforbrug i kWh og kroner. Basis er de målte og indsamlede computerdata.

Desuden er gennemsnitlige elforbrugsværdier for et antal typiske computertyper, konfigurationer og brugsmodeller angivet.

Forslag til videre forskning og udvikling

På langt sigt er det anbefalet at udvikle typiske arbejdsbelastninger, hvor computeren i testen automatisk skifter mellem de forskellige arbejdstilstande, fordi det giver den bedste test af, hvor god computeren og komponenterne er til at skrue op og ned for ydelserne og gå ind i sparetilstande. Det kræver imidlertid mere forskning i forbrugeradfærd og arbejdsbelastninger.

Der er især et forskningsbehov for viden om, hvordan forskellige brugere bruger deres computere. For eksempel hvilke typer programmer de bruger og hvor meget, hvordan bruger de computeren i løbet af en arbejdsdag og fridag hjemme mv.

Forskningen bør baseres på repræsentative brugere i et udvalg af forskellige lande.

3 Computer Power Consumption and Improvement Options

3.1 Computer Development Trends

Overall Trends

The development aim of computers is to make them more powerful than the previous models. Moore's law by increasing performance by 2 every 18 month is still valid. More powerful computers consume more power until not long ago.

Several governments have started focusing on measures for reducing computers' power consumption. This together with problems with thermal limitation on the CPU design, memory design etc. have led to development of more energy efficient computers with more efficient components (processors, memory chips, disk drives etc.) and better power management.

The development is also going on for more diversity in computer models to fulfil the need for a specific purpose e.g. entertainment, multimedia centre, education, business, thin clients, workstations, file servers, print servers, web servers etc.

During several years, the sale of desktop computers has been stabilizing and has started to have a downward tendency. Notebook computer sale is increasing rapidly. The sale of netbooks and PDAs combined with wireless and mobile cell phone is increasing as well.

This is a good tendency when the desire is to reduce energy consumption, because the energy consumption of netbooks, notebook computers, pocket PCs and PDAs is very low compared with desktop computers. The reason is that these products have been designed for long battery life by using energy efficient component and power saving measures during inactive periods.

Use of thin clients connected to servers reduces the need for using powerful desktop computers. Thin clients have low power consumption and low – but sufficient – performance. Typical use is in organization with application server farm, where 15-30 users are sharing a server running the applications. However, it may also become typical for private household users in the future, because they are simple to operate and maintain.

Now development is going for better performance/power relation to save energy during use of a computer. This development is partly driven by government initiatives and the fact that CPUs in its present shape have reached the limit in thermal design with air flow cooling. The design of CPUs also includes the ability to go to different levels of low power modes.

Computer manufacturers are aware of the power consumption and produce environmental data sheets, which include energy consumption in different service levels by running programs to maximize power consumption, routine task, sleep mode, and off.

CPUs

CPUs have changed their architecture from IA-32 to IA-64 (x32 to x64) bit address architecture to overcome the 2 GB limitation on program size. Servers and workstations need 64 bits processors to be able to run more demanding program systems. At the moment, both architectures are produced and in use. Both architectures will probably continue for some years.

To handle thermal limitation, two CPU cores share the same house and sharing L2 cache and running at lower clock frequency to avoid overheating. Both dual and quad cores are in use.

In mobile technology, Intel launched some years ago the processors Core Duo and Core Solo. The Core Duo processor has up to 3-4 times better performance/power than other processors with the same performance. The performance is measured with BAPCO's SYS-mark 2004 SE, which is an office productivity and internet content creation benchmark.

Mobile technology has already become the standard in desktop computers.

Another development is to change from 135 nm technology to 90 and 65 nm technologies. Smaller components mean less leak current and charging time to shift from one logical level to the other in data and processing. This development will continue for some years to come.

Disk Drives

The new development in 2.5" technology to substitute 3.5" technology has shown the possibility to reduce power consumption with approximate 50 % without reduction of performance and capacity.

Another efficient technology is SSD, Solid State Drive, which is a data storage device that uses solid-state memory. These are available today, but not standard device in computers.

By using 2 hard disks in RAID-0, it is possible to increase I/O performance by a factor 2. This reduces wait time on disk actions and the option is available today in many desktop computers. At the present, some notebook computers also offer this possibility.

Servers need other RAID combinations to avoid loss of data by disk failures. Because more disks are in use more power is consumed.

RAM

Demands from operating system, programs and file cache increase the need for more RAM capacity in the computer. If a computer is configured with minimum required memory capacity, the computer has to swap memory contents to and from disk all the time and performs very badly.

Graphic Cards

The development of processors for graphics is still going on. At the present time the power requirement is up to 75-150 Watt for the top level of graphics card for use in entertainment and multimedia centre. 75 Watt is the limit for the space in 1 PCI express (PCIe) socket. A 150 Watt card is a double card using 2 PCIe slots, which is the limit in thermal design with air flow cooling. Computers for entertainment need power supply, which can deliver up to 650 Watt in peak load.

Power Supplies
Power supplies for ATX computer form factors can have a low efficiency at about 64-70 %. It is possible to design the power supply with efficiency over 80 %. Power supplies can have potential for improvement. Inside the computer, dc/dc converters are in use for converting 12 Volt to a low voltage for CPU, memory etc. The original +3.3 Volt supply for CPU is still available, but lower voltage like 2.4 Volt down to 1.0 Volt is needed to power 135, 90, and 65 nm technology. This gives more conversion/regulation loss to the computer.

About 50 % of the supplied power disappears in power conversion and ventilating in the computer during use. Conversion of 12 V down to 1 V to supply the CPU with a load of up to 150 A is managed by using 4 phase regulators each phase delivering up to 40 A.

Connection of servers inside rack to a common ac/dc supply is considered to improve conversion efficiency. Blade servers with common ac/dc power supply are example on this technology.

Server Virtualization
Virtualization of more servers on the same computer server has been possible for some years, but the technology has just recently become mature. Most application servers only use the CPU for a short period of time. By running more virtual servers on the same computer server, the load will increase on the CPU's, but it can still handle response time from the service level agreement.

The potential energy saving by virtualization is very high.

Storage
The need for storage in computers is still increasing. Hard disk capacity has increased without increasing power consumption. In a server rooms and data centres about 50 % of the consumed power is going to keep storage running. The storage is configured in redundant arrays and failure can be handled without data loss.

3.2 Computer Power Consumption

Power Consumption for Computer Types
Figure 3.1 shows the estimated average main power consumption versus computer types in year 2006. The PDA/mobile PC and notebook computer use even less power, when they are running on battery. The power is not including charging of battery. In use on mains power during a day, charging will typically only last a couple of hours.

At high processor and input/output loads, the maximum power can be about 2 times the above shown power limits except for servers, workstations and high-end entertainment computers. They will typically only increase the power consumption with approximately 50 %.

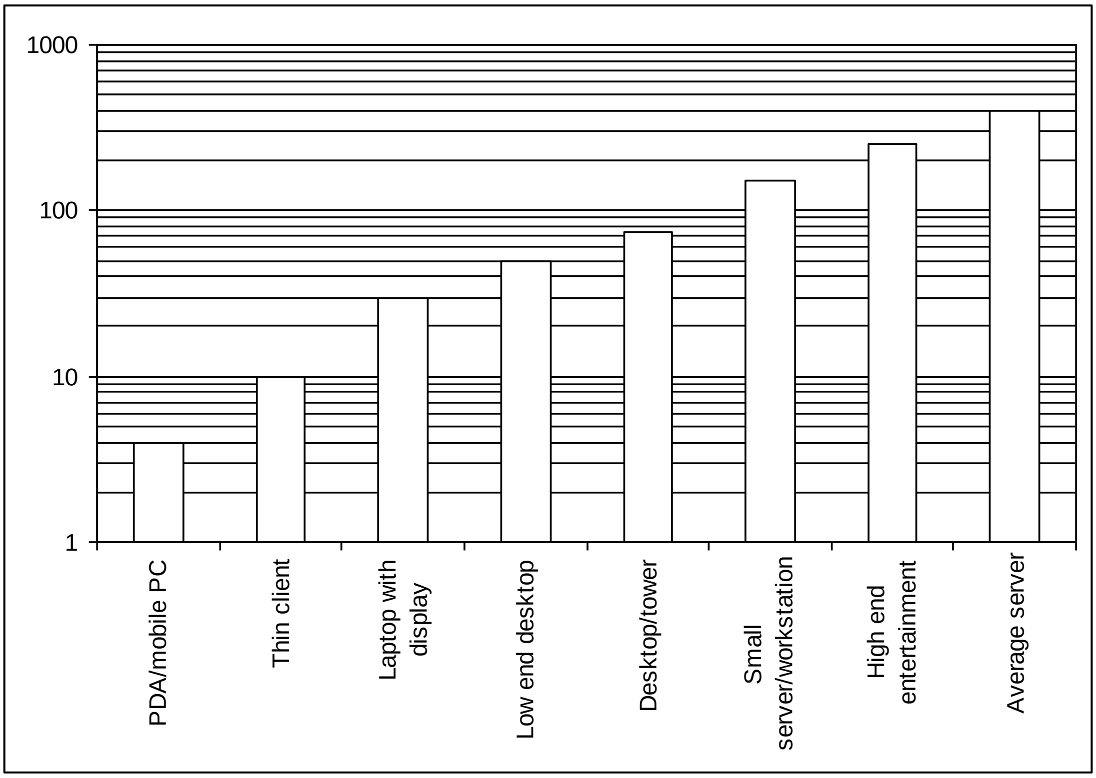

Figure 3.1: Estimated average main power consumption in Watt versus computer types in year 2006.

Estimated Development in Computer Power Consumption
The estimated development of power consumption for computers has followed the development shown in Figure 3.2. For extreme computers the clock frequency and capacity is increasing all the time.

The estimation is rough and does not take into account that technology change also change the power consumption.

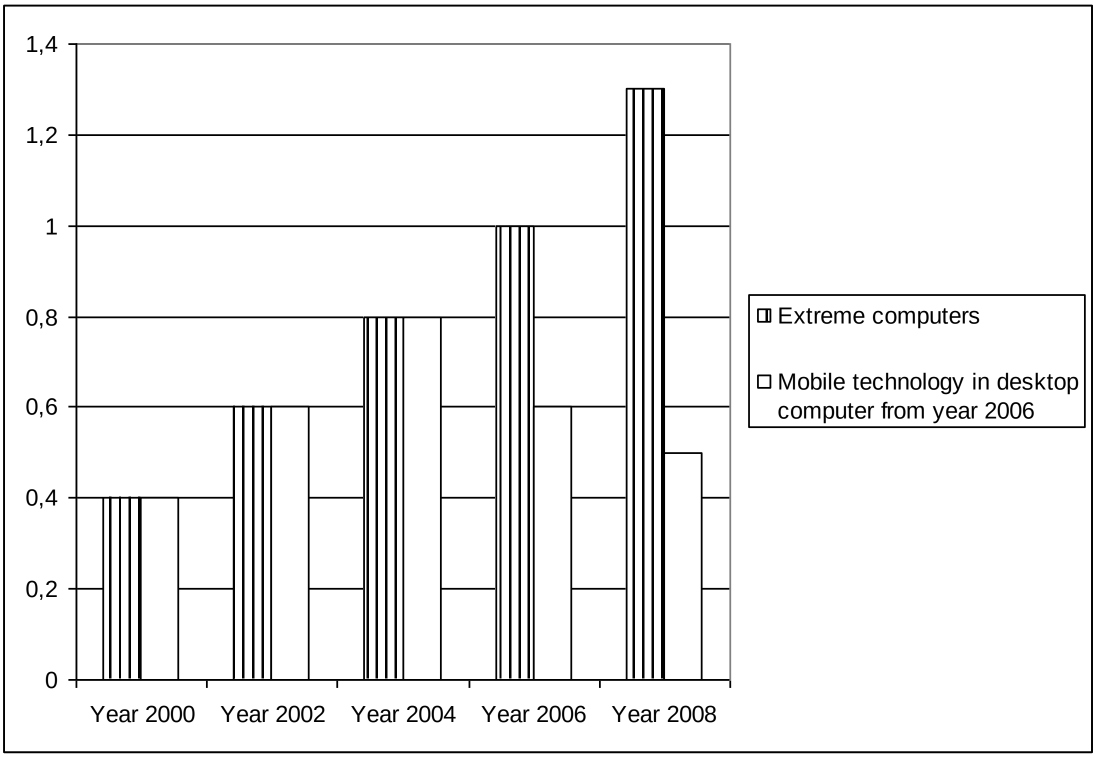

Figure 3.2: Normalized estimated development in main power consumption 2000-2008 for extreme computers and desktop computers change to use mobile technology.

Components and Voltage Levels

Figure 3.3 shows components in a desktop/tower computer and some of the supply voltage levels used today.

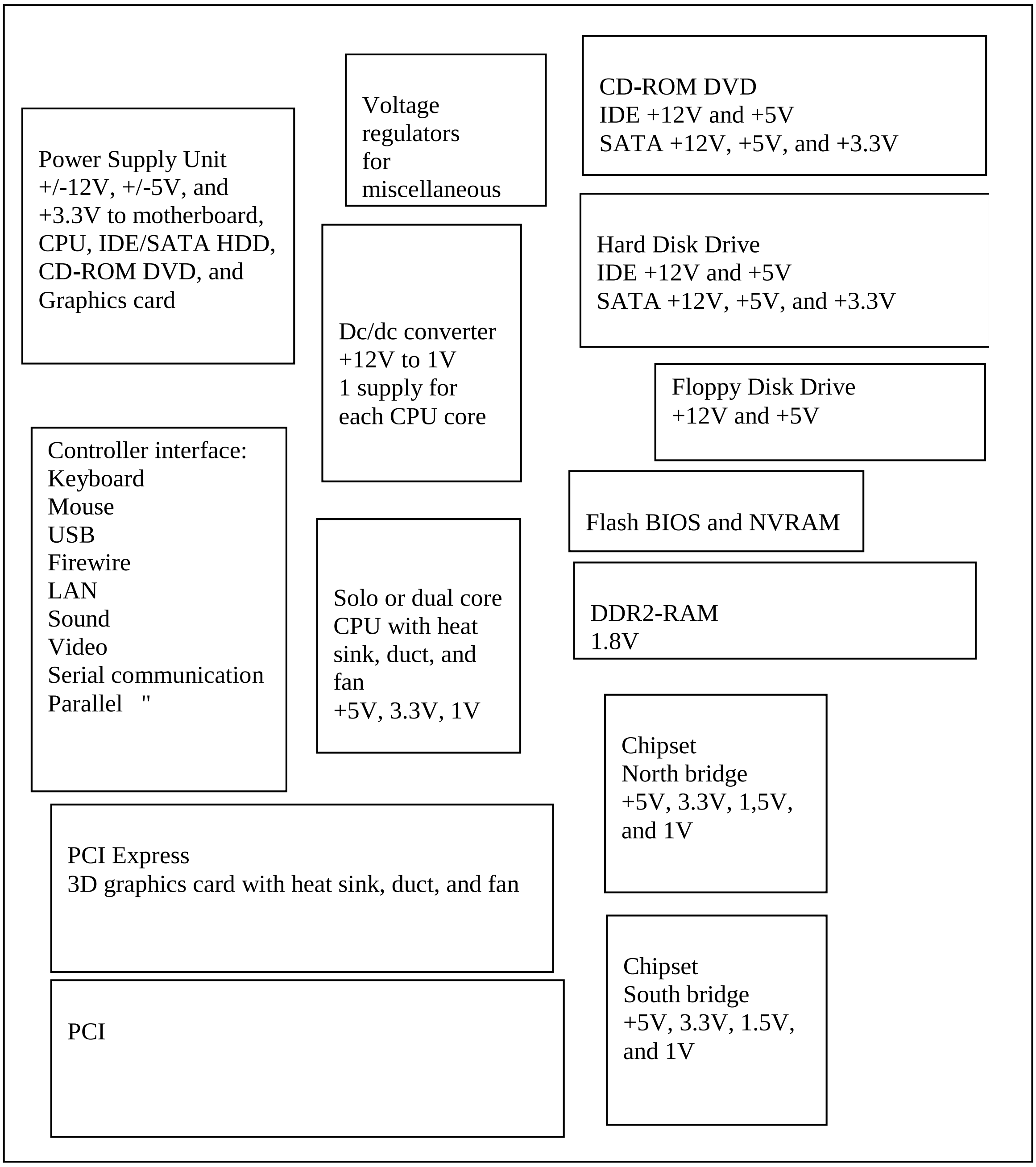

Figure 3.3: Components in a desktop/tower computer.

Power Distribution

In the following, the power distribution between components is shown for different types of computers and different modes.

The computer types are:

- High-end entertainment computer
- Desktop/tower computer
- Notebook computer
- Computer server

Information about these values has been collected by market research based on manufacturers' data sheets for available components.

The power drawn by the computer varies from zero when disconnected to maximum power when all components are at full load. For energy labelling and regulation purposes, often defined working modes with certain characteristics are used, typically off, standby (sleep), idle and maximum. The alternative is a typical usage model measuring consumption when using the computer in a typical way. This is detailed in the following sections.

Below the distribution of power consumption on components for the working modes is shown based on partly estimations and partly calculations by reverse engineering from computer manufacturers' environmental data sheets.

Power Distribution for High-End Entertainment Computer

Figure 3.4 shows the power distribution between components in a high-end entertainment computer. The usage pattern of a high-end entertainment computer is expected to be intensive and most of the time at maximum load.

This can go on for some hours every day, because it is a kind of hobby for the user. It normally works in a world wide network connected to a society of other users through servers. During breaks, the computer runs at idle. After use, the computer is turned off.

The efficiency of the power supply unit is assumed to be 85 %, which is in the high end. The power efficiency of the dc/dc converters is assumed to be 80 %. The Wake-On-LAN function is assumed disabled.

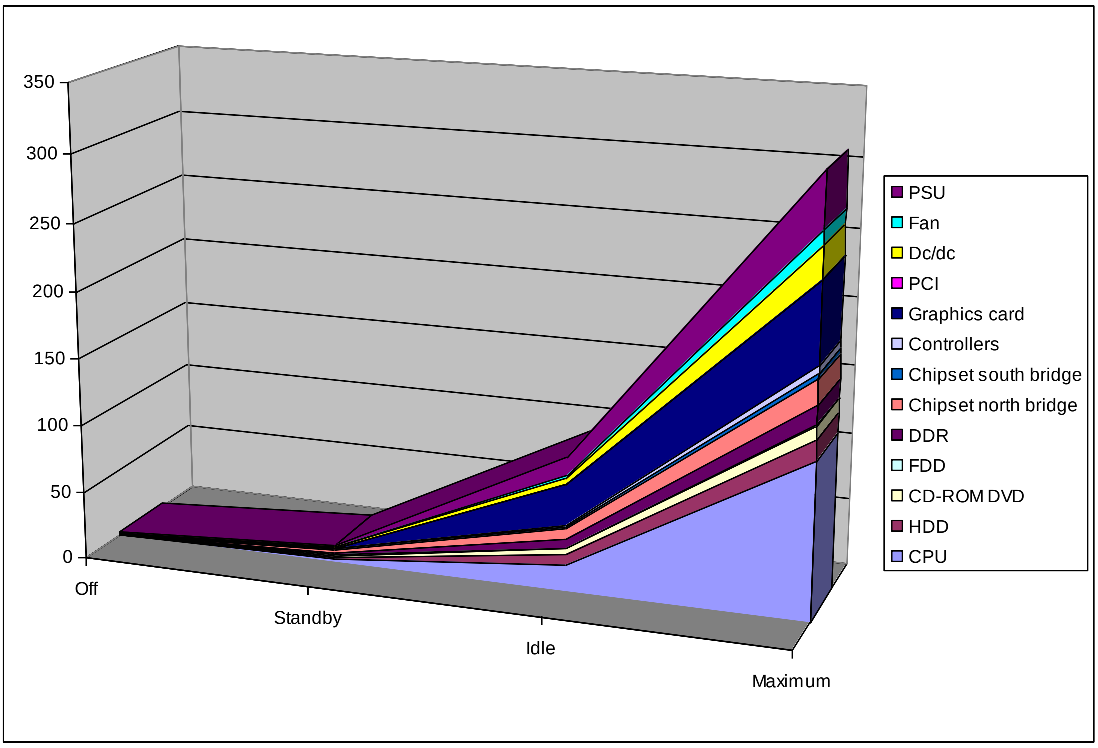

Figure 3.4: Power distribution in Watt between components in a high-end entertainment computer in different modes. Off 2 W, standby (sleep) 13 W, idle 99 W, and maximum 315 W.

Power Distribution for Desktop/Tower Computer

Figure 3.5 shows the power distribution between components in a desktop/tower computer with mobile CPU technology. This kind of computer has a high performance/Watt relation.

The target for this computer is office use with a need for excellent performance on text processing, e-mailing, internet browsing, images processing and calculation processing. It is more expensive than low-end desktop computers.

During use, the load is generally very low, so most of a working day the computer is in idle mode. Compared with a normal desktop/workstation this kind of computer is only using half the power of a normal desktop/tower computer.

The efficiency of the power supply unit is assumed to be 85 %, which is in the high end. The power efficiency of the dc/dc converters is assumed to be 80 %. The Wake-On-LAN function is assumed disabled.

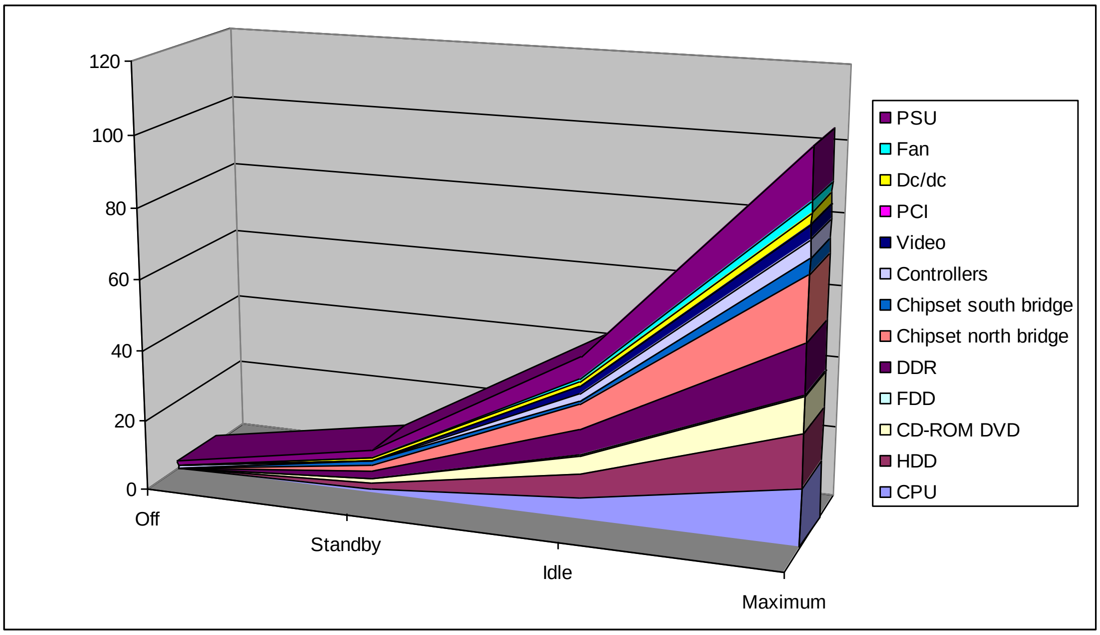

Figure 3.5: Power distributions in Watt between components in a desktop/tower computer with mobile CPU. Off 2 W, standby (sleep) 12 W, idle 45 W, and maximum 106 W.

Power Distribution for Notebook Computer

Figure 3.6 shows the power distribution between components in a notebook computer powered from mains supply. This kind of computer has sufficient performance to work with office programs and be used as a multimedia computer.

It is equipped with modem, LAN, wireless and bluetooth communication etc. It can go online on different ways and can synchronize files, mail, and calendar with a cell phone, and PDA/mobile PC. The efficiency on the power supply is assumed to be 75 %. Wake-On-LAN is disabled.

When the notebook is working on battery, the power saving is normally activated by the operating system, so it is possible to power down the notebook computer during a working day.

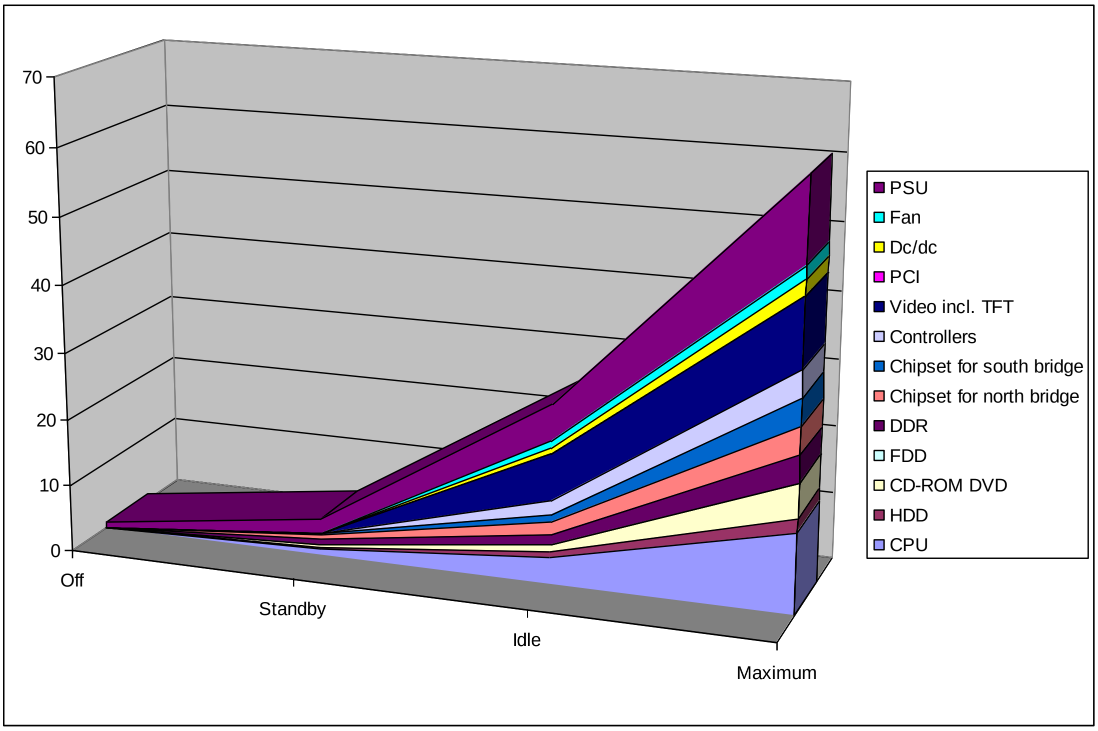

Figure 3.6: Power distribution in Watt between components in a notebook computer powered from main supply. Off 1 W, standby (sleep) 5.5 W, idle 27 W, and maximum 62 W.

Many notebooks are connected through port replicators or docking stations for office use. An external TFT display, keyboard, mouse etc. can be easily connected with the notebook. In this mode, the notebook works on mains power.

During use the load is normally low and when the user is occupied with other things, the notebook computer is using power in idle stage. The power used by the notebook with port extender is nearly the same as a thin client computer, but with the advantages of being equipped with storage, so it can run programs and use storage independent of the network and an application server.

The efficiency by charging and discharging the battery is not high. A little bit over 50 % of the energy used for charging can be retrieved from the battery. The losses come from the electro-chemical effect in the Lion battery. The conversion loss is about 30 %. When the power supply have an efficiency of approximately 75 % the result 0.7x0.75=0.54. Running the notebook on battery is only needed, when the computer is out of range of mains power supply.

Power Distribution for Computer Server

Figure 3.7 shows the power distribution between components in a server powered from Uninterruptible Power Supply through 2 redundant Power Supply Units. This server is equipped with 2 server CPUs, which have more L2 cache than normal CPUs.

The server is meant to be an all round server for file and application service configured with 5 Hard Disk Drives with SCSI or SAS interface in RAID. 2 are in RAID 1 (mirror) and 3 are in RAID 5 (stripe with parity). RAM capacity is 8 GByte Error Checking and Correcting. The network is connected through 2 1000Mbit/sec. ports.

Due to the low load of the power supply caused by redundancy, the efficiency is assumed to be 65 % in idle and 70 % at maximum load.

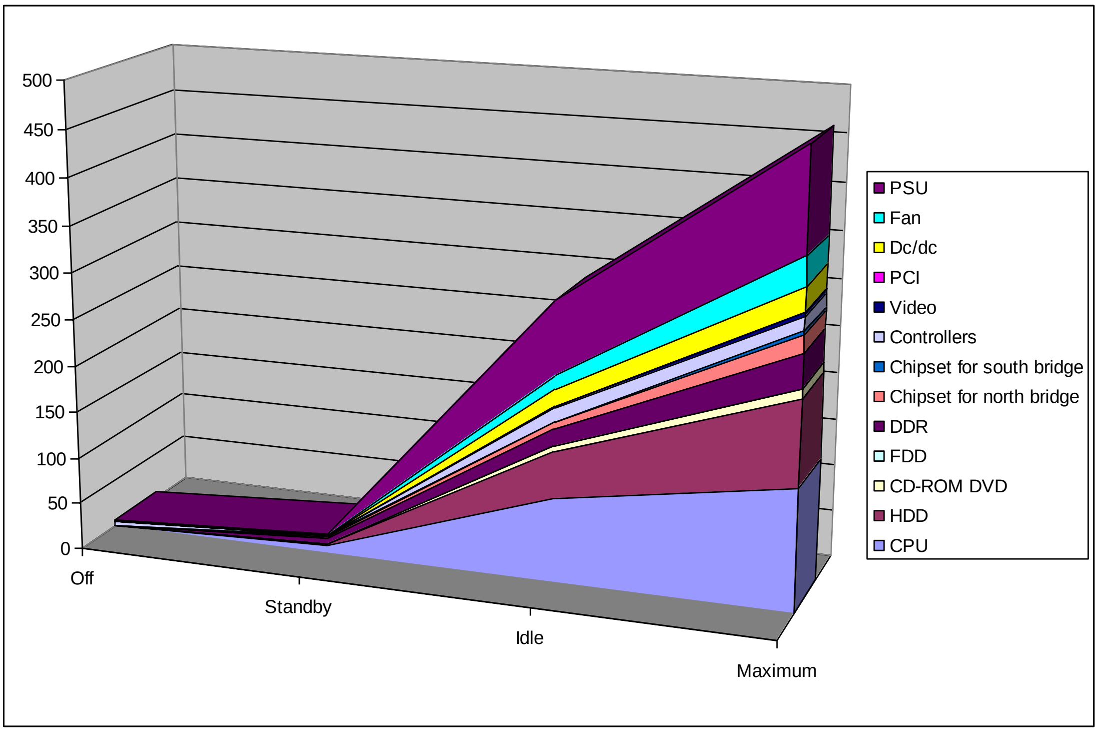

Figure 3.7: Power distribution in Watt between components in a server powered from UPS. Off 7 W, standby (sleep) 22 W, idle 297 W, and maximum 471 W.

Depending on the services running on the server, it is either low loaded or high loaded, but typically low loaded. The important characteristic by a server is its response time, which should be as low as possible. To get that L2 cache is important for application service. By file service a fast disks and array of disks is important.

Power consumption in 19" wide rack mounted servers can be very high. The example of a server is 2 Units high, which is equal to 3.5". A rack has a height of 42 U. This gives space for 21 of this kind of servers. If the rack is filled with this kind of servers, the footprint of the rack can be from 6 to 10 kW.

In addition of the power consumption of the servers themselves, it is needed to remove the heat from the servers. Typically, air conditioning or cooling systems are used, which can cost up to the same power consumption as the servers use.

Servers are also sensitive for power breaks and must be protected with UPS. UPS have an efficiency of about 90 %.

For servers there are several options for saving energy. It is possible to use 2.5" hard disks, which use 50 % of the power compared to 3.5" hard disks and they have nearly the same performance. CPUs with 2 or 4 cores, which are developed in 65 nm technology for servers, have better performance/Watt relation than former generations of CPUs. They are also designed to better handle virtual machines.

Another efficient technology is blade servers, where several blades are installed in the same cabinet with common PSUs, network interface cards, and management system. The blades can be started and stopped by the management system.

4 Energy Criteria Design and Measurement Definitions

4.1 Criteria Design

Criteria Considerations

Traditionally, i.e. ten to 15 years ago, energy labelling and similar schemes targeted the standby and sleep consumption of computers and other appliances and energy criteria were only set for standby and sleep modes. The power limit values were high, e.g. older Energy Star specifications for computers allowed 15 to 30 Watt in the sleep mode.

The standby and sleep consumptions have been substantially reduced and the on mode consumption constitutes higher proportion of the total annual consumption for computers. Therefore, it is needed to include the on mode in an energy labelling scheme if overall energy efficient solutions are sought, which has been the background for initiating this project.

There are however many choices to take with different consequences when choosing criteria design. In the following, we analyse various approaches of including the on mode consumption in the criteria. The approaches are clearly linked to the complete criteria design and the measurement methods included.

Most important properties to analyse for the various approaches are:

- Testing method: It should be possible for the manufacturers to easily test the computers and the results should be replicable using other test laboratories.
- Product categorisation: The various categories should be clearly defined with no doubts about which category a product belongs to.
- Requirement criteria: The requirement regarding e.g. maximum power consumption for modes or maximum annual energy consumption should be possible to set and to comply with for a certain proportion of the market.
- Consumer transparency: It should be possible for the informed consumer and consumer organisations to understand the test method and requirement and to do the measurements themselves.
- Global applicability: The global nature of the IT industry and IT products makes it preferable globally to use the same measurement methods and often the same energy requirement.

Basic Criteria Options

We present an overview of basic criteria options in Table 4.1, which is detailed below the table. It is possible to combine them and thereby make variations.

Option	Advantages	Disadvantages
Simple modes approach based on off, sleep and idle	• Easy to measure • Easy for the consumer to understand • Secures the maximum power levels in each mode	• Imprecise for heavy load computer usages • Does not give the consumer information on annual consumption
Advanced modes approach based on off, sleep, idle, active and possibly maximum load	• More precise, because it includes the active mode	• As above, but measurements require more work and a measurement method for active should be defined • Imprecise if the user deviates from the usage model established
Simple annual electricity consumption based on the mode consumptions and mode usages	• Informs the consumer about annual consumption • Gives design freedom for the manufacturers	• Requires data on average hours of usage in each mode • Imprecise if the user deviates from the usage model established • Does not reflect real usage and does not show the ability to switch between modes
Annual electricity consumption based on a typical full usage model	• As above • Reflects real usage and show the ability to switch between modes	• Requires data on the full usage • Imprecise if the user deviates from the usage model established • Measurements require more work

Table 4.1: Overview of basic energy criteria options.

<u>Modes Approach Based on Off, Sleep and Idle</u>

This is the traditional approach where requirements are set for the individual modes e.g. maximum:

- Off: 2 W
- Sleep: 4 W
- Idle: 50 W

<u>Modes Approach Based on Off, Sleep, Idle, Active and Possibly Maximum Load</u>

A requirement is included for the active mode e.g. 60 W. The maximum load may also be included, however, this is more typical for requirements to workstations that more often operate at high load levels.

<u>Annual Electricity Consumption Based on the Mode Consumptions and Mode Usages</u>

The annual electricity consumption is calculated based on the mode consumptions and the number of hours in each modes. E.g.:

- Off: 2 W – 3760 hours
- Sleep: 4 W – 3000 hours
- Idle: 50 W – 1000 hours
- Active: 60 W – 1000 hours

For the hourly values above, it is assumed that the computer is not disconnected.

The annual electricity consumption is: 2 W * 3760 hours + 4 W * 3000 hours + 50 W * 1000 hours + 60 W * 1000 hours = 130 kWh.

<u>Annual Electricity Consumption Based on a Typical Full Usage Model</u>
The annual electricity consumption is directly measured during the defined test period.

<u>Definition of the Modes</u>

- Off mode: The computer is switched off in the normal way through the operating system and still connected to the plug. Few components may be active such as the network card if WOL (Wake On Lan) is activated. The consumption is at a stable, low level.

- Sleep mode: This is a low power mode where the active content is saved to RAM or saved to disk. The latter is normally called hibernation. Typically, sleep mode is save to RAM. The consumption is at a stable, low level.

- Idle mode: The computer has been switched on, the operating system has completed loading, a user profile has been created, the machine is not asleep, and activity is limited to those basic applications that the system starts by default. The consumption is quite stable, but may vary corresponding to basic processes of the operating systems, drivers etc.

- Active mode: The computer is carrying out useful work in response to prior or concurrent user input or instruction over the network. This state includes active processing, seeking data from storage, memory, or cache, including idle state time while awaiting further user input and before entering low power modes. The consumption vary from the idle level to maximum level that is determined by 100 % CPU and possibly GPU (graphics processor unit) load and maximum load on other components such as disk drives. The active mode may be defined either as all the time when the computer is on i.e. including the idle period or as just the time when the user is working actively on the computer. When measured, the active is a simulated mode that reflects normal usage.

- Maximum load mode: The computer is using the main components at a maximum level and drawing maximum power.

4.2 Measurement Methods

Measurement of Off and Sleep Mode Levels
The off and sleep modes measurements are quite straightforward. Energy Star and several similar schemes uses the following test procedures for off and sleep modes, respectively:

- "With the UUT (Unit Under Test) shut down and in Off, set the meter to begin accumulating true power values at an interval of less than or equal to 1 reading per second. Accumulate power values for 5 additional minutes and record the average (arithmetic mean) value observed during that 5 minute period."

- "After completing the Idle measurements, place the computer in Sleep mode. Reset the meter (if necessary) and begin accumulating true power values at an interval of greater than or equal to 1 reading per second. Accumulate power values for 5 additional minutes and record the average (arithmetic mean) value observed during that 5 minute period."

See the full description of Energy Star test procedures in Annex B, where details on preparation of the test unit and of the meter etc. are provided.

Measurement of Idle Mode Levels
The measurement of the idle mode is also more or less straightforward and the main issue is to bring the computer into the stable idle mode. Energy Star uses the following test procedures for idle mode:

"Switch on the computer and begin recording elapsed time, starting either when the computer is initially switched on, or immediately after completing any log in activity necessary to fully boot the system. Once logged in with the operating system fully loaded and ready, close any open windows so that the standard active desktop screen or equivalent ready screen is displayed. Between 5 and 15 minutes after the initial boot or log in, set the meter to begin accumulating true power values at an interval of greater than or equal to 1 reading per second. Accumulate power values for 5 additional minutes and record the average (arithmetic mean) value observed during that 5 minute period."

A possible issue with the measurement is which processes and components should be active. E.g. should the hard disk be allowed to spin down during the measurement.

Measurement of Active Mode Levels
The measurement of the active mode is much more complicated compared to the other modes. One or more typically usage models need to be defined and the test software should then simulate these usage models.

Test software is similar to the kind of software used for computer benchmarking.

Measurement of Maximum Load Mode Levels
Maximum load mode levels can be achieved through software such as Linpack and SPECviewperf®. The software stresses the core system (e.g., processor, memory, etc.) and the GPU.

Annual Electricity Consumption Based on a Typical Full Usage Model
Measurement of a typical full usage model will be a combination of the off, sleep, idle and active modes where the software automatically switches between the modes according to the usage model.

4.3 Evaluation of Selected Measurement Methods and Software

Test of On Modes
We have evaluated and tested the various methods for measuring the on modes, i.e. the idle and active modes.

Evaluation of the Idle Mode
The main purpose of the measurements was to analyse the power consumption during the active mode in order to see the variation of the consumption compared to the idle mode.

We tested six computers over a work week. The work comprised typical office work. The power was measured using a logging power meter that logged the power consumption with 1-minute interval. The computers were various models of the notebook computer Lenovo ThinkPad.

The results are presented in the Figures 4.1 - 4.6 below. Please notice that the peaks were due to the battery charging cycles and that periods without consumption was because the computer was unplugged.

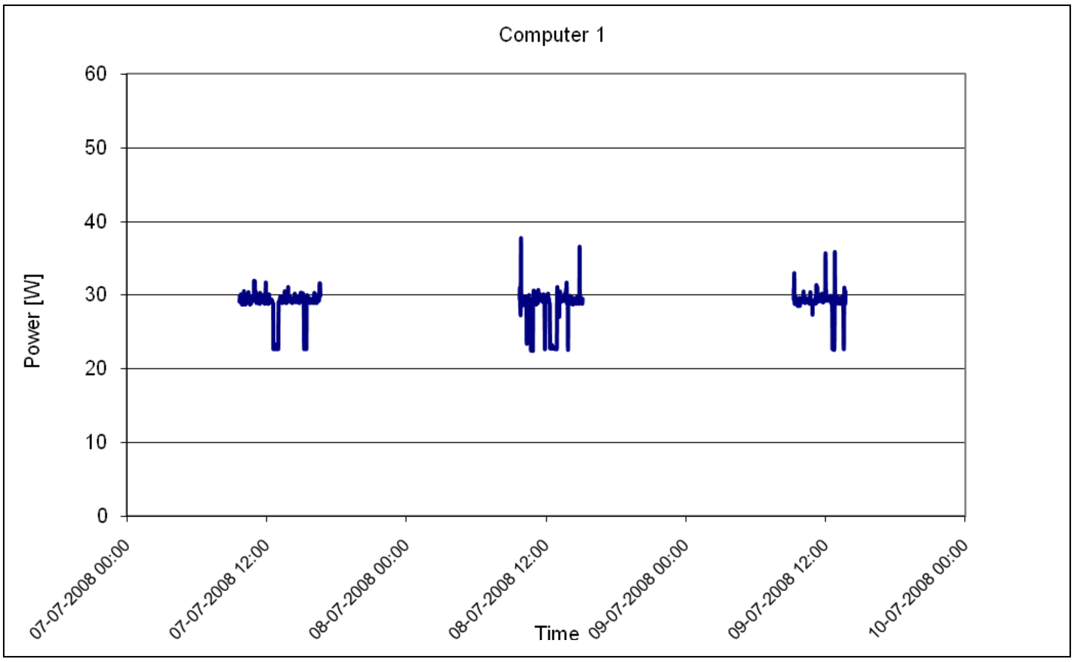

Figure 4.1: Power measurements of computer no. 1.

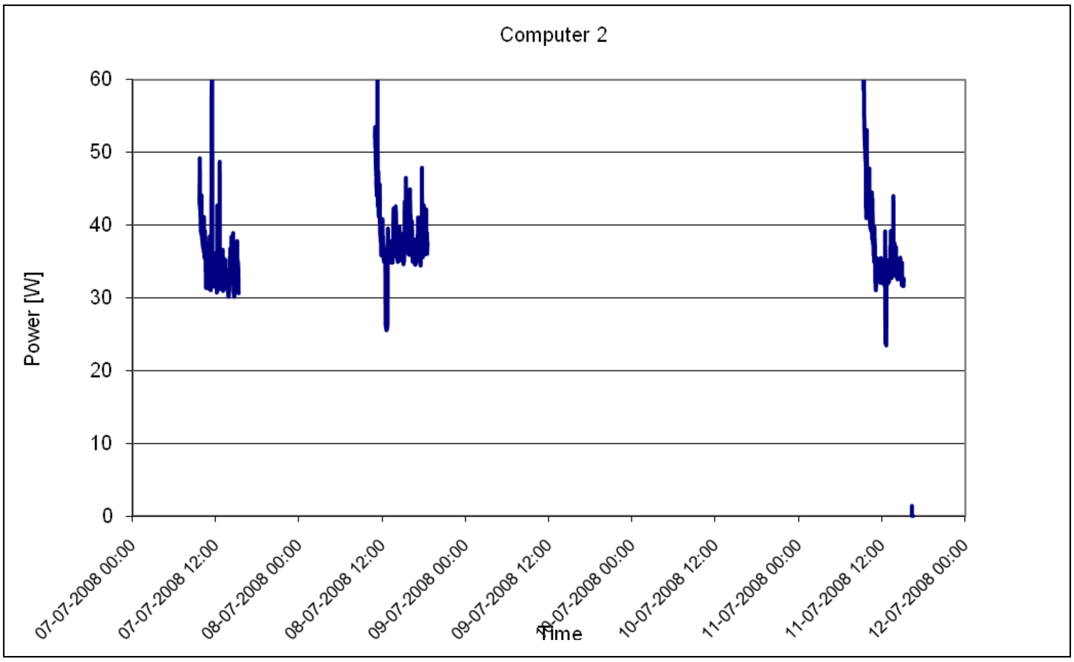

Figure 4.2: Power measurements of computer no. 2.

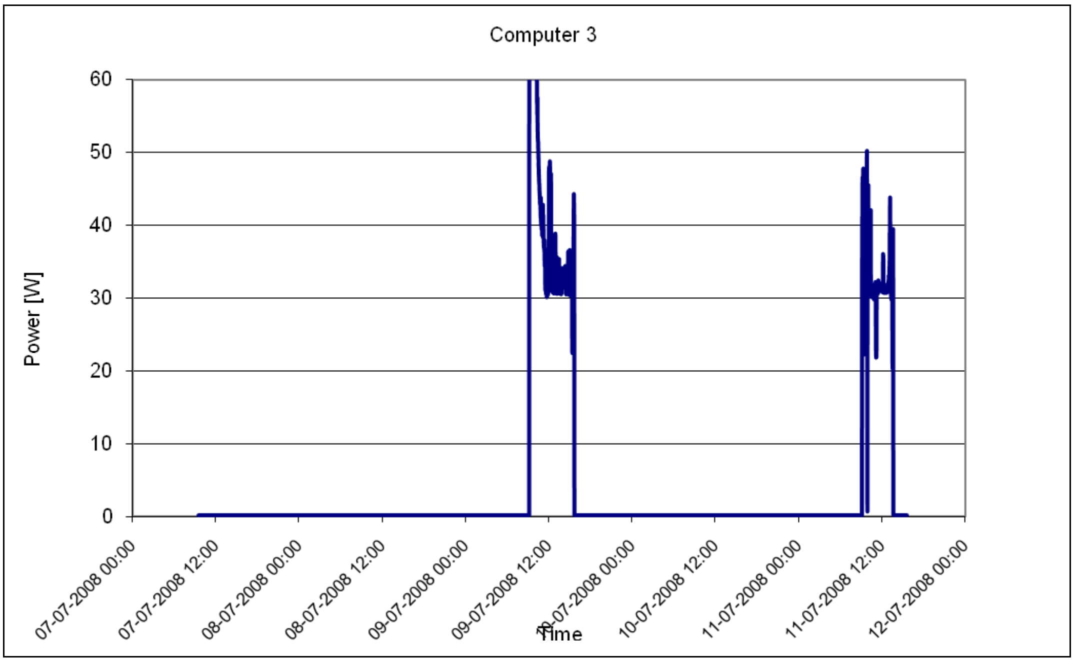

Figure 4.3: Power measurements of computer no. 3.

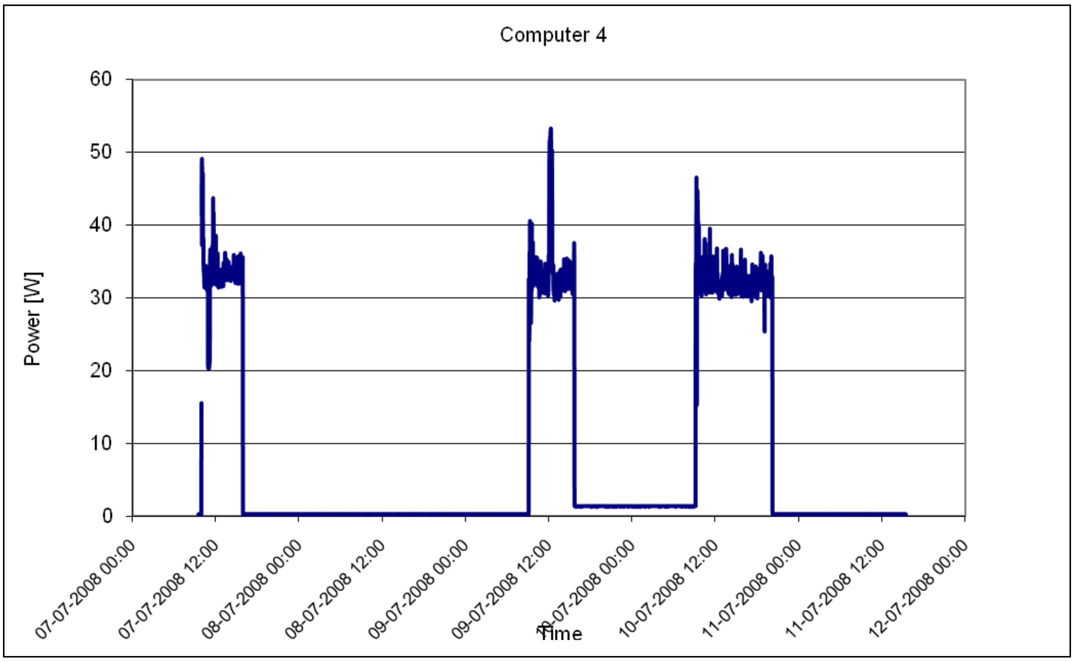

Figure 4.4: Power measurements of computer no. 4.

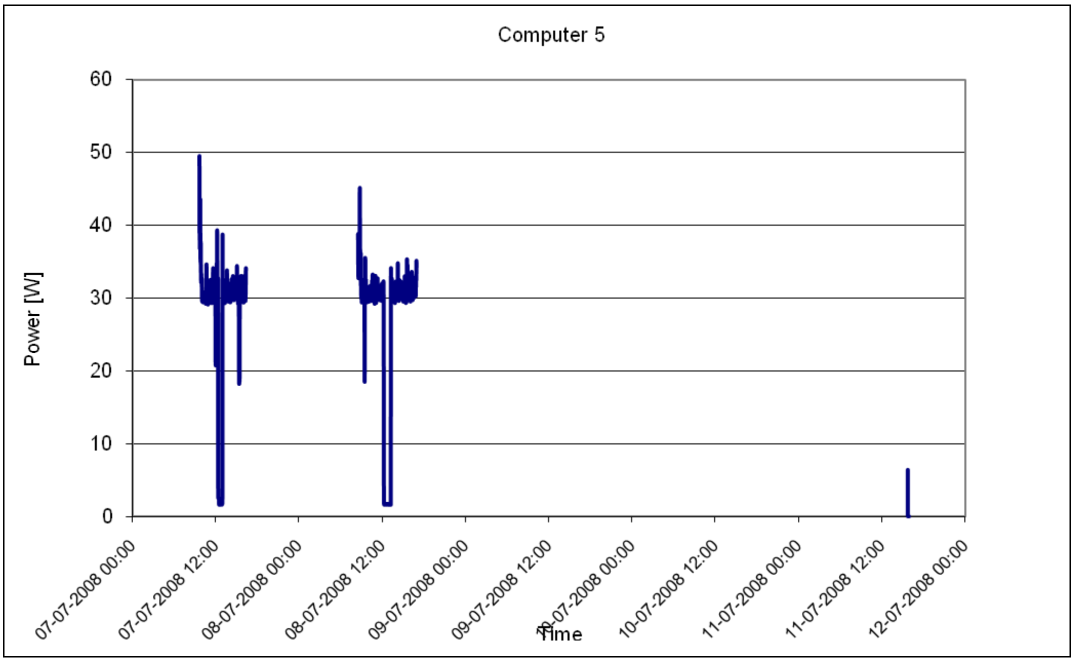

Figure 4.5: Power measurements of computer no. 5.

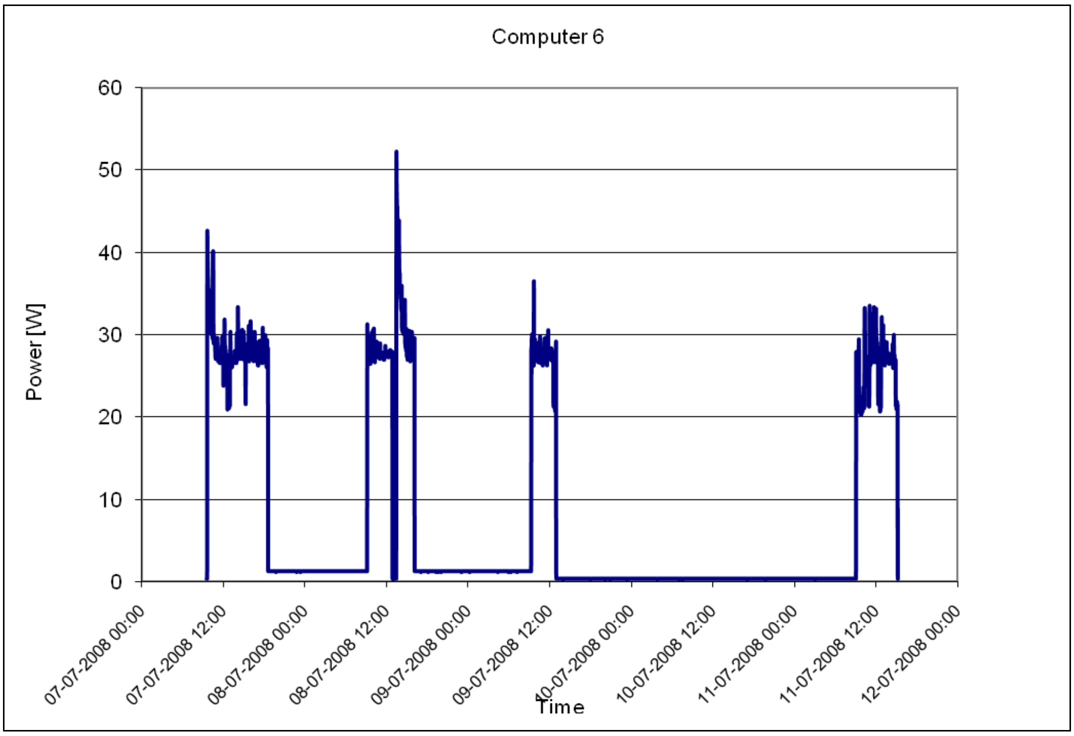

Figure 4.6: Power measurements of computer no. 6.

<u>Conclusion</u>

The conclusion is that the variations in power consumption were not more that 10 percent to 15 percent when excluding the battery charging. For normal office work and with today's computer technology, the idle approach is a good approximation of the on-mode.

For gaming computers and media centres, the power consumption variations will be much higher, typically from 30 to 100 percent depending on the activity level. If these computers will be used for gaming and media purposes most of the usage time, the idle mode will not be a good approximation of the on-mode.

It is however our impression that gaming and media usages today are still at the low end of all computer usages and therefore the idle approach is currently sufficient for most purposes.

The Danish Electricity Saving Trust used already from 2004 with good results the idle mode as a way to include on mode power consumption in the definition of efficient computers. The requirements were used until 2007, where Energy Star version 4.0 specification was in place.

Energy Star version 4.0 specification included for the first time the on mode based on the idle mode, which was based on a similar idle mode measurement method as the Danish Electricity Saving Trust used. Experiences from this project as well as from the Danish Electricity Saving Trust were provided as part of the specification revision work.

Evaluation of Active Mode

The basic idea of measuring the active mode is to design and use a piece of software that can simulate one or more types of usage models, i.e. how various typical users use their computer.

There are many types of this kind of software, however, there are mainly built with benchmarking purposes for computer tests and should be adapted for the purpose of measuring energy consumption for typical usage models.

This was also the plan for the development of Energy Star version 5.0 (originally Tier 2 of version 4.0) and it was therefore decided to have a close cooperation with this development work.

The work comprised development of an industry standard (ECMA[1]) combined with development of the testing software, called EEcomark. The organisation BAPCo[2] was responsible for developing the software on the basis of their commercial test software.

See Annex C for more details on the idea behind the development of the standard and the software.

The ECMA standard “ECMA-383 - Measuring Energy Consumption, Performance and Capabilities of ICT and CE Products” was released on June 2008, see Annex D.

The EEcoMark software was under development with the purpose of being used for Energy Star computer specification version 5.0. It was however not possible for BAPCo to develop the software to a sufficiently stable and reliable level and the idea of using this software for measuring the active mode was abolished.

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[1] ECMA is an industry association founded in 1961 and dedicated to the standardization of Information and Communication Technology (ICT) and Consumer Electronics (CE). Read more on www.ecma-international.org

[2] BAPCo stands for Business Applications Performance Corporation. It is a non-profit consortium whose charter is to develop and distribute a set of objective performance benchmarks based on popular computer applications and industry standard operating systems.

Therefore, version 5.0 has also been based on measurements of the idle, sleep and off modes. A TEC value shall be calculated using these three mode levels and an assumed number of usage hours in each mode. See Energy Star computer specification version 5.0 in Annex B.

4.4 Recommendation of Criteria Design and Measurement Method

Simple Modes Approach
The recommendation is to use a simple modes approach using requirements for off, sleep and idle, where idle is representing the on mode.

For typical office and home use, the idle mode measurements will give sufficiently precise approximation of the power consumption in active use. The reason is that typical office and home use (writing of documents and e-mails, web browsing, use of simple spreadsheets etc.) does not put much more load on the computer than the idle mode does.

For most labelling schemes, this will be a simple and yet effective design that will cover the needs, especially if combined with power management requirements.

Simple Annual Electricity Consumption Approach
If there is a desire for providing more freedom for the manufacturers when they design their computers and for informing the consumers about annual electricity consumption, a requirement for simple annual electricity consumption can be established.

The power consumption in off, sleep and idle will be multiplied with a fixed set of number of hours on the modes.

The number of hours in each mode can be set according to typical values for the area. Energy Star Computer Specification version 5.0 uses the hour values in Table 4.2.

Mode	Desktop	Notebook
Off	4818	5256
Sleep	438	876
Idle	3504	2628

Table 4.2: Hour values for calculating annual electricity consumption.

Advanced Approaches
The advanced approaches use workloads for measuring the active mode or all the modes corresponding to a typical full usage model.

Especially the latter approach by using a full usage model will be the theoretical best way of measuring the energy efficiency of a computer because it includes power management capabilities by using a piece of software that simulates the computer use over a full period e.g. a working day. The reason is that it will show how capable the computer and the components are to decrease and increase their services and to go into low-power modes.

It is however very difficult to simulate the active mode or full usage model, because very few data exist about use of computers that can be used for simulating the usage models.

Furthermore, the tool should be used at a global level, where there can be differences in usage models between the countries.

Therefore, it is not recommended to use the advanced approaches unless such workloads or usage models combined with a software tool are available.

Measurement Method

In order to simplify the measurement we recommend to use the Energy Star Computer Specification version 5.0 (see Annex B) or later versions.

This measurement assumes that the screen is blanked. If there is a need to include the screen consumption, the screen should not be blanked and the luminance level should be as shipped. The criteria level and all the measurements should naturally be measured similarly.

Notebooks will be measured without battery or with the battery fully loaded.

5 Establishment of Criteria

5.1 Criteria Framework

We will use the Simple Modes Approach that can be extended to Simple Annual Electricity Consumption Approach.

We therefore base the criteria on the following modes:

- Off mode
- Sleep mode
- Idle mode

Additional requirements such as for power management can be added, however, for this study, we are focusing on the power levels.

We use the same computer categorisation as Energy Star Computer Specification version 5.0, however, without using adders for additional functionality. The measurement is also the same as in the Energy Star specification. The screen is thus blanked and the battery is not being charged.

These categories for desktop computers are:

A: All desktop computers that do not meet the definition of categories B, C, or D

B: Must have equal to 2 physical cores and greater than or equal to 2 gigabytes (GB) of system memory.

C: Must have greater than 2 physical cores and at least one of the following two characteristics:

- Greater than or equal to 2 gigabytes (GB) of system memory
- A discrete GPU

D: Must have greater than or equal to 4 physical cores and at least one of the following two characteristics:

- Greater than or equal to 4 gigabytes (GB) of system memory
- A discrete GPU with a Frame Buffer Width greater than 128-bit

These categories for notebook computers are:

A: All desktop computers that do not meet the definition of categories B or C

B: Must have a discrete GPU

C: Must have:

- Greater than or equal to 2 physical cores
- Greater than or equal to 2 gigabytes (GB) of system memory
- A discrete GPU with a Frame Buffer Width greater than 128-bit.

5.2 Data Set

We had an opportunity of using the data set collected by the US EPA as part of the development process of Energy Star Computer Specification Version 5.0. These data were measured and provided by the computer manufacturers using the Energy Star measurement methodology (see Annex B).

The data set comprises:

- 214 desktop computers
- 268 notebook computers

The data set is available here at www.energystar.gov/index.cfm?c=revisions.computer_spec

5.3 Criteria for Power Consumption

Modes Levels

We have analysed all the data and based on the measured consumption for off, sleep and idle modes, we have set the limit for power consumption with the target that 20 to 25 percent of the products would comply.

For some of the product categories, many products had very similar power consumption and just 1 Watt of change in level would qualify e.g. additional 15 percent-point. In these cases, the lower level was chosen.

The proposed levels for each product group and category are shown in Table 5.1 and 5.2 below together with the total number and percent of compliant products.

Desktops	A	B	C	D
Off, W	2	2	2	2
Sleep, W	3	3	3	3
Idle, W	42	46	62	68
Total number	44	68	31	40
Comply	25%	25%	26%	25%

Table 5.1: Proposed power levels for off, sleep and idle for each configuration category for desktops.

Notebooks	A	B	C
Off, W	2	2	2
Sleep, W	3	3	3
Idle, W	12	17	37
Total number	174	75	19
Comply	18%	15%	21%

Table 5.2: Proposed power levels for off, sleep and idle for each configuration category for desktops.

E.g., a category A notebook cannot use more than 2 W, 3 W and 12 W respectively for off, sleep and idle modes. About 18 % of the notebooks in the data set comply.

Annual Electricity Consumption

These levels can be combined with the number of hours in each mode used in the Energy Star computer specification, Table 5.3, and the corresponding annual energy consumption figures can be calculated, see Table 5.4 and 5.5.

Mode	Desktop	Notebook
Off	4818	5256
Sleep	438	876
Idle	3504	2628

Table 5.3: Number of hours in each mode based on Energy Star 5.0 computer specification.

Desktops	A	B	C	D
Annual energy consumption, kWh/year	158	172	228	249

Table 5.4: Proposed annual energy consumption for each configuration category for desktops.

Notebooks	A	B	C
Annual energy consumption, kWh/year	53	71	141

Table 5.5: Proposed annual energy consumption for each configuration category for notebooks.

6 Typical Electricity Consumption and Calculation Tool

On the basis of the data measured and collected for computers, we provide average electricity consumption values for a number of typical computer types, configurations and usage models.

Furthermore, we provide a spreadsheet calculation tool where all combinations of types, configurations and usage models can be calculated and two scenarios can be compared, e.g. a current scenario and a new scenario or two purchase scenarios. The results of the comparison are reported as energy and money.

6.1 Average Electricity Consumption Data

In the below two tables, we provide average electricity consumption values for 40 typical computer types, configurations and usage models. Table 6.1 shows the consumption for energy efficient types, while Table 6.2 shows non energy efficient types. More combinations can be calculated using the calculation tool.

The efficiency level is the only difference between the two tables. An energy efficient computer complies with the most recent version of Energy Star specification or similar requirements.

Type of computer	Age Years	Screen size Inch	Docking station	Usage model	Consumption KWh/year
Notebook: Netbook	0 - 1	10	No	Home user: Medium activity	17
Notebook: Standard	0 - 1	14	No	Home user: Medium activity	22
Notebook: Standard	1 - 3	14	No	Home user: Medium activity	25
Notebook: Graphics	0 - 1	17	No	Home user: Medium activity	29
Notebook: Media	0 - 1	18	No	Home user: High activity	114
Notebook: Netbook	0 - 1	10	No	Office user: Medium activity	24
Notebook: Standard	0 - 1	14	Yes	Office user: Medium activity	44
Notebook: Standard	1 - 3	14	Yes	Office user: Medium activity	47
Notebook: Graphics	0 - 1	17	Yes	Office user: Medium activity	55
Notebook: Media	0 - 1	18	Yes	Office user: High activity	132
Desktop: Mini	0 - 1	None	No	Home user: Medium activity	34
Desktop: Standard	0 - 1	None	No	Home user: Medium activity	51
Desktop: Graphics	0 - 1	None	No	Home user: Medium activity	66
Desktop: Media	0 - 1	None	No	Home user: Medium activity	77
Desktop: Gaming	0 - 1	None	No	Home user: High activity	307
Desktop: Mini	0 - 1	None	No	Office user: Medium activity	47
Desktop: Standard	0 - 1	None	No	Office user: Medium activity	72
Desktop: Graphics	0 - 1	None	No	Office user: Medium activity	96
Desktop: Media	0 - 1	None	No	Office user: Medium activity	112
Desktop: Gaming	0 - 1	None	No	Office user: High activity	307

Table 6.1: Annual energy consumption for a selection of energy efficient computers under certain assumptions.

Type of computer	Age Years	Screen size Inch	Docking station	Usage model	Consumption KWh/year
Notebook: Netbook	0 - 1	10	No	Home user: Medium activity	25
Notebook: Standard	0 - 1	14	No	Home user: Medium activity	31
Notebook: Standard	1 - 3	14	No	Home user: Medium activity	37
Notebook: Graphics	0 - 1	17	No	Home user: Medium activity	41
Notebook: Media	0 - 1	18	No	Home user: High activity	207
Notebook: Netbook	0 - 1	10	No	Office user: Medium activity	34
Notebook: Standard	0 - 1	14	Yes	Office user: Medium activity	56
Notebook: Standard	1 - 3	14	Yes	Office user: Medium activity	62
Notebook: Graphics	0 - 1	17	Yes	Office user: Medium activity	70
Notebook: Media	0 - 1	18	Yes	Office user: High activity	225
Desktop: Mini	0 - 1	None	No	Home user: Medium activity	52
Desktop: Standard	0 - 1	None	No	Home user: Medium activity	82
Desktop: Graphics	0 - 1	None	No	Home user: Medium activity	102
Desktop: Media	0 - 1	None	No	Home user: Medium activity	123
Desktop: Gaming	0 - 1	None	No	Home user: High activity	465
Desktop: Mini	0 - 1	None	No	Office user: Medium activity	70
Desktop: Standard	0 - 1	None	No	Office user: Medium activity	114
Desktop: Graphics	0 - 1	None	No	Office user: Medium activity	145
Desktop: Media	0 - 1	None	No	Office user: Medium activity	177
Desktop: Gaming	0 - 1	None	No	Office user: High activity	465

Table 6.2: Annual energy consumption for a selection of non energy efficient computers under certain assumptions.

6.2 Calculation Tool

We have developed a user-friendly tool for calculation of replacement of computers or comparison of two purchase scenarios. The tool is aiming at Danish users and the language is therefore Danish. It has been developed in Microsoft Excel.

The calculation tool calculates the electricity consumption for computers on the basis of typical computers or own power consumption measurements and of typical usage models.

It can compare two scenarios. For example, an organisation wanting to replace computers can compare the present situation with a new situation based on considered products. Another use is if an organisation will compare the effect of two purchase scenarios.

The tool is based on typical computers and usage models and therefore there may be large variations compared to specific situations.

Sammenligning

Elforbrug situation 1	0 kWh/år	0 kr./år
Elforbrug situation 2	0 kWh/år	0 kr./år
Forskel situation 1 til situation 2	0 kWh/år	0 kr./år
Elpris	2,00 kr./kWh	

Figure 6.1: The result box with comparison of scenario 1 and 2.

The result box gives the annual electricity consumption in kWh and kr. (DKK) for each of the two scenarios and the difference between the two scenarios. It is possible to adjust the electricity price (yellow field).

For each of the two scenarios, there is an input box for providing data on the computers and the usage models. We go through the data fields below. In the screen dumps, the input box has been split into two boxes, while it is one box in the calculation tool.

Antal	Type computer	Alder	Energieffektiv	Skærmstørrelse	Dockingstation til bærbar	Elforbrug: Slukket - watt		Sleep - watt		Tændt - watt	
						Standardtal	Egne tal	Standardtal	Egne tal	Standardtal	Egne tal
121	Bærbar: Standard	1 - 3 år	Nej	14 tommer	Ja	2,0		4,0		29,2	
35	Stationær: Grafik	Mere end 3 år	Nej	Ingen skærm eller slukket	Nej	5,0		8,0		96,0	
94	Egne elforbrugstal - skriv ind -->					4,7	4,7	5,3	5,3	84,0	84,0
						<-- Udfyld tomme felter		<-- Udfyld tomme felter		<-- Udfyld tomme felter	
						<-- Udfyld tomme felter		<-- Udfyld tomme felter		<-- Udfyld tomme felter	
						<-- Udfyld tomme felter		<-- Udfyld tomme felter		<-- Udfyld tomme felter	
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						<-- Udfyld tomme felter		<-- Udfyld tomme felter		<-- Udfyld tomme felter	
						<-- Udfyld tomme felter		<-- Udfyld tomme felter		<-- Udfyld tomme felter	
						<-- Udfyld tomme felter		<-- Udfyld tomme felter		<-- Udfyld tomme felter	
						<-- Udfyld tomme felter		<-- Udfyld tomme felter		<-- Udfyld tomme felter	
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Figure 6.2: Input box for computers.

Explanation of the fields in the input box for computers:

- "Antal": Numbers of computers of same type and usage models.
- "Type computer": Nine fixed types of computers can be selected with a drop down menu. Furthermore, it can be selected that the user has made own power measurements, see the example in row three above. In that case, no further input data should be made except the measurements in the yellow fields.
- "Alder": Age, three levels can be selected.
- "Energieffektiv": Energy efficient or not can be selected.
- "Skærmstørrelse": Screen sizes in inches for notebooks and integrated computers can be selected.
- "Dockingstation til bærbar": Docking station for notebooks can be selected.
- "Elforbrug – Slukket – Sleep – Tændt": Calculated power consumption in off, sleep and on based on the selections made or on own measurement data.

If data input is lacking, the message "Udfyld tomme felter", "fill in empty fields", is shown.

Type bruger	Brug af computeren: Slukket - timer/år		Sleep - timer/år		Tændt - timer/år		Beregnet elforbrug: Pr. computer	I alt	Kommentarer
	Standardtal	Egne tal	Standardtal	Egne tal	Standardtal	Egne tal	KWh/år	KWh/år	
Kontorbruger: Mellem aktivitet	6285		900		1575		62	7521	
Kontorbruger: Høj aktivitet	5160		600		3000		319	11151	
Egne tal - skriv ind -->	0		0		0		0	0	
	<-- Udfyld 'Type bruger'		<-- Udfyld 'Type bruger'		<-- Udfyld 'Type bruger'				
	<-- Udfyld 'Type bruger'		<-- Udfyld 'Type bruger'		<-- Udfyld 'Type bruger'				
	<-- Udfyld 'Type bruger'		<-- Udfyld 'Type bruger'		<-- Udfyld 'Type bruger'				
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	<-- Udfyld 'Type bruger'		<-- Udfyld 'Type bruger'		<-- Udfyld 'Type bruger'				

Figure 6.3: Input box for usage models.

Explanation of the fields in the input box for usage models:

- "Type bruger": Type of user.
- "Brug af computeren – Slukket – Sleep – Tændt": Use of the computer in off, sleep and on in hours per year.
- "Beregnet elforbrug – Pr. computer – I alt": Calculated annual electricity consumption in kWh per computer and totally for all the computer based on the data for the computer and the usage model.
- "Kommentarer": Comments.

In next section we provide the various selection choices and the data assumptions.

6.3 Data Assumptions

All the assumptions for the data used in the calculation tool and for the average electricity consumption data are shown in the below tables. Sources are the data measured and collected for computers in this project.

Naturally, there could be found many examples with technical data and usage models deviating from the figures below. The assumptions made are valid for typical products and usage models within the groups.

	Power - Watt					
	Energy Efficient			Not Energy Efficient		
Type of computer	**Off**	**Sleep**	**On**	**Off**	**Sleep**	**On**
Notebook: Netbook	0.5	1	9	1	2	13
Notebook: Standard	0.5	1	11	1	2	16
Notebook: Graphics	0.5	1	15	1	2	22
Notebook: Media	0.5	1	26	1	2	56
Desktop: Mini	1	2	25	2	3	35
Desktop: Standard	1.2	2	40	2.5	4	60
Desktop: Graphics	1.2	2	55	2.5	4	80
Desktop: Media	1.2	2	65	2.5	4	100
Desktop: Gaming	1.2	2	100	2.5	4	150

Table 6.3: Assumed power levels for off, sleep and on for the various type of computers.

Explanation of the computer types:

- Notebook: Netbook: A small notebook with limited computer capacity and with screen sizes typically up to about 10 inches.

- Notebook: Standard: A typical computer for home or office use for e-mailing, web browsing, text processing, spreadsheets and lighter graphical work. The notebook does not have a discrete graphic card.

- Notebook: Graphics: As the standard notebook, but more powerful and with a discrete graphic card.

- Notebook: Media: A powerful computer with a larger, discrete graphic card for media centre use, graphics work, gaming etc.

- Desktop: Mini: A small desktop with limited computer capacity and without discrete graphic card.

- Desktop: Standard: A typical computer for home and office use for e-mailing, web browsing, text processing, spreadsheets and lighter graphical work. The computer does not have a discrete graphic card.

- Desktop: Graphics: As the standard computer, but more powerful and with a discrete graphic card.

- Desktop: Media: A powerful computer with a larger, discrete graphic card for media centre use, graphics work, gaming etc.

- Desktop: Gaming: A very powerful computer dedicated gaming and similar workloads.

An energy efficient computer complies with the most recent version of Energy Star specification or similar requirements.

Size Inch	Adder On Watt
8	2.2
9	2.7
10	3.4
11	4.1
12	4.9
13	5.7
14	6.6
15	7.6
16	8.6
17	9.7
18	10.9
19	12.2

Table 6.4: Power adder for on mode for active monitors on notebooks and integrated computers.

Adder - Watt		
Off	Sleep	On
0.5	1	5

Table 6.5: Adder for notebook dockingstations.

	Multiplicator		
Age years	Off	Sleep	On
0 - 1	1	1	1
1 - 3	1.5	1.5	1.1
Older	2	2	1.2

Table 6.6: Power multiplicator for age of computer.

Type of user	Annual hours in each mode		
	Off	Sleep	On
Home user: Low activity	8060	200	500
Home user: Medium activity	7494	234	1032
Home user: High activity	5160	600	3000
Office user: Low activity	7360	400	1000
Office user: Medium activity	6285	900	1575
Office user: High activity	5160	600	3000

Table 6.7: Usage models for different types of users.