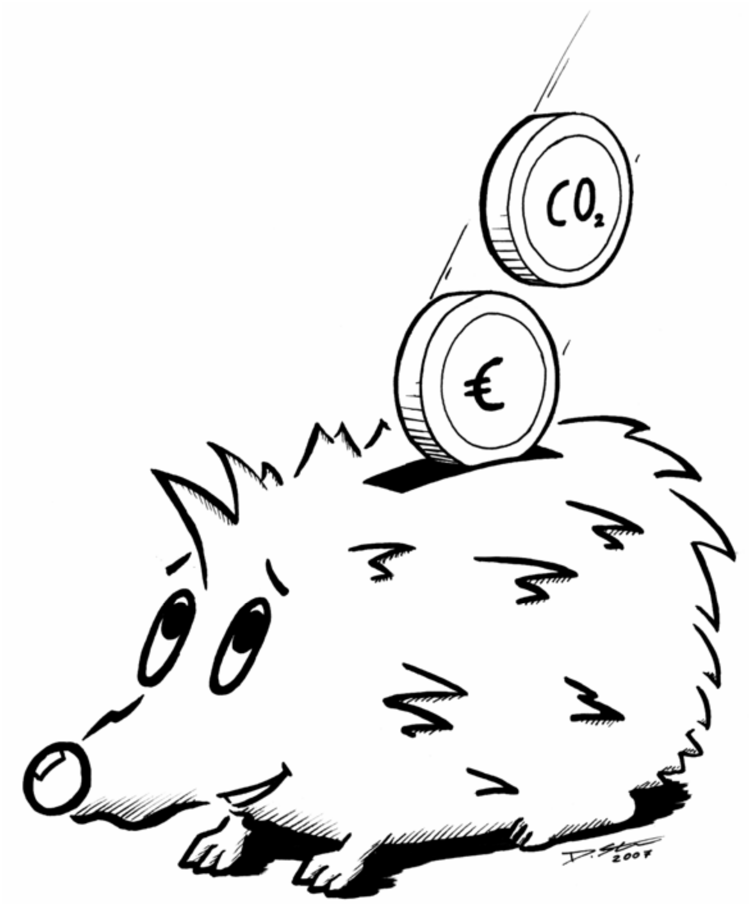
Fraunhofer Institut
Umwelt-, Sicherheits-,
Energietechnik UMSICHT

Study

Environmental Comparison of the Relevance of PC and Thin Client Desktop Equipment for the Climate, 2008



Prepared for:
IGEL Technology GmbH
Heiko Gloge
Schlachte 39/40
28195 Bremen, Germany

Funded by:
Verein zur Förderung der Umwelt-, Sicherheits- und Energietechnik e.V.

Oberhausen, 24 April 2008

Fraunhofer Institut Umwelt-, Sicherheits-, Energietechnik UMSICHT

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Environmental Comparison of PC and Thin Client Desktop Equipment, 2008

Prepared by:
Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT
Head of the Institute
Prof. Dr.-Ing. Eckhard Weidner
Osterfelder Strasse 3
46047 Oberhausen, Germany

Project Team:
Dipl.-Inform. (FH) Christian Knermann | Project Manager
Deputy Head of IT Management Department
Phone: +49 (0)2 08/85 98-11 18
E-mail: christian.knermann@umsicht.fraunhofer.de

Dr.-Ing. Markus Hiebel (MSc) | Deputy Project Manager
Resources Management Business Unit
Phone: +49 (0)2 08/85 98-11 81
E-mail: markus.hiebel@umsicht.fraunhofer.de

Dr.-Ing. Hartmut Pflaum
Head of Resources Management Business Unit
Phone: +49 (0)2 08/85 98-11 71
E-mail: hartmut.pflaum@umsicht.fraunhofer.de

Manuela Rettweiler, M.A.
Marketing, Communication, Business Development
Phone: +49 (0)2 08/85 98-14 12
E-mail: manuela.rettweiler@umsicht.fraunhofer.de

Dipl.-Ing. Andreas Schröder
Deputy Head of Information Technology in Process Engineering Business Unit
Phone: +49 (0)2 08/85 98-11 31
E-mail: andreas.schroeder@umsicht.fraunhofer.de

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1 Executive Summary

Classification of the project

In view of the debate about climate control and sustainability, manufacturers of IT technology have realized that end customers (private and commercial) are increasingly concerned about the ecological aspects of buying a PC, laptop or network equipment and that energy and eco-efficiency can often have an effect on the buyer's decision-making. But in many cases only isolated, individual aspects are considered, such as energy consumption, while the equipment is being used, or the use of safe toxicological materials. What is missing is a holistic ecological evaluation across the life phases of production, use and recycling/disposal.

Tasks and procedure

In this study the results of the previous study »Environmental Comparison of PC and Thin Client Desktop Equipment« from 2006, the comparison of these device types will be elaborated further. The production phase, usage phase and disposal phase will be considered. The methodology, data records and results are based on the EU report »Personal Computers (desktops and laptops) and Computer Monitors« [IVF, 2007]. On the basis of different deployment scenarios the energy saving potential of an IT infrastructure based on thin clients and server-based computing will be presented for different sized companies. In addition, potential innovation directions will be identified and market estimations will be performed.

Ecological footprint of the IT industry and sustainability concepts

Not only the eco-toxicological effects of the substances used in and emissions from the production process, but also the material intensity of the raw materials that are used – mainly non-renewable and thus finite – show that the ecological footprint is becoming increasingly larger due to the growing intensity in the use of information and communication technology. When IT components are running they consume a considerable amount of energy and, according to estimates, in Germany make up 3 % of the country's total electricity consumption [Hiebel et al., 2007]. But the fast growing amount of waste from IT usage – caused by the shorter innovation cycles and the associated shortened usage time of the electric devices – and waste handling are causing a problem. In Europe the quantity of old electrical equipment is growing at a rate almost three times faster than other types of waste. Often old equipment is reused in less developed countries with lower environmental standards under conditions that put people's health and the environment at risk. This development can be countered with the concepts of eco-efficiency and dematerialization, in which the focus is not on a material product, such as a computer, but on the function or the task to be fulfilled. In the IT industry this means developing alternative systems and infrastructures that are able to fulfil the same functions with the same level of quality with much less effect on the environment.

Methodology and procedure

The subject of the study is thus the environmental effects of supplying a user with IT services, using PCs and thin clients. The entire life cycle is considered. For this purpose suitable key figures are adapted to the customer's special requirements. To calculate the burden during the operation phase, Fraunhofer UMSICHT uses the GEMIS[1] program. The German electricity mix is used to calculate the emissions from the use of electrical energy. Data from the EU study [IVF, 2007] is used for the production, manufacturing and disposal phases. This data is compared for the respective life cycle phases.

Because of the higher accuracy and so that we could ensure comparability, we collected data for the operation phase ourselves using measuring technology. We used effect categories (such as global warming potential measured in CO_2 equivalents [CO_2eq]). For the usage scenarios we mapped different device configurations and our own scenarios (verified by the usage behavior measured in our own network).

Summary of the results

For the summarizing evaluation of the ecological comparison in the following the emphasis will be on the greenhouse gas relevance of IT equipment. Hence, only the **GWP** (Global Warming Potential in kg CO_2eq per unit) will be considered.

Monitors

With monitors there is a clear dominance of the operation phase over all other phases (75 to 83 % of the GWP). The production phase follows with a large gap. Here the distribution phase (which also includes the final installation of the devices) is surprisingly high. In an analysis of a 5-year usage period, LCD monitors (277 kg CO_2eq) produce about half the emissions of a CRT monitor (543 kg CO_2eq).

Desktop PC and notebook

As the VDU Directive states that an external monitor must be used with a notebook, the monitor will not be considered further in a direct comparison between desktop PCs and notebooks (in other words, the monitor integrated into the notebook does not provide any system advantage). Here, too, the operation phase dominates (63 to 86 % of the GWP), followed by the manufacturing phase. In the disposal phase the recycling of plastics and PCBs produces an environmental credit. If we consider a 5-year usage period the notebook (250 kg CO_2eq) produces almost 5 times less greenhouse gases than a desktop PC (1,211 kg CO_2eq).

Thin client and thin client + pro rata share of server

The operation phase also dominates with thin clients (73 to 89 % of the GWP), followed by the manufacturing phase. In the disposal phase there is a much smaller environmental credit as smaller volumes of plastic and PCBs can be recycled. The thin client device alone achieves a GWP of 185 kg CO_2eq; the thin client, including a pro rate share of the server (obligatory for operation), has a GWP of 554 kg CO_2eq.

[1] Global Emission for Model Integrated Systems (GEMIS) from Öko Institut: http://www.oeko.de/service/gemis/de/index.htm

Summary

Together with a desktop PC, changing from a CRT to an LCD monitor can reduce the CO_2eq emissions of the complete system by more than 15 % over a period of five years. This change has already been made at many workplaces and the range of devices available on the market consists almost entirely of LCD monitors. However, the high proportion of desktop PCs (81 %) in the overall system is noticeable.

If a desktop PC is replaced by a thin client and terminal server, the emissions of the workstation are reduced by more than 54 %. In terms of a complete system with LCD monitor the saving potential is 44 %.

In a stationary location a notebook saves 79 % of CO_2eq emissions compared to a PC and approx. 55 % compared to a thin client and server. But this result has to be put into relation because the differentiated consideration of the use of notebooks was not a subject of this study. It was assumed that a notebook is used solely as a stationary device (cf. Sect. 10).

Examples of ecological calculations

In relation to usage in a small to medium-sized enterprise with 300 workstations the use of thin clients can save more than **148 t CO_2eq** emissions over a five-year period if 75 % of the workstations in the company could be changed to thin clients. A VW Golf TDI could drive more than **1,093,000 km** and thus circle the earth 27 times with this volume of emissions. If the savings potential is interpolated to a large company with 10,000 workstations to be supported, in such an environment over a five-year usage period more than **4,923 t CO_2eq** would be saved if 75 % of the PC workstations were replaced with thin clients. Assuming an annual distance of **20,000 km,** a fleet of **364 cars** of the above type could be driven for **five years** with this level of CO_2eq emissions.

Macro-economic aspects

The market for thin clients is growing faster than the desktop PC market, however, at a much lower level. In the »EU-15« countries and »Western Europe« in 2008 more than 27 million new desktop PCs will be sold compared to just 1.2 million thin clients (market share: 4.3 %). At present, thin clients are used almost exclusively in companies, while the majority of PCs are purchased by private households. For example, in 2005 approx. 43 %, or about 11.2 million desktop PCs were in use in companies. In 2008 this percentage should drop to roughly 40 %. This corresponds to about 10 million PCs. It must also be considered that because of technical requirements at present not all PCs used in companies could be substituted with thin clients. With the current technological status at least 8.2 million of the new desktop PCs sold in 2008 in the EU-15 countries could be replaced with thin clients; in Germany the figure would be 1.6 million devices. Based on the values determined in Section 6, over a five-year usage phase for the equipment **5,382,000 t CO_2eq** could be saved in the EU-15 countries as a whole and **1,050,000 t CO_2eq** in Germany.

The following technologies and current developments show ways of covering a broader spectrum of applications in future with thin clients and server-based

Future optimization potential for IT infrastructures

computing. There are also ways of improving the utilization factor and efficiency of the respective infrastructures:

- 64-bit computing
- Virtualization (application virtualization, application streaming, server virtualization, desktop virtualization)
- Energy saving options at the workplace
- Citrix® PowerSmart (technology for server controlling)
- Thin clients in private households and »Web 2.0« (dematerialization of domestic information and communication systems, deployment of functions and services and not devices)

Recommendations for action

Based on the results, recommendations for action for a »Thin Clients 2008« strategic sustainability concept can be specified as follows:

Table 1-1: Specific recommendations for action for a »Thin Clients 2008« strategic sustainability concept

Recommendations→ / Area ↓	Specific Measures
Perception and spread of thin clients	▪ Include thin client systems in procurement guidelines ▪ Carry out model projects with public institutions
Image	▪ Marketing/PR campaign to raise awareness in broad-based population strata (also for decision-makers) ▪ Explain the thin client concept on a level that is understood by the general public (if necessary, with BITKOM)
Ecological optimization of thin clients (medium-term)	▪ Design for environment – LC-oriented* → replace especially environmentally relevant components, reduce the use of material ▪ Energy efficiency – LC-oriented* ▪ Energy saving presettings in thin clients
Ecological optimization of the entire IT infrastructure (longer-term)	▪ Energy saving software and hardware systems for networks ▪ Reduce the number of network components ▪ Reduce the amount of cooling needed in data centres
Research and development	▪ Sensitivity analysis for a model for an ecological comparison of thin clients ▪ Investigate competitors' thin client systems ▪ Extend contact and cooperate with partners of the EU study to compare methodology, data and results ▪ Develop larger R&D projects (national, EU-level)

* LC: Life Cycle

2 Introduction

Sustainable development is understood to mean a development that satisfies the needs of the current generation without putting future generations at risk of being unable to satisfy their needs according to their own discretion. Consequently, the objectives are to reduce the consumption of resources and emissions in order to minimize people's ecological footprint on the earth. Tools for implementing a more environmentally friendly style of management include carbon trading on the basis of the Kyoto Protocol. Concrete actions on a local level must be followed up by global concepts, which develop a long-term strategy to ensure the survival of humankind in view of the limited environmental resources. The IT sector is also coming more and more under the spotlight, since, at a rapidly increasing pace, it is entering almost all aspects of our lives and for a long time has been the basis for dematerialization hopes among industrial companies.

Against this background, many manufacturers of IT technology have also recognized that end customers (private and commercial) are not only interested in speed, more performance and more storage capacity, but that ecological aspects are playing an increasingly important role when it comes to buying a PC, laptop or network and customers are asking specifically about the energy or ecological efficiency of the equipment. Almost all manufacturers of PCs and components have now adjusted to this and have recently also started featuring environmental aspects in their advertising. In many cases, isolated individual aspects, such as power consumption in the usage phase, the use of toxicologically safe substances are considered and assessed. What is missing in many cases is a holistic, ecological evaluation across the life phases of production, use and recycling/disposal. This information is needed before a strategic discussion can be held about which innovations will make the information and communication sector on the whole – also through new technical concepts – more energy-efficient, more environmentally friendly and, perhaps, even more sustainable.

In this study, based on the results of the previous study »Environmental Comparison of PC and Thin Client Desktop Equipment« from 2006, the comparison of these device types will be specified and elaborated further. In the subsequent study the production phase, the usage phase and the disposal phase will be considered. As a basis for comparison the latest findings from the EU report »Personal Computers (desktops and laptops) and Computer Monitors« will be used. Based on the improved data situation, especially the material and energy intensity of production will be compared and put in relation to the electrical scrap occurring in the disposal phase.

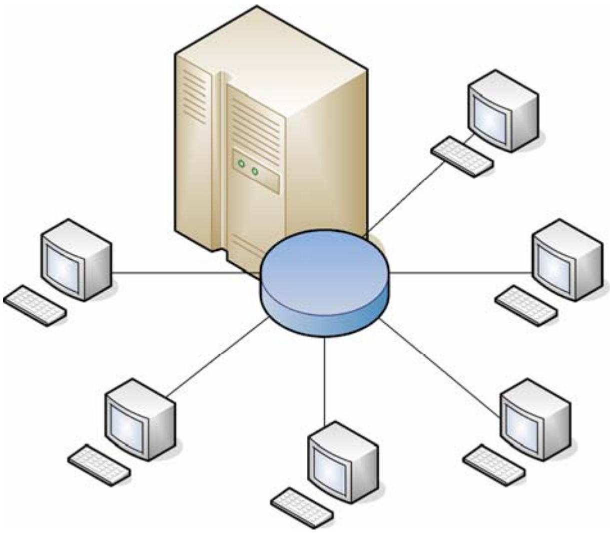
In regard to the operation phase the energy saving potential of an IT infrastructure based on thin clients and server-based computing will be presented for different sized companies, using different deployment scenarios. It will also be explained how much technical improvements, such as 64-bit computing and desktop virtualization can increase the efficiency of thin clients or, in some cases, even enable certain application cases that could not be covered in the past. Demoscopic and statistical data (sales figures for new equipment, total number of devices in households and companies) will be used to determine the potential for thin clients in terms of the German and European markets.

2.1 Fundamentals: Server-based computing

2.1.1 Classic terminal environment

The fundamentals of today's Terminal Services can be traced back to the mainframe environments of the 1950s and 1960s. As resources such as processors and memory were significantly more expensive in relation to their performance in those days than they are now, only a few mainframes were available. These machines were already multi-user and multi-tasking capable and could be used simultaneously by several users in a so-called timesharing process. The processing capacity of the system was divided into individual sessions at very short time intervals so that every user had the impression that the system was available exclusively for them. However, a network between a client and server as we understand it today did not yet exist back then. The clients – in the jargon often described as »dumb terminals« because they had no computing capacity of their own – were generally connected to the mainframe, their host system, in a star configuration via serial lines and were used solely to transfer the entries to the host and to show the text-based output of the system (cf. Figure 2-1).

Figure 2-1: Mainframe and terminals (Diagram: Fraunhofer UMSICHT)

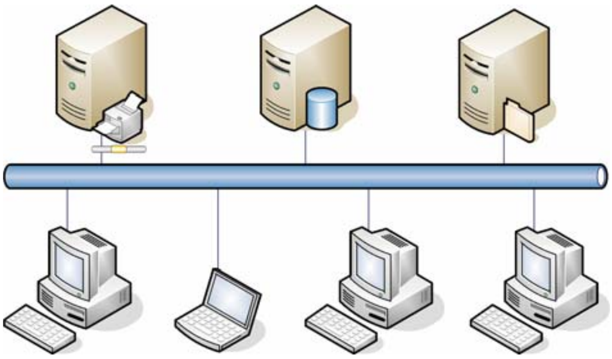


Even during the following years, which saw the development of the UNIX® operating system and the TCP/IP network, the multi-tasking and multi-user concepts remained and were considerably extended via text-based access. For instance, the X11 protocol and the introduction of the corresponding terminals, which communicate with their hosts via the network, created the possibility of distributed, server-based work with graphical user interfaces (GUI).

2.1.2 Client/server networks

The rapid market penetration of the IBM PC® at the start of the 1980s and the associated economic success of Microsoft with its MS-DOS® operating system and the Windows® GUI approach were based mainly on the fact that a standardized mass product was made available at a price that was previously unconceivable in the computer world. Systems were further developed and eventually the client/server networks that we know today were created. Data is processed locally on desktop systems in terms of distributed resources, the useful data is exchanged via the network with server services, such as file, print, database services, and other computers (cf. Figure 2-2) with the advantage that every user has »his or her own« computing capacity.

Figure 2-2: Client/server network (Diagram: Fraunhofer UMSICHT)



2.1.3 Microsoft® Terminal Services

Despite the initial rapid spread the personal computer could not achieve the breakthrough as a platform for use in companies, as the cooperative multi-tasking implemented in the operating systems of early PCs was not suitable for stable, parallel operation of several business-critical applications. This is because in cooperative multi-tasking the resources, such as the processor and main memory, are managed by the application programs. This means that an application must »voluntarily« release the resources for other applications, which can lead to a situation where a defective application blocks the machine.

With pre-emptive multi-tasking the operating system itself manages the resources and can thus force the release of these resources and suspend or terminate defective applications. Accordingly, the 32-bit »Windows NT® 3.1« operating system, which was presented in 1993, was completely re-designed and implemented pre-emptive multi-tasking (cf. [Dapper et al., 1997], p. 15 ff.). However, multi-user support – a matter of course for users of the UNIX® operating system for many years – was still missing. Hence, Microsoft commissioned Citrix to develop the corresponding functionality for Windows NT®. This came on to the market in 1995 in the form of *WinFrame*® and allowed interactive work on remote Windows® servers. The product was well accepted on the market, which led Microsoft to licence the underlying technology *MultiWin* and market it as an independent product from the next Windows® version. The Windows NT® 4.0 Terminal Server Edition was initially a completely independent product with a separate code base, and this also applied to the »normal« Windows NT® incompatible Service Packs. From this Microsoft developed Terminal Services, which have been a component of the operating system since Windows® 2000 (cf. [Mathers, 2000], pp. 27-29).

2.1.4 Citrix Presentation Server™

Even though the basic functionality of Terminal Services with licensing of MultiWin technology by Microsoft resulted in the Windows® operating system, this was not the end of the cooperation with Citrix. WinFrame® was followed by MetaFrame®, an add-on product for Windows® Terminal Server (cf. [Mathers, 2000], p. 68 ff.). Now renamed Citrix Presentation Server™, this product considerably extended the basic functionality of Windows® Terminal Services, now in the fourth generation, and optimized them for use in larger companies and distributed LAN/WAN environments.

The principle of the Presentation Server is that terminal servers are no longer seen as stand-alone systems, but are aggregated into a *server farm*. In addition to the known possibility of starting a complete desktop session on a terminal server, the Presentation Server offers the concept of *published applications*. Instead of the complete desktop a single application is started on the terminal server and is displayed on the client as a so-called »seamless window«. This means that the application is seamlessly integrated into the user interface on the client computer and can be used transparently by the end user as if it was installed locally. For more transparency and user friendliness, Citrix® clients display the available applications independently from the servers that deploy them. As opposed to Microsoft® Terminal Services, users no longer have to connect specifically with a server and have no idea where their application is located; now they only have to do *what* they want. Corresponding functionalities will be integrated in Microsoft's Windows Server™ 2008, even in the basic product.

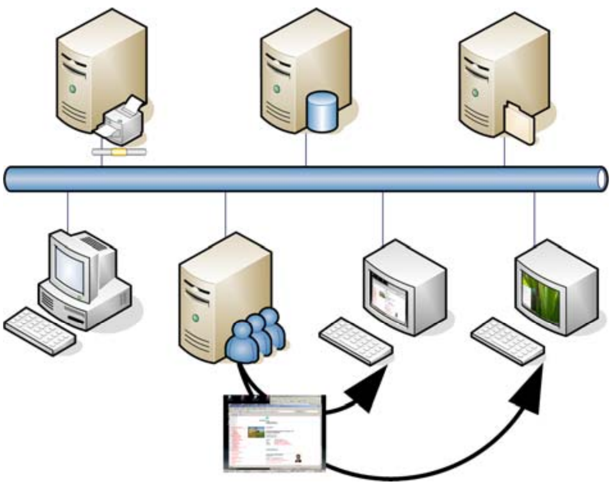
2.1.5 Thin clients and Server-Based Computing

In addition to the possibility of connecting to a terminal server with a traditional PC workstation, the end user can also install a modern terminal – a so-called thin client – at his or her workplace. These devices are much smaller than PC systems and generally contain no moving parts, such as a hard disk or ventilator (cf. Figure 2-3). All data processing and computing is done on the server.

Figure 2-3: Thin client (left) compared to a desktop PC (Photo: Fraunhofer UMSICHT)

As opposed to the historical version, no useful data is exchanged between the client and server via the network, but only user entries as well as video and audio output (cf. Figure 2-4).

Figure 2-4: Server-based computing (Diagram: Fraunhofer UMSICHT)

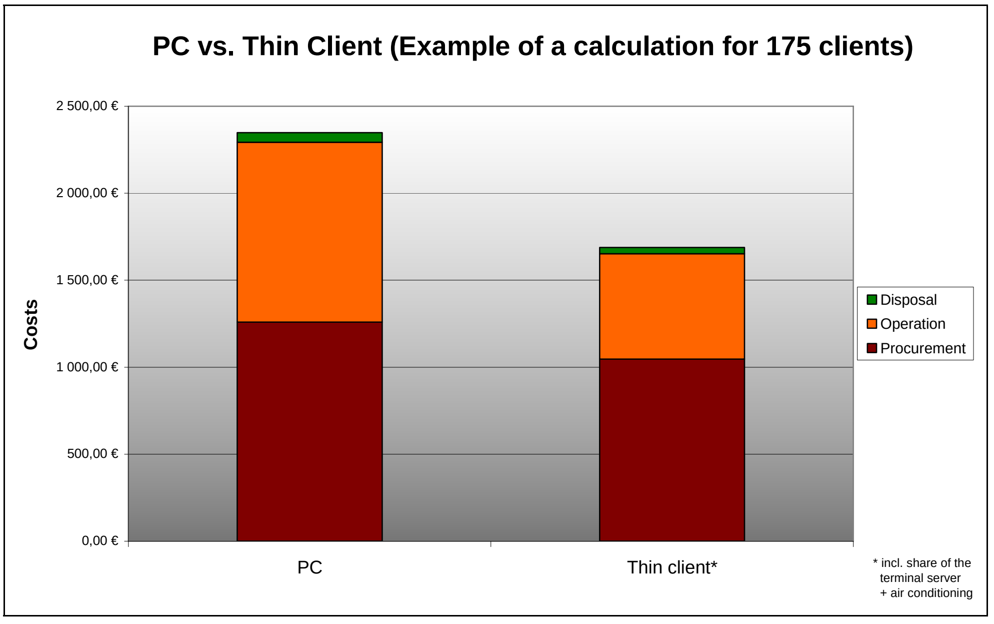


Thin clients offer users the usual graphical interface instead of the earlier console. All resources that are needed to process data and execute programs are located on the server.

2.2 Economic viability analysis

Although the purchase prices for PCs have fallen considerably over the past years, while their performance has increased in the same time, the subsequent costs of such an infrastructure must not be ignored. Every single workstation needs individual administration (cf. [Mathers, 2000], p. 12 ff.). An economic viability analysis by Fraunhofer UMSICHT confirms this fact with extensive examples of calculations (cf. [UMSICHT, 2008]). Within the scope of the analysis, PCs supplied via automatic software distribution and thin clients were investigated. For an example company with 175 workstations over an assumed utilization period of five years, costs of approx. €2,350.00 were determined for an automatically administered PC while only €1,690.00 were calculated for a thin client, including the share of the terminal server and air conditioning, over the same period (cf. Figure 2-5).

Figure 2-5: Economic viability analysis »PC vs. Thin Client«



The potential savings of more than 27 per cent are achieved not only through the cheaper purchase price, but especially through the lower running costs in the operation phase. In this calculation, however, electricity was calculated at a flat-rate price and no other environmental aspects were considered. These will now be investigated separately within the scope of this study and will then be interpreted in terms of the entire management costs.

3 Environmental effects of information technology

3.1 Global climate change

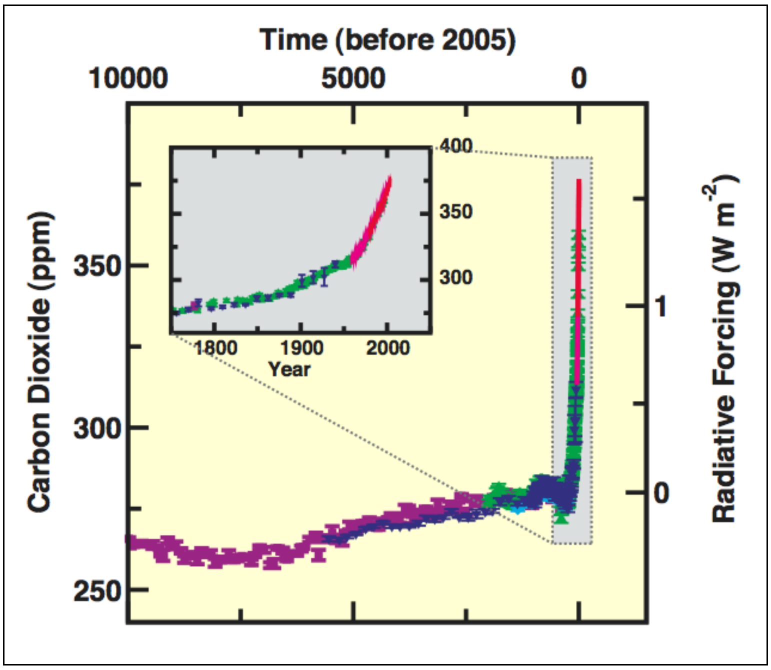
Since the era of industrialization our everyday lives have been simplified by technical aids. However, the increasing use of technologies in the individual areas of our lives also increases the effect on the environment. The anthropogenic factors associated with the greenhouse effect is an example of how the increased use of fossil fuels increase the amount of CO_2 emissions and contribute to global warming.

Figure 3-1: Poster for the film »An Inconvenient Truth«

The CO_2 concentration in the earth's atmosphere is an indication of the changes in environmental conditions. What Al Gore's film »An Inconvenient Truth«[2] presented to a wide public is manifested in the report from the Intergovernmental Panel on Climate Change (IPCC). According to the report the CO_2 concentration has increased from 280 ppm at the beginning of industrialization to 379 ppm in 2005. This value is the highest concentration in the last 650,000 years (CO_2 concentration 180-300 ppm). We should not expect to see an end to the increasing CO_2 concentration in the near future. The annual rate of increase is between 1.4 and 1.9 ppm (cf. [IPCC, 2007], p. 2).

[2] http://www.climatecrisis.net

Figure 3-2: Increasing CO_2 concentration since the beginning of industrialization (Source: [IPCC, 2007])



The increasing CO_2 concentration and the resulting greenhouse effect cause a continuous increase in global warming. Heat waves, tornadoes and other natural catastrophes are the consequence. To counteract further temperature rises, CO_2 emissions must be reduced by 70 to 80 % (cf. [IPCC, 2007], p. 8).

3.2 Energy and material intensity in the IT industry

In the climate change discussion a new "culprit" was identified at the start of 2007: the IT industry. According to Gartner market research about two per cent of global CO_2 emissions are caused by the manufacture, use and disposal of equipment in the information sector[3]. This corresponds roughly to the volume emitted by international airlines [Gartner, 2007].

Much of this is due to the energy intensity of the production processes. For instance, the following table [Kuehr, 2003] illustrates the material and energy intensity of PCB production in Japan – for the entire industry and for a single computer. Although this data is older and relates to 1995, the consumption of electricity and fossil fuels demonstrate the industry's energy needs.

[3] This figure also includes PCs and mobile phones that are used privately.

Table 3-1: Material and energy intensity of PCB production (Source: [Kuehr, 2003])

Inputs	1995 Japan use/ emissions[7]		1995 global use/ emissions		Use/emissions per desktop system	
Blank boards	73,318	tons	293,000	tons	1.70	kg
Resin etchants	2,789	tons	11,200	tons	0.06	kg
Solder	3,188	tons	12,800	tons	0.07	kg
Copper	8,573	tons	34,300	tons	0.20	kg
Aluminum	1,650	tons	6,600	tons	0.04	kg
Plastic	6,265	tons	25,100	tons	0.14	kg
Electricity	1.17 billion	kWh	4.67 billion	kWh	27	kWh
Fossil fuels	244 million	liters oil	975 million	liters oil	5.6	liters oil
Embodied fossil	0.596 million	tons	2.38 million	tons	14	kg
Water	60.2 billion	liters	241 billion	liters	780	liters
Outputs						
Waste acid	408600	tons	1.63 million	tons	9.4	kg
Waste alkali	181234	tons	725000	tons	4.2	kg
Sludge	19771	tons	79000	tons	0.45	kg
Waste plastic	12522	tons	50100	tons	0.29	kg
Other	36906	tons	148000	tons	0.84	kg
Total	659034	tons	2.64 million	tons	15	kg

Source: EIAJ (1997).

Besides the medium to long-term climatic effects of CO_2 emissions the production has direct effects on humans and the environment at the production facilities. Greenpeace investigated water samples from the vicinity of factories that manufacture PCBs and semi-conductors in China, Mexico, Thailand and the Philippines [Greenpeace, 2007]. The wastewater and the ground water contained bromine-based flame retardants and plasticizers, chlorine-based solvents and high concentrations of heavy metals. Not only the ecotoxicological effects of the substances used in these factories but also the material intensity of the raw materials, most of which are non-renewable, finite raw materials (Table 3-1), shows that the ecological footprint is growing continuously due to the more intensive use of information and communication technology.

The energy requirements of IT components of the operating equipment must also be considered. For example, at the start of the century a group of researchers headed by Kaoru Kawamoto and Jonathan G. Koomey at the Lawrence Berkeley National Laboratory estimated that 2 % of the USA's entire power consumption could be attributed to computers and the corresponding network components [Kawamoto, 2001]. For Germany the estimates vary between 3-8 %, for Japan between 3.3-4.3 % [Plepys, 2004]. The figures include IT components in companies and private households.

3.3 Recycling and disposal

It is not only the quantity of CO_2 emissions caused by the fast growing industry that are a problem, the volume of waste and how it is handled is also a growing problem. In Europe the volume of electrical equipment waste is increasing almost three times as fast as other waste. The growing quantity of waste is due to the shorter innovation cycles and the associated shorter usage life of the electrical equipment. Consequently, in Europe various laws force manufacturers to arrange for their equipment to be taken back and recycled. However, about 70 % of the worldwide electrical scrap ends up in China [GAP, 2007].

Electrical scrap is exported to less developed countries – in some cases illegally – where it is recycled in conditions that damage health and the environment. The reasons given for this are the growing volumes of waste and the limited capacities of recycling facilities as well as the lower costs in less developed countries. Greenpeace investigated recycling facilities in India and China and published the results in a study [Greenpeace, 2005].

In some of the recycling facilities there much of the work is done outdoors. To recover valuable raw materials (e.g. nonferrous metals) PCBs are dipped in acid, monitors are smashed on the street and residual PVC is burned outdoors. The recycling companies dispose of the parts that are not useful in unlawful landfill sites on the outskirts of the villages. This form of recycling has a negative impact on humans and the environment. Within the framework of the study, samples of water, soil and air from the facilities were analyzed. A high concentration of lead, tin, copper, cadmium and other heavy metals was measured.

The environmental impact is not limited to the direct surroundings of the recycling facilities, the workers carry contaminants home with them in their clothing. Although the houses are not close to the workplace, house dust measurements also showed high concentrations of copper, lead, tin and other heavy metals. Another hazard for the environment is the shredding of old electrical equipment. The shredded material, mainly PCBs, is rinsed continuously with water. The water is not recycled, it is fed directly into the sewage systems without any treatment. The concentration of lead, copper, nickel and antimony in the sewage systems was 200 to 600 times higher than the normal concentration.

3.4 »Rebound effects«

The environmental problems caused by the IT industry are increasing, as the market is growing faster than production efficiency increases (cf. [Plepys, 2004], pp. 3 and 4). On the other hand, it could be said that the global market is growing rapidly *because* production is becoming more efficient and hence *cheaper*.

This development, known in literature as the »rebound effect«, means that total requirements for material and energy in a system increases although the energy and material intensity needed to produce individual products falls (cf. [Plepys, 2004], Appendix B, Paper I). This is due to the fact that, as efficiency increases, the purchase price of individual products falls and demand increases. The effect is increased in the case of the IT industry due to shorter innovation cycles.

3.5 Eco-efficiency and dematerialization

The above-described development can be counteracted with the concepts of eco-efficiency and dematerialization. The aim of eco-efficiency, a term coined by the World Business Council for Sustainable Development at the start of the 1990s, is to align production and product use towards sustainability. This means reducing the environmental effects to an extent where negative effects do not exceed the environment's natural ability to regenerate.

The key for fulfilling this aim is dematerialization – reducing the energy and material intensity of a product or a service. The core of this concept is not to focus on a material product, such as a computer, but on the function or task that is to be fulfilled (cf. [Plepys, 2004], p. 13ff). In the case of the IT industry this means developing alternative systems and infrastructures that are able to fulfill the same functions in the same quality with much less effect on the environment.

4 Underlying legal conditions

This section aggregates laws and regulations that are relevant for the production, operation and disposal of IT components.

4.1 EU level and internationally

European regulations and their implementation in national law must be considered when IT equipment is manufactured and put into circulation. The following regulations appear especially relevant in terms of environmental compatibility.

Table 4-1: Statutory requirements for computer systems (excerpt, does not claim to be complete)

EU level	Germany
Directive 2002/96/EC Waste electrical and electronic equipment WEEE	Law governing the sale, return and environmentally sound disposal of electrical and electronic equipment (Electrical and Electronic Equipment Act – ElektroG)
Directive 2002/95/EC Hazardous substances in electrical and electronic equipment (RoHS)	ElektroG
Directive 2006/12/EC on waste (waste framework directive)	KrW-/AbfG (Closed Substance Cycle Waste Management Act)
Directive 2005/32/EC for energy-using products (EuP)	Law governing the environmentally sound design of energy-using products (Energy-Using Products Act, EBPG) [not yet passed by the German Bundestag]

The main intention of EU Directive 2002/96/EC (WEEE) is to reduce electrical and electronic waste and to encourage recycling and other forms of reuse, such as the establishment of a national collection system. The recovery rate must be at least 75 %, of this 65 % must be recycled or fed to a substance recovery system. The EU Directive »Restriction of the use of certain hazardous substances in electrical and electronic equipment« (2002/95/EC), or RoHS for short, limits the use of certain substances in electrical and electronic equipment. For example, the directive specifies that no lead must be used when electronic components are soldered and bans the use of certain flame retardants and thus encourages the use of substitute products. Directive 2005/32/EG »Energy using Products« defines a framework for the requirements for the environmentally sound design of energy-using products. The aim is to save energy and resources during the products' »life cycle«. This includes the use of recycled material, reducing any form of emissions in the atmosphere, air, water and soil and reducing the mass and volume of the product to save resources.

4.2 Germany

In Germany the EU Directives 2002/96/EC and 2002/95/EC were implemented in national law in the ElektroG. The EU Directive 2005/32/EC, which was passed in July 2005, was implemented into national law in the act governing the »environmentally sound design of energy-using products«. The required recycling rates of the EU specifications were integrated [ElektroG, 2007].

4.3 Other 'Lead Markets' (USA)

As opposed to Japan, South Korea and many European countries the USA has no recycling program for electrical and electronic equipment. States such as Washington, Maine and Maryland have passed a »return law« and a dozen other states plan to introduce similar laws. Apart from this recycling system, which is limited to certain states, large companies such as Dell and HP are active in the area of electrical equipment recycling. For example, HP organizes voluntary collection trips in which old equipment that customers hand over to specialist outlets at no cost is collected [AP, 2007].

4.4 Labels, initiatives, test seals and certificates

Apart from the above-mentioned laws in Germany there are no regulations on a federal or state level which, for example, specify in procurement guidelines that »public authorities« may use only »ecologically practical« and thus »energy-saving systems«. Consequently, when procuring electrical and electronic equipment, public authorities have sufficient leeway to recommend energy-saving systems such as thin clients.

4.4.1 Energy Star

In addition to the EU Directives and their implementation in national law we also have the Energy Star from the US Environmental Protection Agency (EPA) (»Environmental Protection Agency«). This international, voluntary labeling program was introduced in 1992 for energy-saving office equipment [Energy Star, 2008]. The conditions were made more stringent in the latest amendment to the Energy Star specifications (Energy Star 4.0). They now regulate not only the energy consumption of computers during standby and soft-off operation, but also the power consumption when they are idle. For instance, they demand the use of a so-called »80-Plus« power supply, which must have an efficiency of at least 80 % from a loading of 20 % of the nominal power, as well as default power saving modes for monitors (after 15 minutes) and the complete PC after 30 minutes [Windeck, 2008-2].

The Energy Star specifications divide equipment into categories, which are allocated different requirements. For example, according to Energy Star 4.0 a computer in Category C[4] may consume maximum 95 watts in idle mode, the maximum for a system in Category B[5] is 65 watts and 50 watts in Category A[6]. In addition, it is regulated that the power consumption may not exceed 2 watts when the machine is switched off. Equipment classes or categories for thin client systems do not yet exist in the Energy Star specifications.

4.4.2 Blue Angel, EU Eco Label, Nordic Swan

The Energy Star is also a model for other environmental labels, like the »Blue Angel«[7] or the »EU Eco Label«[8]. At present, both specify limit values according to Energy Star 3.0. The so-called »Nordic Swan«[9] is already aligned to Energy Star 4.0 [Windeck, 2008]. Only the »Blue Angel« distinguishes the term thin client, but evaluates the equipment the same as desktop computers.

4.4.3 Office TopTen

The »Office Top Ten«[10], a neutral Internet-based selection aid, is based on the Energy Star system. It is aimed at professional buyers in the public and private areas and provides them with tools such as a procurement guideline, tender aids, and extensive information and advice section and specific press and PR work to choose above-average, energy-efficient office equipment. A recommended TopTen criterion is defined in the procurement guideline [Dena, 2007] as follows: »A central server deploys the services (e.g. office software) for a large number of clients (e.g. office computers) via a network. Since this means that the necessary computing is outsourced to the central server, the clients have much less performance potential on the hardware side.« The systems are known as thin clients, although the performance data shows that server-supported office PCs are in use.

4.4.4 TCO

In addition to the named labels there is also the »TCO« seal (Tjänstemännens Centralorganisation – Salaried Employees' Central Organization), which has defined standards in the areas of ergonomics, electromagnetic fields, energy efficiency and environment since 1992. With the »TCO'95« seal, bromine and chlorine-based flame retardants were banned in plastics, almost ten years be-

4 Multi-core/processor system, separate graphic card with min. 128 MB memory, either min. 2 GB main memory, TV card or several hard disks; corresponds to the requirements of a power user
5 Multi-core/processor system, min. 1 GB main memory; corresponds to the requirements of a medium user
6 Not category B or C, only a single-core processor; corresponds to the requirements of a light user
7 http://www.blauer-engel.de
8 http://www.eco-label.de
9 http://www.svanen.nu
10 http://www.office-topten.de

fore the implementation of the EU's »RoHS Directive« (see above). But the »TCO« seal goes beyond the »RoHS Directive« and also bans other bromine-based flame retardants, including DecaBDE[11], which is still allowed in the EU in spite of its harmful effects, which have been confirmed in studies [Boivie, 2007].

4.5 Ergonomics, VDU Directive

The regulation governing safety and health protection for work with visual display units, the VDU Directive [in Germany, BildscharbV, 1996] regulates the requirements for VDU workplaces and their ergonomic design. In the annex to this directive the following requirements are defined for screens, keyboards and mouse:

»(…)

4. The screen shall be free of reflective glare and reflections liable to cause discomfort to the user.

5. It must be possible to turn and tilt the VDU easily.

.

6. The keyboard shall be tiltable and separate from the screen so as to allow the worker to find a comfortable working position avoiding fatigue in the arms or hands.

7. The work desk or work surface shall have a sufficiently large surface and allow flexible arrangement of the screen, keyboard, documents and other related equipment. The space in front of the keyboard shall be sufficient to provide support for the hands and arms of the operator.

(…)«

These points must be especially considered in the assessment of notebooks as, when they are being procured, additional external monitors and input equipment are required to meet the requirements of the VDU Directive.

[11] Flame retardant: deca-brominated diphenyl ether

5 Methodology

Subject of the investigation are the environmental effects of supplying a user with IT services, based on a PC and a thin client. The entire life cycle is considered, in other words:

- the production, manufacturing and distribution phases,
- the usage phase,
- the disposal phase.

Suitable key figures are used for this purpose. Fraunhofer UMSICHT uses the GEMIS[12] program for calculations. German values (e.g. for the electricity mix) are used as a basis. Data from the EuP study (IVF, 2007) is used for the production, manufacturing, distribution and disposal phases. At the present time the authors know of no other studies that go into the subject matter in such depth and are so complete. In this study, various data (energy consumption, particulate matter, acidification potential, etc.) was gathered. This data is compared for the respective life cycle phases.

Because of the higher level of accuracy required and to ensure comparability we determined the data for the operation phase ourselves using technical measuring equipment. For comparability reasons we also used effect categories (here the global warming potential measured in CO_2 equivalents (CO_2eq)[13].

The required conversion keys (such as thin client users per server) will be described in the next sections.

5.1 Definition of scenarios

To enable a comparison of PC and thin client desktop equipment, in the first step it is necessary to model equivalent deployment scenarios. The requirements for the systems differ depending on the user type and are described below. To evaluate energy efficiency this means that the relevant average power input in the operation phase has to be considered. A comparison of nominal capacities for the respective power units is not meaningful. Instead, the specific energy consumption in practical use has to be evaluated. This requires the development of a model that is as close to reality as possible to provide underlying conditions under which the client systems to be investigated can be compared.

12 Global Emission Model for Integrated Systems (GEMIS) from the Öko-Institut: http://www.oeko.de/service/gemis/de/index.htm
13 Besides CO_2 the greenhouse gas category includes five other greenhouse gases (e.g. methane and nitrous oxide). The individual gases are assessed according to their greenhouse gas relevance and are then aggregated in the effect category (greenhouse gases).

In the development of the model, only aspects with a direct connection to the operation of the equipment at the users' workplace are considered. Accordingly, the terminal servers, for example, that are required to operate thin clients are taken into account in the deployment scenarios. Components in the general IT infrastructure, such as routers, switches, file or print servers are needed regardless of whether PCs or thin clients are deployed. These are not considered, as there is no noticeable difference in the environmental effects.

5.1.1 Users

As already explained in the course of the economic viability analysis »PC vs. Thin Client« (cf. [UMSICHT, 2008], p. 83ff), the question arises – primarily for the sizing[14] of the terminal server – as to how a system should be equipped to successfully manage a specific load and which number of user sessions specific hardware can support. The load is determined according to the end user's work content, which is why it has become established in trade literature to use two to four typical user types, including suitable application cases.

In the course of this study, as in the above-mentioned economic viability analysis, a model comprising the three user groups, *light user*, *medium user* and *power user* (cf. following table) is used.

Table 5-1: Different user types

User type	Use	Description
Light User	Normally uses just one application. In most cases a program for data input or e-mail is deployed.	Has very low requirements for computing capacity and main memory.
Medium User	Uses two or three applications simultaneously. This includes browsers, client/server applications with database access and also tools such as Microsoft® Office.	The requirements for computing capacity are higher than those of the light user.
Power User	Consistently uses several applications simultaneously, processes large graphics/documents, works intensively with e.g. Microsoft® Outlook® and Microsoft® Excel® incl. creating diagrams, calculations using large data volumes.	Multitasking operation, highest computing capacity and high main memory requirements.

Typically, a *light user* is a case officer with very moderate requirements for system performance. This user works primarily with one application, such as an e-

[14] The term "server sizing" includes all considerations in regard to system dimensions (processing capacity, central memory and processors) to fulfill daily operations requirements.

mail program, a web browser or the client of an ERP system[15]. The *medium user*, often known as a knowledge worker (cf. [Microsoft, 2003]), operates several standard software products parallel to each other and thus has higher demands on the system. The *power user* or *heavy user* group works with programs other than standard applications, with resource-hungry applications, such as image processing software, large databases or a software development environment.

5.1.2 PC systems

To evaluate the power consumption in a company the following standard PCs from the Fraunhofer UMSICHT inventory were used as an example:

PC System 1, built 2004

- Processor: Intel® Pentium® 4 (3 GHz)
- Main memory: 512 MB
- Hard disk: 80 GB (IDE)
- Optical drive: 1x CD-RW burner (IDE)
- Power unit: 210 W
- Housing format: Mini tower

PC System 2, built 2006

- Processor: Intel® Pentium D 945 (3.4 GHz)
- Main memory: 1024 MB
- Hard disk: 160 GB (SATA)
- Optical drives: 1x DVD-ROM, 1x DVD-RW burner (SATA)
- Power unit: 300 W
- Housing format: Midi tower

PC-System 3, built 2007

- Processor: Intel® Pentium Core 2 Duo (2.2 GHz)
- Main memory: 1024 MB
- Hard disk: 160 GB (SATA)
- Optical drives: 1x DVD-ROM, 1x DVD-RW burner (SATA)
- Power unit: 300 W
- Housing format: Midi tower

15 Enterprise Resource Planning (ERP) generally means database-based software systems for business planning, as offered by Microsoft, Oracle, Sage or SAP, for example.

5.1.3 Thin clients

Within the scope of the calculation model presented in Section 5.2 the PC was compared to the thin client model »IGEL 3210 LX Compact«. This device is deployed as a standard client at Fraunhofer UMSICHT. It is suitable for communication with terminal servers via conventional protocols such as Microsoft RDP and Citrix ICA, has a local web browser and is compatible with conventional systems for desktop virtualization. As it is the most popular device from the market leader in Germany, it is regarded as being representative within the framework of this study[16]. The device has the following hardware properties:

Thin client »IGEL 3210 LX Compact«

- Processor: VIA Eden CPU (600 MHz)
- Main memory: 256 MB
- Flash memory: 128 MB (CF card)
- Power unit: 22 W
- Housing dimensions: 240 x 225 x 43 mm

5.1.4 Terminal servers

In the scenarios for the deployment of thin clients it must be especially considered that they cannot be considered on their own, as they depend on applications executed by the server which are deployed via Terminal Services. Hence, as the computing load is largely provided on the terminal servers, it is necessary to apportion their environmental effects among the clients on a pro rata basis, which in turn leads to the question as to how many user sessions a single terminal server can execute.

The subject of sizing and scaling of terminal servers has already been dealt with in a joint study carried out by Microsoft and HP (cf. [Microsoft, 2003]). This study differentiated two groups of end users in the categories »Data Entry Workers«, who are mainly employed entering data in a program, and »Knowledge Workers«, who work with several office applications in multitasking operations (cf. [Microsoft, 2003], p. 9). Apart from the fact that users these days seldom start just one application but usually at least an e-mail client and browser at the same time, the study is based on rather unrealistic values for main memory requirements of just 3.5 MB per »Data Entry Worker« and 9.5 MB per »Knowledge Worker«. This is used to justify the estimation that with one HP ProLiant DL360 G3 server– equipped with max. two Intel® Xeon® processors and 4,096 MB main memory – it is possible to operate between 200 and

[16] Naturally, there is a wide range of thin client models on the market, some of which are more compact and with fewer hardware components. But there are also larger models with more extensive components. A survey and evaluation of the market average in Germany or Europe would far exceed the scope of this study. Hence, one device was chosen as an example, which covers the traditional area of server-based computing and the requirements of a medium user.

440 user session simultaneously, depending on the category. However, experiences from productive operation of the terminal server farm at Fraunhofer UMSICHT shows that certain processes of commonly used applications, such as Adobe® Reader®, Microsoft® Outlook® or other products in the Microsoft® Office Suite need more than 20 MB – much more than estimated by Microsoft and HP. Consequently, the values were reviewed and corrected in our own investigations.

Within the framework of the Fraunhofer study into the economic viability of thin client workstations (cf. [UMSICHT, 2006], p. 93ff) several extensive considerations regarding sizing and scaling of terminal servers have been determined. Within the course of the study and based on the question as to how a specific load can be defined, hardware with the performance rating of an HP ProLiant DL360 G3 was developed as a recommendation. This recommendation was based on the following considerations:

- In relation to its deployment as a terminal server the main components of an application server are main memory and processor. According to the state, of the art large hard disk capacities are not needed, as data is stored on dedicated machines. However, a hard disk sub-system with a high transfer rate, usually SCSI, which supports simultaneous access by numerous devices, must be used. This is necessary, as the user profiles are stored locally on the server and application programs are also started locally on the server.

- As commonly used systems with four or more processors generally include a complicated storage sub-system, which is not relevant for the application purpose, these servers are disproportionately expensive. The most economic solution is to procure dual-processor systems to which more servers can be added according to the principle of »many small ones instead of a few big ones« when the performance limit is reached.

- Assuming that the individual user sessions need at least 64 MB memory and that the actual expected processor load is difficult to determine ex ante, a maximum of 35 *medium users* were assumed for each dual processor.

Based on these assumptions, to develop the productive terminal server farm at Fraunhofer UMSICHT at the end of 2004 the HP ProLiant DL360 G3 systems were purchased. After more and more PC workstations were migrated to thin clients the farm was extended by more HP ProLiant DL360 G4p servers at the start of 2007.

Now, after three years of productive operation, the above assumptions can be verified ex post. This is possible since the required statistical data is available from the LANrunner® system[17] developed by Fraunhofer UMSICHT, which confirms that the values in the Microsoft/HP study were, in fact, much too high, while at the end of 2006, before the terminal server farm was extended, the system was already overburdened with 35 users per server. Observing a terminal server in the productive environment of Fraunhofer UMSICHT over 24 hours[18] showed a clear correlation between the number of users and the capacity utilization of the system; it was not the processors that were the limiting factor, but the available physical main memory (cf. Figure 5-1 to Figure 5-3).

Figure 5-1: Active sessions of a terminal server over 24 hours

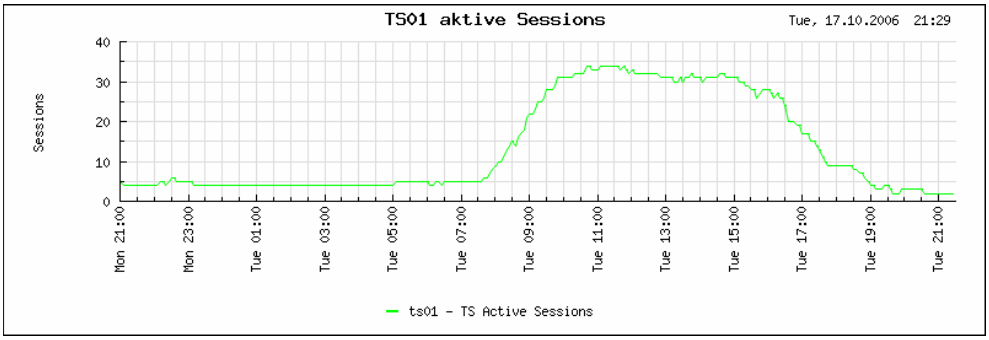
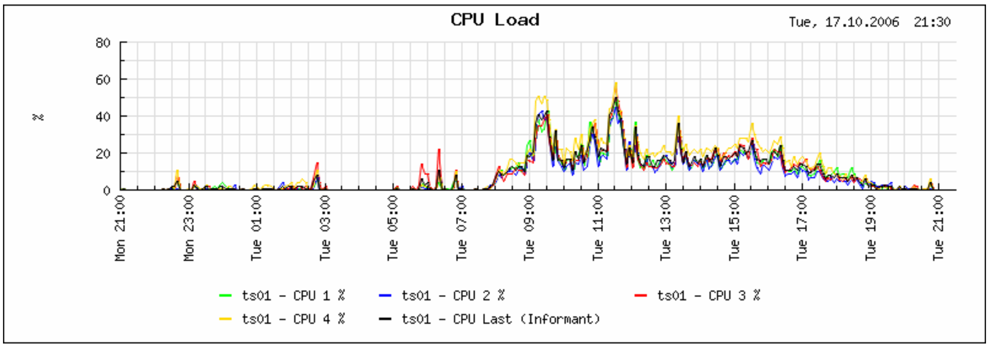


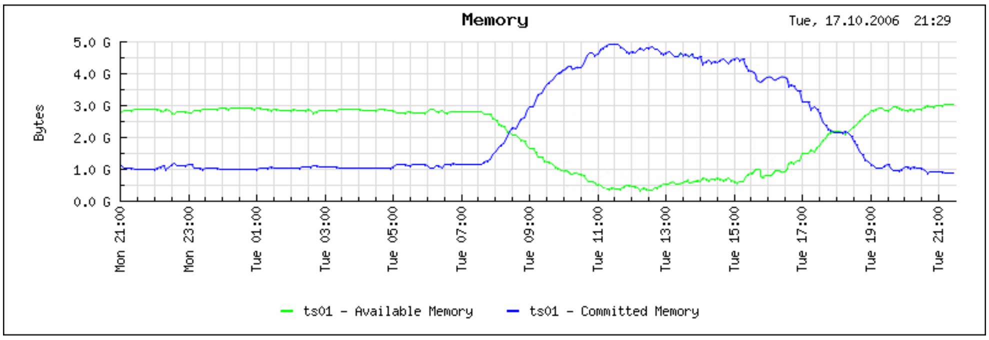
Figure 5-2: Processor load of this terminal server over 24 hours



17 With the help of the LANrunner® system it is possible to determine and visualize network statistics via Simple Network Monitoring Protocol (SNMP)

18 The observation period of 24 hours was chosen for the sake of simplicity. Over weekly and monthly views it was verified that these measurements are actually representative.

Figure 5-3: Available physical memory of the server over 24 hours



After the expansion of the farm in 2007 the load of the individual servers was reduced. But the correlation between the number of sessions and the capacity utilization of the processor and main memory remained (cf. Figure 5-4 to

Figure 5-6).

Figure 5-4: Active sessions of a terminal server over 24 hours

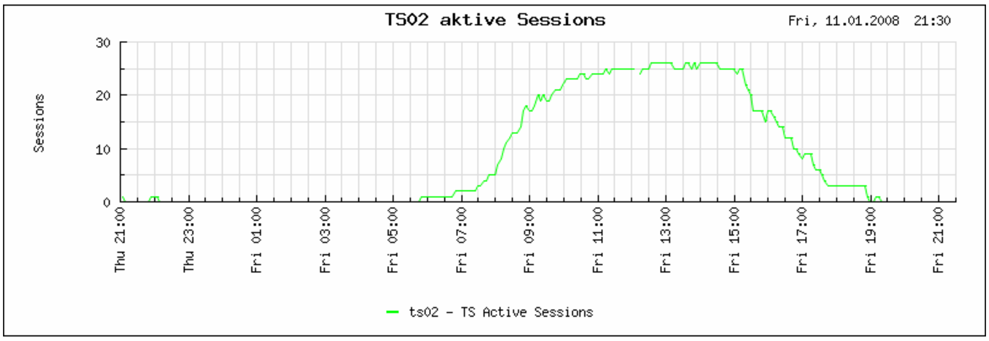


Figure 5-5: Processor load of this terminal server over 24 hours

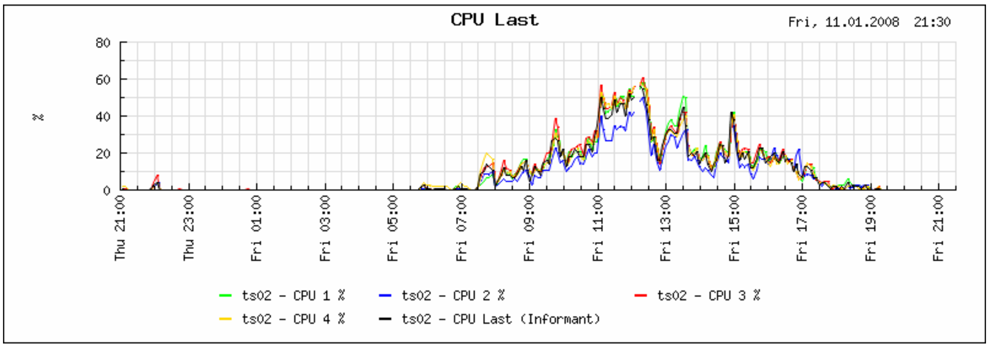
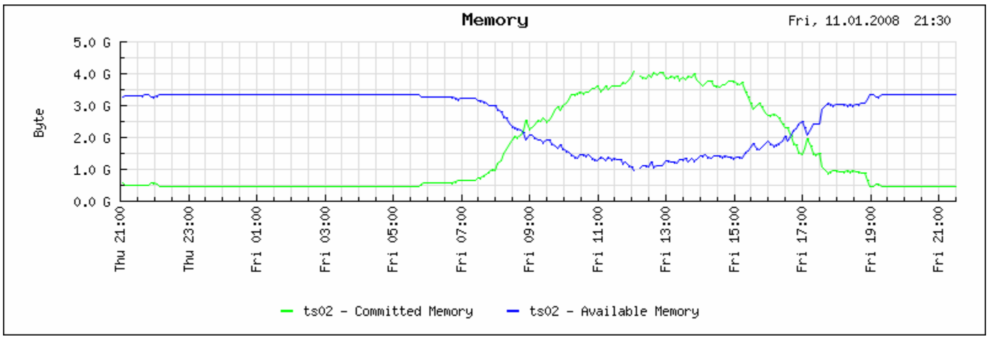


Figure 5-6: Available physical memory of the server over 24 hours



The sessions are users who are connected with the terminal server in a desktop session and who operate several applications, for example, from the Microsoft® Office Suite, web browser and database clients simultaneously and who thus correspond to the *medium user* category. Against the background that *light users* use individual applications which also place fewer demands on the system resources than the previously mentioned products, it is expected that up to 50 such sessions can be operated with a HP DL360 G4p server. This estimate and our own measurements are supported by operational experiences at Fischer Ges.m.b.H.[19], which presented its terminal server environment as a test study at Citrix iForum™ 2005 in Munich, Germany, and which, according to its own statements, supplies more than 50 users per server with the client program for its ERP system with the HP DL360 server model.

As opposed to this, the resource requirements for *power users*, who operate numerous applications simultaneously in multitasking mode, rise accordingly, which allows us to assume that the server can handle only 20 sessions of this type. To calculate the energy requirements within the scope of this study the identical server hardware of the HP DL360 G4p was used as a basis for the three user types.

Hardware equipment of the terminal server

- Type: HP ProLiant DL360 G4p
- Processor: 2x Intel® Xeon® Processor (3.4 GHz)
- Main memory: 4 GB PC2-3200 DDR2 400 SDRAM
- Hard disk: 2x 36.4 GB U320 Hard disk (15,000 rpm)
- Power unit: 2x 460 W (1+1 redundant)

The server, or the material and energy intensity in production, and the power consumption during operation was apportioned to the clients on the basis of the above considerations:

19 Fischer Ges.m.b.H. produces winter sport products (http://www.fischer-nordicwalking.com/de/) and carbon parts for the automotive industry (http://www.fischer-ct.com/de/fct/)

Table 5-2: Apportioning the terminal server to the clients (allocation key)

User type	Apportioning factor according to sessions per server
Light User	1/50
Medium User	1/35
Power User	1/20

Software equipment of the terminal server

All considerations regarding server sizing and apportioning the server shares are based on the assumption that a 32-bit operating system is used on the terminal server. This is justified by the fact that at present no experience values are yet available for the productive deployment of 64-bit terminal servers. The terminal servers on which the calculation model is based are operated with the following, typical software:

- Microsoft® Windows Server™ 2003 R2 Enterprise Edition incl. SP 2
- Citrix Presentation Server™ 4.0 Enterprise Edition incl. HRP 3
- Adept Scientific EndNote X
- Adobe® Flash® Player 8
- Adobe® Reader® 8
- CorelDRAW® Graphics Suite 12
- Microsoft® Internet Explorer 7
- Microsoft® Office 2003
- Mindjet® MindManager X5™
- OriginLab OriginPro 7.5
- SIGMA (FhG ERP system based on Oracle® Forms)
- SUN Java™ Runtime 6 (Update 3)

It is assumed that 32-bit operating systems are still the main systems used in many companies and that the calculation model is thus representative. The potential that can come from a changeover to a 64-bit platform is described in Section 9.1.

5.2 Production, manufacturing and distribution phases

The data for the production, manufacturing and distribution phases were taken from the EuP study [IVF, 2007]. Annex 2 contains the weight and environmental data for the two monitor types (LCD + CRT) and data about desktop PCs and laptops.

The weight data alone do not provide much information about the material intensity or environmental relevance, but as well as the volume it is important to estimate the transport data. Consequently, for categorization and further calculation both (weight + environmental effects) are listed in Section 6.

Average compositions of the respective objects being investigated are assumed. Values from different manufacturers are »blended« to achieve anonymous results. The functional unit is thus, for example »one computer«. The data required for this was obtained from the manufacturers with the help of a questionnaire. The individual components were split up according to category (e.g. containing iron, plastic, electronic components, paper, etc.) and according to the material that corresponds to the category (e.g. ABS[20], LDPE, PC for plastics). Data was recorded using the MEEUP methodology (Methodology Study Eco-Design of Energy-using Products) [MEEUP, 2005]. Calculation is then automated via standard data records for the environmental impact of the individual materials.

For instance, energy and raw materials are needed to manufacture these materials, and emissions are released. The following parameters were calculated for each material:

- **Gross energy requirement** (GER) in MJ. This value corresponds to the consumption of primary energy (before losses due to energy conversion). The primary energy is bonded in primary energy carriers, such as coal, biomass and oil. An additional parameter is the proportion of the GER in the form of electricity and the proportion of energy bonded in the products (e.g. in plastics). Only the gross energy requirement (GER) was considered for the comparison in Section 6.
- **Water consumption** in liters, split into the quantity of water for the processes and water for cooling purposes. In the course of the study the emphasis will be on process water because this has to be treated.
- **Waste volume** in g, split into hazardous and non-hazardous waste[21]
- **Emissions in the air**
    - GWP = Global Warming Potential, (measured in CO_2 equivalents)
    - AD = Acidifying Potential (measured in SO_2 equivalents)
    - VOC = Volatile Organic Compounds (measured in mg)
    - POP = Persistent Organic Pollutants (measured in ng toxicity equivalents)
    - HM = Heavy Metals (measured in ng nickel equivalents)

[20] Plastic types: ABS = Acrylonitrile butadiene styrene, PC = Polycarbonate, LDPE = Low Density Polyethylene
[21] The term »hazardous waste« (in Germany this used to be called waste requiring special supervision) was coined by the EU. In the European Waste Cataloguer hazardous waste is identified with a star. It must be accompanied by special certificates in Europe (e.g. during transportation).

  - PAH = Polycylic Aromatic Hydrocarbons (measured in ng nickel equivalents)
  - PM = Particulate Matter (measured in g)
- **Emissions in water** split into eutrophication potential (measured in PO_4 equivalents) and metal emissions (measured in mercury equivalents)

In addition to these emissions, further environmental impacts are caused by joining these components; extra emissions based on the pro rate quantities are calculated for the manufacturing phase. The values proposed by the program were taken over.

In the last step the parts are joined (final assembly). Then the products are shipped to the respective wholesale and retail outlets. Both are included in the distribution phase. The emissions for this step are based on the volume of the products and the question whether they are ICT or consumables weighing less than 15 kg. This question was answered with yes in all cases.

All results can then be set off against the number of computers that are sold throughout Europe to estimate the potential savings.

5.3 Operation phase

The need for spare parts during the operation phase was not considered, as the focus is on energy consumption.

Important for the environmental effects of an IT infrastructure during the operation phase is the power input, or specifically the effective power. When measuring the power input it must be considered that the power units used in computer systems create a phase shift between current and voltage due to the capacitive and inductive effects. The product of the effective values of current and voltage is the apparent power. This is given in volt-amperes (VA). The proportion of apparent power that does actual work (i.e. is used as power and ultimately converted into heat) is the effective power and is given in watts (W). The connection between apparent and effective power is characterized by the power factor, PF. With a power factor of PF=1 the apparent and effective powers are identical. Measuring equipment that does not take account of this phase shift records the apparent power but not the effective power that is relevant for energy consumption and thus provides values that are too high.

Accordingly, to measure power input in the operation phase a measuring device was used that takes account of the power factor and the effective power. An analyzer for the quality of power supply in single-phase systems, type »Chauvin Arnoux C.A 8230«[22] was used. In combination with a clamp-on am-

[22] http://www.chauvin-arnoux.com/Produit/Famille_detail.asp?idFam=1946&idPole=1

meter type »Chauvin Arnoux MN 93A«, which was configured to a maximum of 5 A, the measuring range, with a permissible overload of 20 %, covered amperage in the range [5 mA; 6 A]. The maximum error rate of the device in this range is ±0.5 %. The maximum error of the clamp-on ammeter is added to that of the device. In the [5 mA; 50 mA[range this is ±(1 %+0,1 mA), in the [50 mA; 500 mA[range it is ±1 % and in the [500 mA; 6 A] range ±0,7 %.

Figure 5-7: Measuring power on the IGEL Thin Client (Photo: Fraunhofer UMSICHT)

By displaying the measured values in real time the device can be used as a data logger which integrates measured values such as voltage, current, power factor, apparent and effective power at configurable intervals of 1, 5, 20 seconds to 1, 2, 5, 10 and 15 minutes and stores the average value over the interval. Accordingly, measurements were carried out on devices at Fraunhofer UMSICHT while they were in productive use. The measurements were then validated on the basis of the average values in [IVF, 2007]. The environmental impact was calculated on the basis of the emissions of CO_2 equivalents (CO_2eq) that are to be expected according to the German electricity mix. In the updated GEMIS standard process »El-KW-Park-DE-2000« for the supply of one kWh_{el} in the German electricity mix, these are 0.61 kg CO_2eq (0.58 kg of this is CO_2) [GEMIS, 2008]. Compared to the previous study [UMSICHT, 2006] there is a slight reduction in CO_2 emissions per kWh_{el} resulting from improved efficiency and the increased use of renewable energy.

The following cases were considered in the measurements.

5.3.1 Monitors

Monitors were measured randomly over a short period of 60 minutes, as the monitors are not the main focus of the investigation. The aim of the measurements was only to show the relationship between the power input of desktop computers and monitors. A distinction was made between two operation statuses:

- **Operation:** During the operation phase a medium user performs the usual office work on the computer, which means that the content of the screen changes.
- **Off/»soft-off«:** The monitor was switched off and the power input was measured in »soft-off« status.

Four device types were measured:

- 17" CRT monitor
- 19" CRT monitor
- 17" TFT monitor
- 19" TFT monitor

5.3.2 Notebooks

Notebooks were also measured randomly over a short period of 60 minutes, as they are not the main focus of the investigation. The measurements were carried out only to show the relationship between the power consumption of PCs and portable devices in stationary use in the office.

- **Operation:** During the operation phase a medium user performed the usual office work on a notebook.
- **Off/»soft-off«:** The system was closed and the power consumption was measured in »soft-off« status.

In both cases the device battery was charged continuously, which means that only the actual power consumption for stationary operation was measured.

A differentiated analysis is not the subject of this study. On the one hand, notebooks are only suited for continuous use in the office to a limited extent (cf. Section 4.5) and, on the other hand, notebooks are used differently to stationary PCs or thin clients especially because they are portable. Hence, in a detailed analysis the completely different usage behavior, which depends on the company and use, must be mapped and evaluated. For instance, if the device is used often out of the office, the power consumption varies considerably according to the configuration of the energy schema. In addition, the battery is often charged and discharged. Accordingly, in an eco balance over the life cycle the disposal and procurement of additional batteries would have to be considered. In the EuP report the battery is not balanced as a separate material category, but is included in the »big caps and coils« category. In other words, in a future study, materials used in notebook batteries should be evaluated in more detail.

5.3.3 Desktop PCs

Several desktop PCs were measured over several 24-hour periods, while users performed their usual tasks for 8-9 hours within that time. Outside working time a distinction was made between the following cases:

- **Operation/»Idle«:** PCs were not switched off at the end of the working day and ran throughout the night in »idle« mode; in other words, without any load.
- **Off/»soft-off«:** The system was closed at the end of the working day and the power consumption was measured in the »soft-off« status.

In this way the power consumption could be measured during operation, outside the working day (night, weekend, bank holidays) and as an average over one day.

It was assumed that the PCs were not switched off, as especially power users tend to leave them switched on constantly. There are several reasons for this. On the one hand, power saving rules have not yet been consistently established for desktops and there is a lack of system guidelines in companies specifying that all users should switch off their computers or send them to sleep. Other reasons are simply the general user's behavior (cf. [IVF, 2007], p. 91):

- A computer, which (as perceived by the user) needs a long time to boot up or to wake up from sleep mode is switched off as seldom as possible.
- Instability and errors on waking up considerably limit the use of this function in practice.
- Administrators do not want systems to be switched off so that updates can be installed automatically at night.
- Broadband connections and applications such as chat sites and real-time communication cause users to leave their systems switched on.
- If a computer appears to be »switched off«, users generally do not check whether it is still consuming electricity.

Specific information about how many systems are not switched off or which have no power management function varies. The EuP Report lists sources in which in the commercial environment only six to 25 per cent of computers use power management, while in private households only three per cent are regularly put into sleep mode when they are not being used (cf. [IVF, 2007], p. 94f).

In its latest study, the British environmental organization, Global Action Plan, (cf. [GAP, 2007], p. 6) assumes that an estimated 30 % of office PCs in the UK are continuously not switched off – a value which is probably similar in other industrial nations. For the USA the environmental authority, EPA, has determined that almost 60 % of desktop computers are not switched off at night [Lüke, 2007]. Positive changes can be expected only in the medium to long term (see Section 9.3).

Within the scope of the calculation model a conservative approach was taken and we assumed that a third of all PCs run continuously.

5.3.4 Thin clients

Several thin clients were measured over several periods of 24 hours, while users carried out their usual work for 8-9 hours within that time. The thin clients were all switched off at the end of the day[23]. Hence, power consumption could be measured during operation, in »soft-off« mode and as an average over one day.

5.3.5 Terminal servers

One of the productive terminal servers was measured for several periods of 24 hours. Initially, only one of the server's two redundant power units was connected. Then the more practice-related case with two power units was investigated to determine whether efficiency and power consumption changes through the use of both power units. A distinction was made between the following cases for operation with two power units:

- **Working day:** The power consumption of the servers was measured during the normal working hours at Fraunhofer UMSICHT while users carried out their usual work and the servers then continued to run in »idle« mode, with no load, overnight.
- **Work-free day:** The power consumption of the server was measured over the weekend to determine how much electricity it consumes in »idle« mode.

The corresponding values were added to the thin clients according to the allocation factor for medium users.

[23] Users, also power users, have no reason not to switch their thin client off overnight. While the client is switched off the session is kept on the server and can be reconnected the following day within a short time. All the programs that were opened on the previous day can be used again immediately.

5.4 Recycling/disposal

For the disposal and recycling phases the data was also determined using the methodology (calculation with Excel®) of the EuP study. Naturally, there are uncertainties here, as the proportions for reuse, substance recycling and energetic utilization can vary considerably depending on computer manufacturer, age and collection model.

For the disposal phase it is assumed that **no** coolant was used for the IT equipment. The necessary cooling is implemented by passive and active fans. It is also assumed that **no** mercury is used in the products (monitors, PC, servers, etc.). This is defined in the RoHS Directive (in force since 1 July 2006) and, in addition to mercury, also includes lead, cadmium, chromium (VI), polybrominated biphenyls (PBB) and polybrominated diphenyl ether (PBDE). Mercury may have been used in older computers in mercury batteries, electrodes and switches, sensors and relays.

It is assumed that the printed circuit boards (PCB) are **easy** to dismantle. This increases the proportion of recycled metals from the PCBs to 50 % by weight, which produces a 20 % bonus for PCBs, as they no longer have to be manufactured from new material [MEEUP, 2005].

The values for plastics recycling were left at 1 % for reuse, 9 % for substance recycling and 90 % for energetic utilization [MEEUP, 2005].

It is assumed that approx. 5 % of the materials end up in landfill sites. The recycling rate for metals and glass is estimated to be 95 %. The recycling rates for metals vary according to the type of metal – from 85 % cast iron and 60 % for copper tubes and sheets to 0 % for copper wire [MEEUP, 2005].

Recycling incurs expenditure. However, as primary material and energy is replaced, in most areas on the whole this is reflected as a **credit**. This credit in the disposal phase includes the utilization of plastics and electronic components [without LCD/CRT]). The credits for metals and other fractions are **already** taken into account in the production phase.

In other words, for the defined scenarios the comparison for the disposal phase was made according to the MEEUP method.

6 Results and evaluation

6.1 Production phase

6.1.1 Desktop PCs

The table below shows the materials required to produce an office desktop PC. It can be seen that among the weight proportions the steel component of the housing is the heaviest (6.3 kg), followed by paper for the packaging (2.3 kg). In total the office desktop PC weighs about 12.6 kg. The next heaviest groups are the electronic components.

Table 6-1: Composition of an office desktop PC [Table 59 from [IVF, 2007]]

EuP Lot 3 prep study: Office desktop PC				MZ
Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	LDPE	246	1-BlkPlastics	1-LDPE
2	ABS	381	1-BlkPlastics	10-ABS
3	PA 6	138	2-TecPlastics	11-PA 6
4	PC	264	2-TecPlastics	12-PC
5	Epoxy	98	2-TecPlastics	14-Epoxy
6	Flex PUR	2	2-TecPlastics	16-Flex PUR
7	Steel sheet galvanized	6312	3-Ferro	21-St sheet galv.
8	Steel tube/ profile	107	3-Ferro	22-St tube/profile
9	Cast iron	483	3-Ferro	23-Cast iron
10	Ferrite	0	3-Ferro	24-Ferrite
11	Stainless 18/8 coil	10	3-Ferro	25-Stainless 18/8 coil
12	Al sheet/ extrusion	315	4-Non-ferro	26-Al sheet/extrusion
13	Al diecast	15	4-Non-ferro	27-Al diecast
14	Cu winding wire	257	4-Non-ferro	28-Cu winding wire
15	Cu wire	334	4-Non-ferro	29-Cu wire
16	Cu tube/sheet	67	4-Non-ferro	30-Cu tube/sheet
17	Powder coating	2	5-Coating	39-powder coating
18	Big caps & coils	483	6-Electronics	44-big caps & coils
19	Slots /ext. Ports	310	6-Electronics	45-slots / ext. ports
20	Integrated Circuits, 5% Silicon, Au	69	6-Electronics	46-IC's avg., 5% Si, Au
21	Integrated Circuits, 1% Silicon	96	6-Electronics	47-IC's avg., 1% Si
22	SMD & LEDs avg	194	6-Electronics	48-SMD/ LED's avg.
23	PWB ½ lay 3.75 kg/m2	78	6-Electronics	49-PWB 1/2 lay 3.75kg/m2
24	PWB 6 lay 4.5 kg/m2	163	6-Electronics	50-PWB 6 lay 4.5 kg/m2
25	Solder SnAg4Cu0.5	48	6-Electronics	52-Solder SnAg4Cu0.5
26	Cardboard	2287	7-Misc.	56-Cardboard

To estimate the environmental impact the calculations from Annex 2 of the EuP were used. Gross energy requirement is 1.9 GJ. This value is determined by SMDs and LEDs (average), integrated circuits (5 % Si, Au), galvanized steel sheet and big caps and coils.

Process water consumption is 745 liters. This is mainly due to the production of the integrated circuits (5 % Si, Au) and SMD and LEDs.

The production process produces 0.57 kg of hazardous waste[24] and 27 kg of waste. The hazardous waste is produced mainly in the production of printed circuit boards (PCB). The normal waste comes from production of the steel sheets and copper wire.

117 kg CO_2eq of greenhouse gases are produced. The SMD and LED components as well as integrated circuits are mainly responsible for this.

The acidification potential is 1,072 g SO_2eq, mainly caused by the production of SMD and LED, followed by circuits.

Volatile organic compounds (VOC) are caused mainly in the production of circuits and the SMDs and LEDs and total 7.63 mg.

Persistent organic pollutants (POPs) make up 183 ng i-TEQ[25]. The main source for this is the manufacture of steel sheets.

Emissions of heavy metals are at a level of 221 mg Ni-eq, mainly caused by the production of SMDs and LEDs, followed by circuits and steel sheets.

Emissions of polycyclic aromatic compounds (PAC) are 139 mg Ni-eq. These are produced mainly by the big caps and coils and during the manufacture of aluminum sheets.

According to the table, 139 g of particulate matter was produced. This was caused mainly by the production of the steel sheets, the big caps and coils. In this calculation there is a deviation in the total, as the total individual emissions add up to just 81.46 g.

There is a similar deviation in regard to water emissions. Here the total is 407.1 mg Hg/20eq (mainly caused by integrated circuits) and for eutrophication potential 7,362.3 mg PO_4eq (mainly caused by slots/ext. ports, integrated circuits and epoxy).

For all the following calculations the totals for PM, metal emissions and eutrophication potential will be recalculated.

24 The term »hazardous waste« (in Germany this used to be called waste requiring special supervision) was coined by the EU. In the European Waste Cataloguer hazardous waste is identified with a star. It must be accompanied by special certificates in Europe (e.g. during transportation).

25 Standardized as toxic equivalent factors (TEQ)

Table 6-2: Environmental impact caused by the production of an office desktop PC; calculations according to MEEUP[26]

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS — EuP EcoReport: RAW OUTPUTS — Assessment of Environmental Impact

Nr: 0 **Product:** Office Desktop PC **Date:** 2008-Feb-06 **Author:** Übertrag Anhang 2 EuP-

MATERIALS EXTRACTION & PRODUCTION

Product					Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght in g	cat.	material	GER MJ	electr MJ	feedst MJ	water (proces ltr.	water (cool) ltr.	haz. Waste g	non-haz. Waste g	GWP kg CO2eq	AD g SO2eq	VOC mg	POP ng i-Teq	HM mg Ni eq	PAH mg Ni eq	PM g	Metal mg Hg/20eq	EUP mg PO4 eq
1	LDPE	246	1-BlkPlastics	1-LDPE	19,14	3,27	12,68	0,74	11,07	1,09	10,87	0,47	1,83	0,12	0,00	0,00	0,03	0,23	0,00	6,55
2	ABS	380,75	1-BlkPlastics	10-ABS	36,18	2,65	17,43	3,54	62,82	3,81	35,00	1,26	6,77	0,00	0,00	0,00	0,69	1,10	0,74	239,81
3	PA 6	137,68	2-TecPlastics	11-PA 6	16,45	2,08	5,36	2,20	30,15	2,62	24,27	1,18	5,38	0,00	0,00	0,00	0,06	0,74	6,75	257,78
4	PC	264,25	2-TecPlastics	12-PC	30,87	3,93	10,04	3,70	30,12	2,64	46,65	1,43	6,72	0,00	0,00	0,00	0,10	1,77	0,04	133,19
5	Epoxy	97,9	2-TecPlastics	14-Epoxy	13,78	2,40	4,17	1,86	37,59	1,86	39,80	0,65	4,30	0,00	0,00	0,00	0,01	1,47	0,00	944,72
6	Flex PUR	1,5	2-TecPlastics	16-Flex PUR	0,16	0,03	0,06	0,11	0,45	0,05	0,82	0,01	0,05	0,00	0,00	0,00	0,03	0,01	0,01	8,53
7	Steel sheet galvanized	6312,3	3-Ferro	21-St sheet galv.	214,62	14,38	0,47	0,00	0,00	0,00	10866,75	17,85	47,12	0,86	164,12	22,37	0,44	17,09	22,41	411,37
8	Steel tube / profile	106,5	3-Ferro	22-St tube/profile	1,81	0,49	-0,02	0,00	0,00	0,00	85,27	0,15	0,38	0,01	1,28	0,28	0,00	0,11	0,17	4,08
9	Cast iron	482,5	3-Ferro	23-Cast iron	4,83	0,07	-0,03	0,63	1,77	0,00	152,16	0,51	1,56	0,06	2,90	0,96	0,01	6,76	0,44	12,66
10	Ferrite	0	3-Ferro	24-Ferrite	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
11	Stainless 18/8 coil	9,5	3-Ferro	25-Stainless 18/8 coil	0,59	0,09	0,04	0,72	0,08	0,00	9,50	0,06	0,53	0,00	0,07	1,41	0,00	0,08	0,82	22,12
12	Al sheet/ extrusion	314,53	4-Non-ferro	26-Al sheet/extrusion	60,59	0,00	0,00	0,00	0,00	0,00	1232,96	3,25	21,17	0,02	1,57	1,14	30,36	5,32	11,01	1,56
13	Al diecast	15	4-Non-ferro	27-Al diecast	0,83	0,00	0,00	0,00	0,00	0,00	11,25	0,05	0,23	0,00	0,50	0,01	0,27	0,06	0,10	0,02
14	Cu winding wire	257	4-Non-ferro	28-Cu winding wire	36,68	0,00	0,00	0,00	0,00	0,21	5150,28	1,89	78,09	0,01	1,02	14,53	1,42	0,78	1,66	40,66
15	Cu wire	333,5	4-Non-ferro	29-Cu wire	38,87	0,00	0,00	0,00	0,00	0,08	6674,00	2,07	97,42	0,00	1,25	18,36	1,79	0,95	31,38	51,53
16	Cu tube/sheet	66,5	4-Non-ferro	30-Cu tube/sheet	3,39	0,00	0,00	0,00	0,00	0,00	532,93	0,18	4,16	0,00	0,68	2,20	0,36	0,10	2,50	4,12
17	Powder coating	1,62	5-Coating	39-powder coating	0,58	0,10	0,07	0,03	0,62	0,03	0,80	0,03	0,10	0,00	0,00	0,00	0,00	0,02	0,00	15,64
18	Big caps & coils	482,5	6-Electronics	44-big caps & coils	184,93	0,00	0,00	16,72	26,54	9,46	289,76	10,46	68,43	0,06	1,04	3,70	98,74	17,18	35,81	3,44
19	Slots / ext. Ports	310	6-Electronics	45-slots / ext. ports	57,99	18,39	0,00	23,14	79,16	5,30	95,38	3,11	57,15	0,00	0,43	11,78	0,60	4,02	9,86	2005,62
20	Integrated Circuits, 5% Silicon, Au	69	6-Electronics	46-IC's avg., 5% Si, Au	380,14	369,73	0,00	346,17	0,00	17,38	357,52	29,22	192,33	4,68	3,37	30,81	1,01	5,03	258,06	1482,19
21	Integrated Circuits, 1% Silicon	95,5	6-Electronics	47-IC's avg., 1% Si	83,48	64,29	0,29	58,40	9,89	61,56	166,96	5,62	77,95	0,00	0,94	17,67	0,28	2,31	0,92	410,30
22	SMD & LEDs avg.	193,5	6-Electronics	48-SMD/ LED's avg.	574,47	558,36	0,00	179,07	0,00	25,29	547,78	32,32	313,56	1,45	2,90	81,60	0,88	9,83	2,85	424,83
23	PWB 1/2 lay 3,75 kg/m²	78	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	21,92	11,74	0,67	13,26	5,99	135,19	204,78	0,88	16,67	0,18	0,21	2,82	0,28	0,40	1,15	287,54
24	PWB 6 lay 4,5 kg/m²	162,5	6-Electronics	50-PWB 6 lay 4.5 kg/m2	59,67	23,75	1,39	78,82	12,48	307,42	661,91	2,55	64,35	0,17	0,83	11,38	1,12	6,02	20,38	396,95
25	Solder SnAg4Cu0,5	48	6-Electronics	52-Solder SnAg4Cu0.5	11,23	9,30	0,00	3,37	0,00	0,22	10,94	0,56	3,10	0,00	0,06	0,16	0,09	0,07	0,00	0,29
26	Cardboard	2286,5	7-Misc.	56-Cardboard	64,02	4,57	36,58	16,11	0,00	0,11	119,62	1,61	2,38	0,00	0,03	0,08	0,01	0,03	0,03	196,78
	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	0	1 917,21	1089,61	89,19	748,60	308,74	574,30	27327,97	117,33	1071,72	7,63	183,20	221,27	138,57	138,57	81,46	407,10

6.1.2 Notebook

The following table shows the materials needed to produce a notebook. For the notebook the integrated monitor is included in the balance. For a notebook the highest weight is for paper (0.92 kg), followed by electric materials (0.5 kg), the metal casing (0.49 kg) and glass for the LCD screen (approx. 0.6 kg). In total the notebook weighs approx. 3.77 kg. In line 24 it can be seen that the »Integrated Circuits, 1 % silicon« are allocated to the category »Integrated Circuits 5 % silicon« and that the »Glass for Lamps« (line 31) was not allocated to any category. This data was left unchanged for this study.

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Table 6-3: Summary for notebooks [Table 61 from [IVF, 2007]]

Nr	Product name		Date	Author
	EuP Lot 3 prep study: Laptops			MZ

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	LDPE	43	1-BlkPlastics	1-LDPE
2	PP	4	1-BlkPlastics	4-PP
3	PS	3	1-BlkPlastics	5-PS
4	EPS	50	1-BlkPlastics	6-EPS
5	PVC	23	1-BlkPlastics	8-PVC
6	ABS	142	1-BlkPlastics	10-ABS
7	PA 6	281	2-TecPlastics	11-PA 6
8	PC	267	2-TecPlastics	12-PC
9	PMMA	36	2-TecPlastics	13-PMMA
10	Epoxy	3	2-TecPlastics	14-Epoxy
11	Steel sheet galvanized	489	3-Ferro	21-St sheet galv.
12	Al sheet/ extrusion	38	4-Non-ferro	26-Al sheet/extrusion
13				
14	Cu wire	60	4-Non-ferro	29-Cu wire
15	Cu tube/sheet	15	4-Non-ferro	30-Cu tube/sheet
16	MgZn5 cast	122	4-Non-ferro	33-MgZn5 cast
17	Powder coating		5-Coating	39-powder coating
18				
19				
20	LCD screen m2 (viewable screen size)	63	6-Electronics	42-LCD per m2 scrn
21	Big caps & coils	501	6-Electronics	44-big caps & coils
22	Slots /ext. Ports	133	6-Electronics	45-slots / ext. ports
23	Integrated Circuits, 5% Silicon, Au	47	6-Electronics	46-IC's avg., 5% Si, Au
24	Integrated Circuits, 1% Silicon	31	6-Electronics	46-IC's avg., 5% Si, Au
25	SMD & LEDs avg	50	6-Electronics	47-IC's avg., 1% Si
26	PWB ½ lay 3.75 kg/m2	5	6-Electronics	49-PWB 1/2 lay 3.75kg/m2
27	PWB 6 lay 4.5 kg/m2	77	6-Electronics	50-PWB 6 lay 4.5 kg/m2
28	Solder SnAg4Cu0.5	7	6-Electronics	52-Solder SnAg4Cu0.5
29	Glass for lamps	1	7-Misc.	54-Glass for lamps
30	Cardboard	921	7-Misc.	56-Cardboard
31	Glass for LCD	362	7-Misc.	

To estimate environmental impact the calculations from Annex 2 of the EuP study were used. Gross energy requirement is 1.1 GJ. This value was determined by the integrated circuits (5 % Si, Au) and the LCD screen.

522 liters of process water was used. This was used mainly in the production of the integrated circuits (5 % Si, Au).

The production process produces 0.23 kg of hazardous waste and 4.2 kg of other waste. Hazardous waste is produced mainly in the manufacture of printed circuit boards. Normal waste arises from production of the copper wire and the steel sheets.

71 kg CO_2eq of greenhouse gases are produced. This is due mainly to the integrated circuits and the LCD screen components.

The acidification potential is 445 g SO_2eq, mainly due to the production of circuits, followed by big caps and coils. This item also includes the notebook battery. As the MEEUP evaluation schema has no separate material category for the battery material, the battery was allocated to this category. When this subject is investigated in future, more attention should be paid to batteries, also in terms of the different ways in which they are used and in regard to the question as to whether frequent charging and uncharging over the life of the device causes a need for additional batteries.

Volatile organic compounds (VOC) are produced mainly in the manufacture of circuits and total 5.57 mg.

23 ng i-TEQ of persistent organic pollutants are produced. The main cause here is the production of steel sheets.

Emissions of heavy metals are at a level of 65 mg Ni-eq, caused mainly during production of the circuits, followed by SMDs and LEDs.

119 mg Ni-eq of polycyclic aromatic compounds are emitted. This is due mainly to the production of big caps and coils and the manufacture of aluminium sheets.

According to the table, 119 g of particulate matter is produced. The main cause of this is the production of the big caps and coils. In this calculation there is a deviation in the total, as the total individual emissions should be 36.88 g.

There is also a deviation in water emissions. Here the total is 369 mg Hg/20eq (mainly caused by integrated circuits) and 3,994 mg PO_4eq for the eutrophication potential (mainly caused by integrated circuits, slots/external ports and PA 6).

Hence, in terms of all types of pollutants a notebook produces less expenditure and emissions than an office desktop PC.

Table 6-4: Environmental impact from the production of a notebook; calculations according to MEEUP[27]

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS — EuP EcoReport: RAW OUTPUTS, Assessment of Environmental Impact

Nr: 0 — **Product:** Laptops at home — **Date:** 2008-Feb-06 — **Author:** Übertrag Anhang 2 EuP-

MATERIALS EXTRACTION & PRODUCTION

Product					Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	material	GER	electr	feedst	water (proces	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	LDPE	43	1-BlkPlastics	1-LDPE	3,35	0,57	2,22	0,13	1,94	0,19	1,90	0,08	0,32	0,02	0,00	0,00	0,01	0,04	0,00	1,14
2	PP	4	1-BlkPlastics	4-PP	0,29	0,03	0,21	0,02	0,16	0,02	0,11	0,01	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,66
3	PS	2,6667	1-BlkPlastics	5-PS	0,23	0,01	0,13	0,01	0,47	0,00	0,06	0,01	0,05	0,00	0,00	0,00	0,32	0,00	0,00	0,15
4	EPS	50,333	1-BlkPlastics	6-EPS	4,21	0,17	2,41	0,29	8,86	0,05	1,91	0,14	0,91	0,00	0,00	0,00	3,06	0,09	0,00	6,27
5	PVC	23,333	1-BlkPlastics	8-PVC	1,32	0,26	0,54	0,26	1,45	0,12	1,57	0,05	0,35	0,00	0,00	0,00	0,00	0,07	0,07	7,33
6	ABS	141,83	1-BlkPlastics	10-ABS	13,48	0,99	6,49	1,32	23,40	1,42	13,04	0,47	2,52	0,00	0,00	0,00	0,26	0,41	0,28	89,33
7	PA 6	280,54	2-TecPlastics	11-PA 6	33,53	4,24	10,92	4,49	61,44	5,33	49,45	2,40	10,95	0,00	0,00	0,00	0,11	1,51	13,75	525,25
8	PC	267,1	2-TecPlastics	12-PC	31,20	3,97	10,15	3,74	30,45	2,67	47,16	1,44	6,79	0,00	0,00	0,00	0,10	1,79	0,04	134,62
9	PMMA	36,333	2-TecPlastics	13-PMMA	4,00	0,48	1,52	0,36	0,94	0,05	3,81	0,22	1,58	0,00	0,00	0,00	0,00	0,19	0,10	75,14
10	Epoxy	2,6667	2-TecPlastics	14-Epoxy	0,38	0,07	0,11	0,05	1,02	0,05	1,08	0,02	0,12	0,00	0,00	0,00	0,00	0,04	0,00	25,73
11	Stell sheet galvanized	489,23	3-Ferro	21-St sheet galv.	16,63	1,11	0,04	0,00	0,00	0,00	842,22	1,38	3,65	0,07	12,72	1,73	0,03	1,32	1,74	31,88
12	Al sheet/ extrusion	37,9	4-Non-ferro	26-Al sheet/extrusion	7,30	0,00	0,00	0,00	0,00	0,00	148,57	0,39	2,55	0,00	0,19	0,14	3,66	0,64	1,33	0,19
13	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
14	Cu wire	60	4-Non-ferro	29-Cu wire	6,99	0,00	0,00	0,00	0,00	0,01	1200,72	0,37	17,53	0,00	0,22	3,30	0,32	0,17	5,65	9,27
15	Cu tube/sheet	15,2	4-Non-ferro	30-Cu tube/sheet	0,77	0,00	0,00	0,00	0,00	0,00	121,81	0,04	0,95	0,00	0,16	0,50	0,08	0,02	0,57	0,94
16	MgZn5 cast	121,67	4-Non-ferro	33-MgZn5 cast	19,69	0,00	0,00	14,42	1,59	0,68	582,31	2,24	5,48	0,01	3,33	0,32	5,93	1,11	2,18	0,44
17	Powder coating	4,7933	5-Coating	39-powder coating	1,71	0,29	0,20	0,09	1,84	0,10	2,36	0,09	0,30	0,00	0,00	0,01	0,00	0,07	0,00	46,27
18	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
19	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
20	LCD scrCenn m² (viewable screen size)	63,167	6-Electronics	42-LCD per m2 scrn	225,08	143,39	0,00	2,84	42,32	0,06	3,28	11,64	3,74	0,03	0,02	0,05	0,01	0,04	0,02	0,00
21	Big caps & coils	501	6-Electronics	44-big caps & coils	192,03	0,00	0,00	17,36	27,56	9,82	300,87	10,86	71,05	0,06	1,08	3,84	102,53	17,84	37,19	3,58
22	Slots / external Ports	132,93	6-Electronics	45-slots / ext. ports	24,87	7,88	0,00	9,92	33,95	2,27	40,90	1,33	24,51	0,00	0,19	5,05	0,26	1,72	4,23	860,02
23	Integrated Circuits, 5% Silicon, Au	46,833	6-Electronics	46-IC's avg., 5% Si, Au	258,02	250,95	0,00	234,96	0,00	11,79	242,66	19,83	130,54	3,17	2,29	20,91	0,69	3,41	175,16	1006,02
24	Integrated Circuits, 1% Silicon	31,167	6-Electronics	46-IC's avg., 5% Si, Au	171,71	167,01	0,00	156,37	0,00	7,85	161,49	13,20	86,87	2,11	1,52	13,92	0,46	2,27	116,56	669,50
25	SMD & LED avg	50,267	6-Electronics	47-IC's avg., 1% Si	43,94	33,84	0,15	30,74	5,21	32,40	87,88	2,96	41,03	0,00	0,49	9,30	0,15	1,21	0,48	215,96
26	PWB 1/2 lay 3,75 kg/m2	4,8	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	1,35	0,72	0,04	0,82	0,37	8,32	12,60	0,05	1,03	0,01	0,01	0,17	0,02	0,02	0,07	17,69
27	PWB 6 lay 4,5 kg/m²	76,867	6-Electronics	50-PWB 6 lay 4.5 kg/m2	28,22	11,24	0,66	37,28	5,90	145,42	313,10	1,21	30,44	0,08	0,39	5,39	0,53	2,85	9,64	187,77
28	Solder SnAg4Cu0,5	6,9667	6-Electronics	52-Solder SnAg4Cu0.5	1,63	1,35	0,00	0,49	0,00	0,03	1,59	0,08	0,45	0,00	0,01	0,02	0,01	0,01	0,00	0,04
29	Glass for lamps	0,6667	7-Misc.	54-Glass for lamps	0,01	0,01	0,00	0,01	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
30	Cardboard	921	7-Misc.	56-Cardboard	25,79	1,84	14,74	6,49	0,00	0,04	48,18	0,65	0,96	0,00	0,01	0,03	0,00	0,01	0,01	79,26
31	Glass for LCD	362,33	7-Misc.	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
32	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	0	1 117,72	630,41	50,51	522,45	248,86	228,70	4230,64	71,15	444,69	5,57	22,63	64,69	118,54	118,54	36,88	369,06

6.1.3 LCD monitor 17"

The following table shows the materials required to produce a 17" LCD monitor.

The 17" LCD monitor weighs about 6.8 kg. The main weight is the ferrous housing (1.8 kg + 1.2 kg). The next major weight is plastic (ABS with 0.68 kg), followed by paper at 0.65 kg.

Table 6-5: Composition of a 17" LCD monitor [Table 63 from [IVF, 2007]]

EuP Lot 3 prep study: LCD displays			MZ	
Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	LDPE	164	1-BlkPlastics	1-LDPE
2	EPS	279	1-BlkPlastics	6-EPS
3	PVC	43	1-BlkPlastics	8-PVC
4	ABS	679	1-BlkPlastics	10-ABS
5	PA 6	422	2-TecPlastics	11-PA 6
6	PC	385	2-TecPlastics	12-PC
7	PMMA	153	2-TecPlastics	13-PMMA
8	E-glass fibre	120	2-TecPlastics	18-E-glass fibre
9	Aramid fibre	6,5	2-TecPlastics	19-Aramid fibre
10	Steel sheet galvanized	1854	3-Ferro	21-St sheet galv.
11	Al sheet/ extrusion	39	4-Non-ferro	26-Al sheet/extrusion
12	Cu wire	190	4-Non-ferro	29-Cu wire
13	Powder coating	1,0	5-Coating	39-powder coating
14	LCD screen m2 (viewable screen size)	91	6-Electronics	42-LCD per m2 scrn
15	Big caps & coils	41	6-Electronics	44-big caps & coils
16	Slots /ext. Ports	37	6-Electronics	45-slots / ext. ports
17	Integrated Circuits, 5% Silicon, Au	13	6-Electronics	46-IC's avg., 5% Si, Au
18	Integrated Circuits, 1% Silicon	20	6-Electronics	47-IC's avg., 1% Si
19	SMD & LEDs avg	11	6-Electronics	48-SMD/ LED's avg.
20	PWB ½ lay 3.75 kg/m2	30	6-Electronics	49-PWB 1/2 lay 3.75kg/m2
21	PWB 6 lay 4.5 kg/m2	20	6-Electronics	50-PWB 6 lay 4.5 kg/m2
22	Solder SnAg4Cu0.5	7,6	6-Electronics	52-Solder SnAg4Cu0.5
23	Glass for lamps	26	7-Misc.	54-Glass for lamps
24	Cardboard	650	7-Misc.	56-Cardboard
25	Office paper	55	7-Misc.	57-Office paper
26	Misc glass	308	7-Misc.	
27	Cast iron	1165,0	3-Ferro	23-Cast iron

To estimate the environmental impact the calculations from Annex 2 of the EuP study were used. Gross energy requirement is 0.8 GJ. This value is determined by the LCD screen and production of the circuits. The gross value is similar to the energy requirement for manufacturing a CRT monitor.

About 151 liters of process water are needed. This is mainly due to production of the integrated circuits (5 % Si, Au).

The production process produces 0.13 kg of hazardous waste and 8.2 kg of other waste. The hazardous waste is produced mainly in the production of printed circuit boards. Normal waste is produced during production of the copper wire and the steel sheets.

The greenhouse gases make up 46 kg CO_2eq. Mainly responsible for this are the LCD screen and the integrated circuit components.

The acidification potential is 235 g SO_2eq, mainly caused by the production of the copper wire and the circuits.

Volatile organic compounds (VOC) are dominated by emissions during production of the circuits. They make up a total of 2 mg.

In terms of persistent organic pollutants, 57 ng i-TEQ are produced. This is caused mainly in the manufacture of the steel sheets.

Emissions of heavy metals are 38 mg Ni-eq, mainly caused in the production of copper wire.

Emissions of polycyclic aromatic compounds reach 33 mg Ni-eq. The main cause of this is the manufacture of the EPS plastic followed by big caps and coils.

According to the table, 33 g of particulate matter was produced. This is caused mainly in the production of cast iron. In this calculation there is a deviation in the total, as the total individual emissions should add up to 37 g.

This deviation also exists in the water emissions. Here the total is 112 mg Hg/20eq (main producer: integrated circuits) and 3,555 mg PO_4eq for the eutrophication potential (mainly caused by: PA 6, ABS, E-glass fiber).

Table 6-6: Environmental impact from the production of a 17" LCD monitor; calculations according to MEEUP[28]

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ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: RAW OUTPUTS
Assessment of Environmental Impact

Nr: 0 **Product:** **Date:** 08.02.08 **Author:** Copy Annex II of EuP St

MATERIALS EXTRACTION & PRODUCTION

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	material	GER	electr	feedst	water (proces	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	LDPE	164	1-BlkPlastics	1-LDPE	12,76	2,18	8,45	0,49	7,38	0,73	7,25	0,31	1,22	0,08	0,00	0,00	0,02	0,15	0,00	4,37
2	EPS	278,7	1-BlkPlastics	6-EPS	23,32	0,94	13,32	1,59	49,05	0,26	10,55	0,75	5,05	0,00	0,00	0,00	16,96	0,50	0,00	34,73
3	PVC	42,8	1-BlkPlastics	8-PVC	2,42	0,48	0,98	0,47	2,65	0,21	2,87	0,09	0,64	0,00	0,00	0,00	0,00	0,12	0,12	13,44
4	ABS	679,1	1-BlkPlastics	10-ABS	64,53	4,72	31,08	6,32	112,05	6,79	62,43	2,25	12,07	0,00	0,00	0,00	1,23	1,97	1,32	427,73
5	PA 6	422,22	2-TecPlastics	11-PA 6	50,46	6,39	16,43	6,76	92,47	8,02	74,42	3,61	16,48	0,00	0,00	0,00	0,17	2,28	20,70	790,51
6	PC	384,75	2-TecPlastics	12-PC	44,94	5,72	14,62	5,39	43,86	3,85	67,93	2,07	9,78	0,00	0,00	0,00	0,14	2,58	0,06	193,92
7	PMMA	152,85	2-TecPlastics	13-PMMA	16,84	2,00	6,39	1,50	3,97	0,21	16,01	0,92	6,66	0,00	0,00	0,00	0,00	0,78	0,43	316,10
8	E-glass fibre	119,75	2-TecPlastics	18-E-glass fibre	7,88	2,53	1,29	6,50	32,49	0,84	37,27	0,40	3,49	0,00	0,00	0,00	0,01	0,98	5,67	377,38
9	Armid fibre	6,5	2-TecPlastics	19-Aramid fibre	1,67	0,53	0,27	1,38	6,88	0,18	7,89	0,09	0,74	0,00	0,00	0,00	0,00	0,21	1,20	79,89
10	Steel sheet galvanized	1854	3-Ferro	21-St sheet galv.	63,04	4,22	0,14	0,00	0,00	0,00	3191,70	5,24	13,84	0,25	48,20	6,57	0,13	5,02	6,58	120,82
11	Al sheet/ extrusion	39	4-Non-ferro	26-Al sheet/extrusion	7,51	0,00	0,00	0,00	0,00	0,00	152,88	0,40	2,62	0,00	0,19	0,14	3,76	0,66	1,37	0,19
12	Cu wire	189,6	4-Non-ferro	29-Cu wire	22,10	0,00	0,00	0,00	0,00	0,05	3794,28	1,18	55,38	0,00	0,71	10,44	1,02	0,54	17,84	29,30
13	Powder coating	1,03	5-Coating	39-powder coating	0,37	0,06	0,04	0,02	0,40	0,02	0,51	0,02	0,06	0,00	0,00	0,00	0,00	0,02	0,00	9,94
14	LCD screen m² (viewable screen size)	91,3	6-Electronics	42-LCD per m2 scrn	325,32	207,25	0,00	4,11	61,17	0,09	4,75	16,83	5,40	0,04	0,03	0,07	0,01	0,05	0,03	0,00
15	Big caps & coils	41,35	6-Electronics	44-big caps & coils	15,85	0,00	0,00	1,43	2,27	0,81	24,83	0,90	5,86	0,01	0,09	0,32	8,46	1,47	3,07	0,30
16	Slots /ext. ports	36,55	6-Electronics	45-slots / ext. ports	6,84	2,17	0,00	2,73	9,33	0,62	11,25	0,37	6,74	0,00	0,05	1,39	0,07	0,47	1,16	236,47
17	Integrated Circuits, 5% Silcon, Au	12,85	6-Electronics	46-IC's avg., 5% Si, Au	70,79	68,86	0,00	64,47	0,00	3,24	66,58	5,44	35,82	0,87	0,63	5,74	0,19	0,94	48,06	276,03
18	Integrated Circuits, 1% Silicon	20,35	6-Electronics	47-IC's avg., 1% Si	17,79	13,70	0,06	12,44	2,11	13,12	35,58	1,20	16,61	0,00	0,20	3,76	0,06	0,49	0,20	87,43
19	SMD & LEDs avg	10,7	6-Electronics	48-SMD/ LED's avg.	31,77	30,88	0,00	9,90	0,00	1,40	30,29	1,79	17,34	0,08	0,16	4,51	0,05	0,54	0,16	23,49
20	PWB 1/2 lay 3,75 kg/m²	30	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	8,43	4,52	0,26	5,10	2,30	52,00	78,76	0,34	6,41	0,07	0,08	1,08	0,11	0,15	0,44	110,59
21	PWB 6 lay 4,5 kg/m²	19,6	6-Electronics	50-PWB 6 lay 4.5 kg/m2	7,20	2,86	0,17	9,51	1,51	37,08	79,84	0,31	7,76	0,02	0,10	1,37	0,13	0,73	2,46	47,88
22	Solder SnAg4Cu0,5	7,55	6-Electronics	52-Solder SnAg4Cu0.5	1,77	1,46	0,00	0,53	0,00	0,03	1,72	0,09	0,49	0,00	0,01	0,03	0,01	0,01	0,00	0,05
23	Glass for lamps	26	7-Misc.	54-Glass for lamps	0,42	0,34	0,00	0,22	0,00	0,01	0,35	0,02	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,01
24	Cardboard	650	7-Misc.	56-Cardboard	18,20	1,30	10,40	4,58	0,00	0,03	34,01	0,46	0,68	0,00	0,01	0,02	0,00	0,01	0,01	55,94
25	Office paper	54,5	7-Misc.	57-Office paper	2,18	0,33	1,47	4,15	0,00	0,02	3,68	0,03	0,27	0,01	0,00	0,01	0,00	0,09	0,00	288,22
26	Misc glass	307,6	7-Misc.	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
27	Cast iron	1165	3-Ferro	23-Cast iron	11,65	0,16	-0,07	1,51	4,26	0,00	367,39	1,23	3,77	0,14	6,99	2,31	0,02	16,31	1,06	30,56
	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	0	836,04	363,58	105,31	151,09	434,16	129,61	8165,00	46,34	235,29	1,58	57,46	37,77	32,56	32,56	37,07	111,93

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6.1.4 CRT monitor 17"

The following table shows the materials needed to produce a 17" CRT monitor. The total weight of a 17" CRT monitor is 16.4 kg.

It can be seen that the largest weight proportion is glass (approx. 11.1 kg). The second largest proportion is ABS plastic (1.755 kg), followed by paper, at 1.88 kg.

Table 6-7: Composition of a 17" CRT monitor [Table 66 from [IVF, 2007]]

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	EPS	165	1-BlkPlastics	6-EPS
2	PVC	44	1-BlkPlastics	8-PVC
3	ABS	1755	1-BlkPlastics	10-ABS
4	PA 6	447	2-TecPlastics	11-PA 6
5	PC	0,6	2-TecPlastics	12-PC
6	Steel sheet galvanized	126	3-Ferro	21-St sheet galv.
7	Al sheet/ extrusion	14	4-Non-ferro	26-Al sheet/extrusion
8	Cu wire	222	4-Non-ferro	29-Cu wire
9	Powder coating	6,0	5-Coating	39-powder coating
10	CRT screen m2 (nominal screen size)	90	6-Electronics	43-CRT per m2 scrn
11	Big caps & coils	38	6-Electronics	44-big caps & coils
12	Slots /ext. Ports	40	6-Electronics	45-slots / ext. ports
13	Integrated Circuits, 5% Silicon, Au	17	6-Electronics	46-IC's avg., 5% Si, Au
14	Integrated Circuits, 1% Silicon	14	6-Electronics	47-IC's avg., 1% Si
15	SMD & LEDs avg	13	6-Electronics	48-SMD/ LED's avg.
16	PWB ½ lay 3.75 kg/m2	96	6-Electronics	49-PWB 1/2 lay 3.75kg/m2
17	PWB 6 lay 4.5 kg/m2	24	6-Electronics	50-PWB 6 lay 4.5 kg/m2
18	Solder SnAg4Cu0.5	11	6-Electronics	52-Solder SnAg4Cu0.5
19	Glass for lamps	6,5	7-Misc.	54-Glass for lamps
20	Cardboard	1880	7-Misc.	56-Cardboard
21	Office paper	280	7-Misc.	57-Office paper
22	Misc glass	11110	7-Misc.	

To estimate the environmental impact the calculations from Annex 2 of the EuP study were used. Gross energy requirement is 0.8 GJ. This value is determined by the CRT screen and the manufacture of ABS. It is noticeable that only about 0.3 GJ more are needed to produce a notebook.

224 liters of process water are required. This is caused mainly by production of the integrated circuits (5 % Si, Au).

The production process produces 0.26 kg of hazardous waste and 5.8 kg of other waste. The hazardous waste arises mainly in the production of printed circuit boards. The normal waste comes from production of the copper wire.

42 kg CO_2eq of greenhouse gases are produced. This is caused mainly by the CRT screen and integrated circuit components.

Acidification potential is 342 g SO_2eq, caused mainly by production of the CRT screen, the copper wire and the circuits.

Volatile organic compounds (VOC) are dominated by emissions during production of the CRT screen. 74 mg are produced.

In regard to persistent organic pollutants, 7 ng i-TEQ are produced. Steel plate production is mainly responsible for this.

Emissions of heavy metals are 119 mg Ni-eq, the main cause of this is production of the CRT screen, followed by the circuits.

25 mg Ni-eq. of polycyclic aromatic compounds are emitted. This comes mainly from the manufacture of EPS plastic, followed by big caps and coils. In this calculation there is a deviation in the total, as the total individual emissions should add up to 81.46 g.

According to the table, 25 g of particulate matter was produced. Production of the CRT screen was mainly responsible for this. Once more in this calculation there is a deviation in the total, as the individual emissions should add up to 294 g.

This deviation also exists in the water emissions. Here the total is 391 mg Hg/20eq (mainly caused by: integrated circuits) and 5,020 mg PO_4eq for the eutrophication potential (mainly caused by: paper, ABS, PA 6).

Table 6-8: Environmental impact from the production of a 17"CRT monitor; calculations according to MEEUP[29]

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS — EuP EcoReport: RAW OUTPUTS — Assessment of Environmental Impact

Nr: 0 — Product: — Date: 08.02.08 — Author: Copy Annex II of EuP St

MATERIALS EXTRACTION & PRODUCTION

Product					Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	material	GER	electr	feedst	water (proces	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	EPS	165	1-BlkPlastics	6-EPS	13,80	0,56	7,89	0,94	29,04	0,15	6,25	0,45	2,99	0,00	0,00	0,00	10,04	0,30	0,00	20,56
2	PVC	43,8	1-BlkPlastics	8-PVC	2,48	0,49	1,00	0,48	2,72	0,22	2,94	0,09	0,66	0,00	0,00	0,00	0,00	0,13	0,12	13,75
3	ABS	1754,8	1-BlkPlastics	10-ABS	166,74	12,20	80,32	16,32	289,54	17,55	161,31	5,83	31,18	0,00	0,00	0,00	3,17	5,09	3,40	1105,25
4	PA 6	447,47	2-TecPlastics	11-PA 6	53,48	6,77	17,41	7,16	98,00	8,50	78,88	3,83	17,47	0,00	0,00	0,00	0,18	2,42	21,93	837,79
5	PC	0,55	2-TecPlastics	12-PC	0,06	0,01	0,02	0,01	0,06	0,01	0,10	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,28
6	Steel sheet galvanized	126	3-Ferro	21-St sheet galv.	4,28	0,29	0,01	0,00	0,00	0,00	216,91	0,36	0,94	0,02	3,28	0,45	0,01	0,34	0,45	8,21
7	Al sheet / extrusion	14	4-Non-ferro	26-Al sheet/extrusion	2,70	0,00	0,00	0,00	0,00	0,00	54,88	0,14	0,94	0,00	0,07	0,05	1,35	0,24	0,49	0,07
8	Cu wire	222,2	4-Non-ferro	29-Cu wire	25,90	0,00	0,00	0,00	0,00	0,05	4446,67	1,38	64,91	0,00	0,83	12,23	1,20	0,63	20,91	34,33
9	Powder coating	6,03	5-Coating	39-powder coating	2,15	0,37	0,26	0,11	2,32	0,12	2,97	0,11	0,38	0,00	0,00	0,01	0,00	0,09	0,00	58,20
10	CRT screen m² (nominal screen size)	90,2	6-Electronics	43-CRT per m2 scrn	285,84	192,22	0,00	26,18	0,00	4,42	222,61	15,42	97,15	72,25	1,26	84,16	0,00	254,63	1,26	56,80
11	Big caps & coils	37,5	6-Electronics	44-big caps & coils	14,37	0,00	0,00	1,30	2,06	0,74	22,52	0,81	5,32	0,00	0,08	0,29	7,67	1,34	2,78	0,27
12	Slots / external ports	40	6-Electronics	45-slots / ext. ports	7,48	2,37	0,00	2,99	10,21	0,68	12,31	0,40	7,37	0,00	0,06	1,52	0,08	0,52	1,27	258,79
13	Integrated Circuits, 5 % Silicon, Au	17	6-Electronics	46-IC's avg., 5% Si, Au	93,66	91,09	0,00	85,29	0,00	4,28	88,08	7,20	47,38	1,15	0,83	7,59	0,25	1,24	63,58	365,18
14	Integrated Circuits, 1 % Silicon	13,5	6-Electronics	47-IC's avg., 1% Si	11,80	9,09	0,04	8,25	1,40	8,70	23,60	0,79	11,02	0,00	0,13	2,50	0,04	0,33	0,13	58,00
15	SMD & LEDs avg	12,5	6-Electronics	48-SMD/ LED's avg.	37,11	36,07	0,00	11,57	0,00	1,63	35,39	2,09	20,26	0,09	0,19	5,27	0,06	0,64	0,18	27,44
16	PWB 1/2 lay 3,75 kg/m²	96	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	26,98	14,45	0,82	16,32	7,37	166,39	252,03	1,08	20,52	0,22	0,26	3,47	0,34	0,49	1,42	353,90
17	PWB 6 lay 4,5 kg/m²	23,5	6-Electronics	50-PWB 6 lay 4.5 kg/m2	8,63	3,43	0,20	11,40	1,80	44,46	95,72	0,37	9,31	0,02	0,12	1,65	0,16	0,87	2,95	57,40
18	Solder SnAg4Cu0,5	11	6-Electronics	52-Solder SnAg4Cu0.5	2,57	2,13	0,00	0,77	0,00	0,05	2,51	0,13	0,71	0,00	0,01	0,04	0,02	0,02	0,00	0,07
19	Glass for lamps	6,5	7-Misc.	54-Glass for lamps	0,11	0,08	0,00	0,06	0,00	0,00	0,09	0,01	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00
20	Cardboard	1880	7-Misc.	56-Cardboard	52,64	3,76	30,08	13,25	0,00	0,09	98,36	1,32	1,95	0,00	0,02	0,06	0,01	0,02	0,02	161,80
21	Office paper	280	7-Misc.	57-Office paper	11,20	1,68	7,56	21,32	0,00	0,09	18,91	0,16	1,41	0,06	0,01	0,03	0,00	0,46	0,01	1480,75
22	Misc glass	11110	7-Misc.	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
23	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	0	824,00	377,05	145,61	223,72	444,52	258,14	5843,03	41,96	341,90	73,83	7,16	119,31	24,58	24,58	269,78	120,92

6.1.5 Thin client

The following table shows the materials needed to produce a thin client, type IGEL 3210 Compact. The data was recorded in January 2008. The total weight of the IGEL, including packaging, is 3.423 kg. The main proportion is the packaging, at 515 g (paper), followed by the »case base« and »case cover« (2 x 450 g ferrous metal) and the inner case at 436 g ferrous metal. The next heaviest component is the packaging cushion, made from 420 g cardboard, followed by the power cord, with 174 g copper wire, the power supply with 165 g electronics, the cradle, with 126.4 g ABS, the heatsink, with 124 g stainless steel and 112 g printed circuit board (PCB). The board is made from a 4-layer material which is 1.6 mm thick. It corresponds closest to the material »6lay Board 4.5 kg/m²«. All the other components weigh less than 100 g.

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Table 6-9: Composition of the IGEL 3210 LX Compact

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ECO-DESIGN OF ENERGY-USING PRODUCTS — EuP EcoReport: INPUTS — Assessment of Environmental Impact

Nr	Product name	Date	Author

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	M/B			
2	PCB	112,0	6-Electronics	50-PWB 6 lay 4.5 kg/m2
3	Conn CF	2,5	6-Electronics	45-slots / ext. ports
4	Socket DDR2	5,4	6-Electronics	45-slots / ext. ports
5	Socket BIOS	1,0	6-Electronics	45-slots / ext. ports
6	IC SI164	0,3	6-Electronics	47-IC's avg., 1% Si
7	IC VT1612A	1,0	6-Electronics	47-IC's avg., 1% Si
8	IC W83697	2,0	6-Electronics	47-IC's avg., 1% Si
9	IC ICS9P936AF	0,2	6-Electronics	47-IC's avg., 1% Si
10	IC TTL SN74LVC2G74	0,0	6-Electronics	47-IC's avg., 1% Si
11	IC TTL 74HC14	0,0	6-Electronics	47-IC's avg., 1% Si
12	IC TTL SN74AHC1G125DBVR	0,0	6-Electronics	47-IC's avg., 1% Si
13	IC UTL75232L	0,2	6-Electronics	47-IC's avg., 1% Si
14	IC CPU Eden 600MHz	2,0	6-Electronics	46-IC's avg., 5% Si, Au
15	IC NB	2,0	6-Electronics	46-IC's avg., 5% Si, Au
16	IC SB	2,0	6-Electronics	46-IC's avg., 5% Si, Au
17	IC PHY	1,0	6-Electronics	46-IC's avg., 5% Si, Au
18	IC ICS952906FT	0,7	6-Electronics	47-IC's avg., 1% Si
19	IC LM385BDR02.5	0,3	6-Electronics	47-IC's avg., 1% Si
20	IC PWM RT8214OS SOIC-8P	0,3	6-Electronics	47-IC's avg., 1% Si
21	IC PWM ISL9501CV	0,5	6-Electronics	47-IC's avg., 1% Si
22	IC Regulator	0,6	6-Electronics	47-IC's avg., 1% Si
23	IC others	0,0	6-Electronics	47-IC's avg., 1% Si
24	SMT AVR	8,9	6-Electronics	48-SMD/ LED's avg.
25	TRANS	0,1	6-Electronics	47-IC's avg., 1% Si
26	DIODE	0,5	6-Electronics	48-SMD/ LED's avg.
27	FUSE	0,1	6-Electronics	48-SMD/ LED's avg.
28	BEADS	0,5	6-Electronics	48-SMD/ LED's avg.
29	INDUCTOR	9,0	6-Electronics	44-big caps & coils
30	COMMON CHOKE	0,3	6-Electronics	48-SMD/ LED's avg.
31	CONNS	48,3	6-Electronics	45-slots / ext. ports
32	IC FLASH	1,1	6-Electronics	47-IC's avg., 1% Si
33	DIP CAPS	31,7	6-Electronics	44-big caps & coils
34	THERMISTERS	2,0	6-Electronics	48-SMD/ LED's avg.
35	CRYSTAL/OSC	2,0	6-Electronics	48-SMD/ LED's avg.
36	BUZZER	2,0	6-Electronics	45-slots / ext. ports
37	Battery	3,0	6-Electronics	44-big caps & coils
38	Card	13,2	6-Electronics	98-controller board
39	Solder SMT	3,2	6-Electronics	52-Solder SnAg4Cu0.5
40	Solder DIP	9,6	6-Electronics	52-Solder SnAg4Cu0.5
41				
Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
42	CASE base	450,0	3-Ferro	21-St sheet galv.
43	Case cover	450,0	3-Ferro	21-St sheet galv.
44	Power Supply	165	6-Electronics	98-controller board
45	Inner case	436	3-Ferro	21-St sheet galv.
46	Front panel	50,2	1-BlkPlastics	10-ABS
47	Cables	56,7	4-Non-ferro	28-Cu winding wire
48	Speaker	3,29	3-Ferro	24-Ferrite
49	Heatsink(AL)	124	3-Ferro	25-Stainless 18/8 coil
50	Insulator	7,01	1-BlkPlastics	10-ABS
51	Screws	20	3-Ferro	25-Stainless 18/8 coil
52	Rear panel	80	5-Coating	40-Cu/Ni/Cr plating
53	Rubber	3	2-TecPlastics	16-Flex PUR
54	Power cord	174	4-Non-ferro	28-Cu winding wire
55	Smart card reader	24	6-Electronics	98-controller board
56	Cables	1,6	4-Non-ferro	28-Cu winding wire
57	Cradle	126,4	1-BlkPlastics	10-ABS
58	Cradle rubber	0,7	2-TecPlastics	16-Flex PUR
59	Carton	23,46	7-Misc.	56-Cardboard
60	BOX	515	7-Misc.	56-Cardboard
61	BAG	13,4	1-BlkPlastics	1-LDPE
62	Cushion	420	7-Misc.	56-Cardboard
63	Paper/Labels	10	7-Misc.	57-Office paper

To estimate the environmental impact the data was transferred to the Excel table from the EuP study and the resulting values were calculated.

Gross energy requirement is approx. 0.7 GJ. This value is dominated by production of the coating for the rear panel with Cu/Ni/Cr.

255 liters of process water are consumed. This is caused mainly by production of the power supply.

During production, 0.36 kg of hazardous waste and 9.7 kg of »normal« waste are produced. The hazardous waste is produced mainly during production of the printed circuit board (PCB). The normal waste comes from production of the power cord and the coating for the rear panel.

37 kg CO_2eq of greenhouse gases are produced. This is caused mainly by production of the power unit and the coating for the rear panel.

Acidification potential is 427 g SO_2eq, caused mainly by the rear panel coating, the power supply and copper wire in the power cord.

Volatile organic compounds (VOC) are also dominated by emissions during manufacture of the power supply unit and make up 2.5 mg.

71 ng i-TEQ of persistent organic pollutants are produced, caused mainly by production of the rear panel coating.

Emissions of heavy metals are 1,623 mg Ni-eq, caused mainly by production of the rear panel coating.

Emissions of polycyclic aromatic compounds are 24 mg Ni-eq. This is caused mainly by production of the power supply unit.

According to the table, 24 g of particulate matter was produced. The rear panel coating is mainly responsible for this. In this calculation there was a **deviation**, as the individual emissions should add up to 22.7 g.

This deviation also exists in the water emissions. Here the corrected total is 144 mg Hg/20eq (mainly caused by: the power supply unit) and 10,153 mg PO_4eq for the eutrophication potential (mainly caused by: the rear panel coating).

It can be seen that the rear panel Cu/Ni/Cr coating has a very large influence on the result. These items should be reviewed[30].

[30] In discussions with the manufacturer it became clear that this solution was not planned originally. As a result of the implementation of WEEE and RoHS conformity within an existing product line the material used in the production phase had to be changed. The

Table 6-10: Environmental impact from the production of an Igel Compact; calculations according to MEEUP[31]

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Nr: 0 — Product: 0 — Date: 00.01.00 — Author: 0

MATERIALS EXTRACTION & PRODUCTION

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	material	GER	electr	feedst	water (proces	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	M/B	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2	PCB	112	6-Electronics	50-PWB 6 lay 4.5 kg/m2	41,12	16,37	0,96	54,33	8,60	211,88	456,21	1,76	44,35	0,11	0,57	7,85	0,77	4,15	14,05	273,59
3	Conn CF	2,48	6-Electronics	45-slots / ext. ports	0,46	0,15	0,00	0,19	0,63	0,04	0,76	0,02	0,46	0,00	0,00	0,09	0,00	0,03	0,08	16,04
4	Socket DDR2	5,4	6-Electronics	45-slots / ext. ports	1,01	0,32	0,00	0,40	1,38	0,09	1,66	0,05	1,00	0,00	0,01	0,21	0,01	0,07	0,17	34,94
5	Socket BIOS	1	6-Electronics	45-slots / ext. ports	0,19	0,06	0,00	0,07	0,26	0,02	0,31	0,01	0,18	0,00	0,00	0,04	0,00	0,01	0,03	6,47
6	IC SI164	0,25	6-Electronics	47-IC's avg., 1% Si	0,22	0,17	0,00	0,15	0,03	0,16	0,44	0,01	0,20	0,00	0,00	0,05	0,00	0,01	0,00	1,07
7	IC VT1612A	1	6-Electronics	47-IC's avg., 1% Si	0,87	0,67	0,00	0,61	0,10	0,64	1,75	0,06	0,82	0,00	0,01	0,19	0,00	0,02	0,01	4,30
8	IC W83697	2	6-Electronics	47-IC's avg., 1% Si	1,75	1,35	0,01	1,22	0,21	1,29	3,50	0,12	1,63	0,00	0,02	0,37	0,01	0,05	0,02	8,59
9	IC ICS9P936AF	0,22	6-Electronics	47-IC's avg., 1% Si	0,19	0,15	0,00	0,13	0,02	0,14	0,38	0,01	0,18	0,00	0,00	0,04	0,00	0,01	0,00	0,95
10	IC TTL SN74LVC2G74	0,0043	6-Electronics	47-IC's avg., 1% Si	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
11	IC TTL 74HC14	0,0043	6-Electronics	47-IC's avg., 1% Si	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
12	IC TTL SN74AHC1G125DBVR	0,0043	6-Electronics	47-IC's avg., 1% Si	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
13	IC UTL75232L	0,235	6-Electronics	47-IC's avg., 1% Si	0,21	0,16	0,00	0,14	0,02	0,15	0,41	0,01	0,19	0,00	0,00	0,04	0,00	0,01	0,00	1,01
14	IC CPU Eden 600MHz	2	6-Electronics	46-IC's avg., 5% Si, Au	11,02	10,72	0,00	10,03	0,00	0,50	10,36	0,85	5,57	0,14	0,10	0,89	0,03	0,15	7,48	42,96
15	IC NB	2	6-Electronics	46-IC's avg., 5% Si, Au	11,02	10,72	0,00	10,03	0,00	0,50	10,36	0,85	5,57	0,14	0,10	0,89	0,03	0,15	7,48	42,96
16	IC SB	2	6-Electronics	46-IC's avg., 5% Si, Au	11,02	10,72	0,00	10,03	0,00	0,50	10,36	0,85	5,57	0,14	0,10	0,89	0,03	0,15	7,48	42,96
17	IC PHY	1	6-Electronics	46-IC's avg., 5% Si, Au	5,51	5,36	0,00	5,02	0,00	0,25	5,18	0,42	2,79	0,07	0,05	0,45	0,01	0,07	3,74	21,48
18	IC ICS952906FT	0,721	6-Electronics	47-IC's avg., 1% Si	0,63	0,49	0,00	0,44	0,07	0,46	1,26	0,04	0,59	0,00	0,01	0,13	0,00	0,02	0,01	3,10
19	IC LM385BDR02.5	0,3	6-Electronics	47-IC's avg., 1% Si	0,26	0,20	0,00	0,18	0,03	0,19	0,52	0,02	0,24	0,00	0,00	0,06	0,00	0,01	0,00	1,29
20	IC PWM RT8214OS SOIC-8P	0,3	6-Electronics	47-IC's avg., 1% Si	0,26	0,20	0,00	0,18	0,03	0,19	0,52	0,02	0,24	0,00	0,00	0,06	0,00	0,01	0,00	1,29
21	IC PWM ISL9501CV	0,5	6-Electronics	47-IC's avg., 1% Si	0,44	0,34	0,00	0,31	0,05	0,32	0,87	0,03	0,41	0,00	0,00	0,09	0,00	0,01	0,00	2,15
22	IC Regulator	0,609	6-Electronics	47-IC's avg., 1% Si	0,53	0,41	0,00	0,37	0,06	0,39	1,06	0,04	0,50	0,00	0,01	0,11	0,00	0,01	0,01	2,62
23	IC others	0,02	6-Electronics	47-IC's avg., 1% Si	0,02	0,01	0,00	0,01	0,00	0,01	0,03	0,00	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,09
24	SMT AVR	8,944	6-Electronics	48-SMD/ LED's avg.	26,55	25,81	0,00	8,28	0,00	1,17	25,32	1,49	14,49	0,07	0,13	3,77	0,04	0,45	0,13	19,64
25	TRANS	0,054	6-Electronics	47-IC's avg., 1% Si	0,05	0,04	0,00	0,03	0,01	0,03	0,09	0,00	0,04	0,00	0,00	0,01	0,00	0,00	0,00	0,23
26	DIODE	0,465	6-Electronics	48-SMD/ LED's avg.	1,38	1,34	0,00	0,43	0,00	0,06	1,32	0,08	0,75	0,00	0,01	0,20	0,00	0,02	0,01	1,02
27	FUSE	0,0672	6-Electronics	48-SMD/ LED's avg.	0,20	0,19	0,00	0,06	0,00	0,01	0,19	0,01	0,11	0,00	0,00	0,03	0,00	0,00	0,00	0,15
28	BEADS	0,47	6-Electronics	48-SMD/ LED's avg.	1,40	1,36	0,00	0,43	0,00	0,06	1,33	0,08	0,76	0,00	0,01	0,20	0,00	0,02	0,01	1,03
29	INDUCTOR	9,03	6-Electronics	44-big caps & coils	3,46	0,00	0,00	0,31	0,50	0,18	5,42	0,20	1,28	0,00	0,02	0,07	1,85	0,32	0,67	0,06
30	COMMON CHOKE	0,25	6-Electronics	48-SMD/ LED's avg.	0,74	0,72	0,00	0,23	0,00	0,03	0,71	0,04	0,41	0,00	0,00	0,11	0,00	0,01	0,00	0,55
31	CONNS	48,3	6-Electronics	45-slots / ext. ports	9,04	2,86	0,00	3,61	12,33	0,83	14,86	0,48	8,90	0,00	0,07	1,84	0,09	0,63	1,54	312,49
32	IC FLASH	1,145	6-Electronics	47-IC's avg., 1% Si	1,00	0,77	0,00	0,70	0,12	0,74	2,00	0,07	0,93	0,00	0,01	0,21	0,00	0,03	0,01	4,92
33	DIP CAPS	31,65	6-Electronics	44-big caps & coils	12,13	0,00	0,00	1,10	1,74	0,62	19,01	0,69	4,49	0,00	0,07	0,24	6,48	1,13	2,35	0,23
34	THERMISTERS	2	6-Electronics	48-SMD/ LED's avg.	5,94	5,77	0,00	1,85	0,00	0,26	5,66	0,33	3,24	0,01	0,03	0,84	0,01	0,10	0,03	4,39
35	CRYSTAL/OSC	2	6-Electronics	48-SMD/ LED's avg.	5,94	5,77	0,00	1,85	0,00	0,26	5,66	0,33	3,24	0,01	0,03	0,84	0,01	0,10	0,03	4,39
36	BUZZER	2	6-Electronics	45-slots / ext. ports	0,37	0,12	0,00	0,15	0,51	0,03	0,62	0,02	0,37	0,00	0,00	0,08	0,00	0,03	0,06	12,94
37	Battery	3	6-Electronics	44-big caps & coils	1,15	0,00	0,00	0,10	0,17	0,06	1,80	0,07	0,43	0,00	0,01	0,02	0,61	0,11	0,22	0,02
38	Card	13,2	6-Electronics	98-controller board	10,32	7,65	0,04	6,91	1,39	8,61	22,17	0,68	5,77	0,09	0,08	0,97	0,80	0,30	4,40	62,07
39	Solder SMT	3,17	6-Electronics	52-Solder SnAg4Cu0.5	0,74	0,61	0,00	0,22	0,00	0,01	0,72	0,04	0,20	0,00	0,00	0,01	0,01	0,00	0,00	0,02
40	Solder DIP	9,6	6-Electronics	52-Solder SnAg4Cu0.5	2,25	1,86	0,00	0,67	0,00	0,04	2,19	0,11	0,62	0,00	0,01	0,03	0,02	0,01	0,00	0,06
41	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
42	CASE base	450	3-Ferro	21-St sheet galv.	15,30	1,03	0,03	0,00	0,00	0,00	774,68	1,27	3,36	0,06	11,70	1,60	0,03	1,22	1,60	29,33
43	Case cover	450	3-Ferro	21-St sheet galv.	15,30	1,03	0,03	0,00	0,00	0,00	774,68	1,27	3,36	0,06	11,70	1,60	0,03	1,22	1,60	29,33
44	Power Supply	165	6-Electronics	98-controller board	128,94	95,61	0,50	86,35	17,43	107,65	277,14	8,50	72,16	1,06	1,05	12,12	9,96	3,70	55,00	775,85
45	Inner case	436	3-Ferro	21-St sheet galv.	14,82	0,99	0,03	0,00	0,00	0,00	750,58	1,23	3,25	0,06	11,34	1,55	0,03	1,18	1,55	28,41
46	Front panel	50,2	1-BlkPlastics	10-ABS	4,77	0,35	2,30	0,47	8,28	0,50	4,61	0,17	0,89	0,00	0,00	0,00	0,09	0,15	0,10	31,62
47	Cables	56,7	4-Non-ferro	28-Cu winding wire	8,09	0,00	0,00	0,00	0,00	0,05	1136,27	0,42	17,23	0,00	0,23	3,20	0,31	0,17	0,37	8,97
48	Speaker	3,29	3-Ferro	24-Ferrite	0,17	0,01	0,00	0,13	0,00	0,00	8,50	0,01	0,04	0,00	0,13	0,12	0,00	0,01	0,01	0,26
49	Heatsink(AL)	124	3-Ferro	25-Stainless 18/8 coil	7,69	1,20	0,50	9,39	1,05	0,00	124,00	0,77	6,95	0,02	0,95	18,39	0,00	0,98	10,71	288,66
50	Insulator	7,01	1-BlkPlastics	10-ABS	0,67	0,05	0,32	0,07	1,16	0,07	0,64	0,02	0,12	0,00	0,00	0,00	0,01	0,02	0,01	4,42
51	Screws	20	3-Ferro	25-Stainless 18/8 coil	1,24	0,19	0,08	1,51	0,17	0,00	20,00	0,12	1,12	0,00	0,15	2,97	0,00	0,16	1,73	46,56
52	Rear panel	80	5-Coating	40-Cu/Ni/Cr plating	220,72	206,71	0,00	14,96	139,36	4,65	1600,00	9,97	134,07	0,25	31,72	1548,00	0,40	4,23	12,24	7600,35
53	Rubber	3	2-TecPlastics	16-Flex PUR	0,31	0,06	0,12	0,21	0,89	0,10	1,65	0,01	0,10	0,00	0,00	0,00	0,06	0,02	0,01	17,06
54	Power cord	174	4-Non-ferro	28-Cu winding wire	24,83	0,00	0,00	0,00	0,00	0,14	3486,96	1,28	52,87	0,01	0,69	9,83	0,96	0,53	1,13	27,53
55	Smart card reader	24	6-Electronics	98-controller board	18,76	13,91	0,07	12,56	2,54	15,66	40,31	1,24	10,50	0,15	0,15	1,76	1,45	0,54	8,00	112,85
56	Cables	1,6	4-Non-ferro	28-Cu winding wire	0,23	0,00	0,00	0,00	0,00	0,00	32,06	0,01	0,49	0,00	0,01	0,09	0,01	0,00	0,01	0,25
57	Cradle	126,4	1-BlkPlastics	10-ABS	12,01	0,88	5,79	1,18	20,86	1,26	11,62	0,42	2,25	0,00	0,00	0,00	0,23	0,37	0,25	79,61
58	Cradle rubber	0,7	2-TecPlastics	16-Flex PUR	0,07	0,01	0,03	0,05	0,21	0,02	0,38	0,00	0,02	0,00	0,00	0,00	0,01	0,01	0,00	3,98
59	Carton	23,46	7-Misc.	56-Cardboard	0,66	0,05	0,38	0,17	0,00	0,00	1,23	0,02	0,02	0,00	0,00	0,00	0,00	0,00	0,00	2,02
60	BOX	515	7-Misc.	56-Cardboard	14,42	1,03	8,24	3,63	0,00	0,02	26,94	0,36	0,54	0,00	0,01	0,02	0,00	0,01	0,01	44,32
61	BAG	13,4	1-BlkPlastics	1-LDPE	1,04	0,18	0,69	0,04	0,60	0,06	0,59	0,03	0,10	0,01	0,00	0,00	0,00	0,01	0,00	0,36
62	Cushion	420	7-Misc.	56-Cardboard	11,76	0,84	6,72	2,96	0,00	0,02	21,97	0,29	0,44	0,00	0,01	0,01	0,00	0,00	0,01	36,15
63	Paper/Labels	10	7-Misc.	57-Office paper	0,40	0,06	0,27	0,76	0,00	0,00	0,68	0,01	0,05	0,00	0,00	0,00	0,00	0,02	0,00	52,88
64	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	10152,87	671,60	437,62	27,12	255,26	220,82	360,99	9710,58	37,33	426,50	2,48	71,31	1623,18	24,44	24,44	22,73	144,34

rear panel coating in this composition was a reasonable solution to continue to comply with electtromagnetic limit values and, at the same time, fulfill the requirements of WEEE and RoHS. In the new client models this component has been replaced by other materials and the environmental impact is thus less.

6.1.6 Pro rata calculation of the terminal server

Unfortunately, no servers were analyzed in the underlying studies. In order to calculate the pro rata server requirement for thin client operation, we used the office PC composition (cf. Table 7-1) and multiplied this by 1.5, as the server is more powerful. The **1.5** factor comes from comparing the weight of a server (approx. 16 kg) with a standard PC (8.5-12.9 kg) (cf. [UMSICHT, 2006], Table 6).

The values calculated in this way are then divided by **35**, as approx. 35 »medium user« thin clients can be operated with one server. This figure is then added to every thin client.

Table 6-11: Composition of a PC server (adjusted table 59 from IVF, 2007])

	ECO-DESIGN OF ENERGY-USING PRODUCTS		EuP EcoReport: INPUTS Assessment of Environmental Impact	
Nr	Product name Office Desktop PC		Date 2008-Feb-06	Author Ubertrag Anhang 2 EuP-Studie Anpassung Servergewicht *1,5
Pos nr	**MATERIALS Extraction & Production** **Description of component**	**Weight in g**	**Category** **Click &select**	**Material or Process** **select Category first !**
1	LDPE	10,5	1-BlkPlastics	**1-LDPE**
2	ABS	16,3	1-BlkPlastics	**10-ABS**
3	PA 6	5,9	2-TecPlastics	**11-PA 6**
4	PC	11,3	2-TecPlastics	**12-PC**
5	Epoxy	4,2	2-TecPlastics	**14-Epoxy**
6	Flex PUR	0,1	2-TecPlastics	**16-Flex PUR**
7	Steel sheet galvanized	270,5	3-Ferro	**21-St sheet galv.**
8	Steel tube / profile	4,6	3-Ferro	**22-St tube/profile**
9	Cast iron	20,7	3-Ferro	**23-Cast iron**
10	Ferrite	0,0	3-Ferro	**24-Ferrite**
11	Stainless 18/8 coil	0,4	3-Ferro	**25-Stainless 18/8 coil**
12	Al sheet/ extrusion	13,5	4-Non-ferro	**26-Al sheet/extrusion**
13	Al diecast	0,6	4-Non-ferro	**27-Al diecast**
14	Cu winding wire	11,0	4-Non-ferro	**28-Cu winding wire**
15	Cu wire	14,3	4-Non-ferro	**29-Cu wire**
16	Cu tube/sheet	2,9	4-Non-ferro	**30-Cu tube/sheet**
17	Powder coating	0,1	5-Coating	**39-powder coating**
18	Big caps & coils	20,7	6-Electronics	**44-big caps & coils**
19	Slots / ext. Ports	13,3	6-Electronics	**45-slots / ext. ports**
20	Integrated Circuits, 5% Silicon, Au	3,0	6-Electronics	**46-IC's avg., 5% Si, Au**
21	Integrated Circuits, 1% Silicon	4,1	6-Electronics	**47-IC's avg., 1% Si**
22	SMD & LEDs avg.	8,3	6-Electronics	**48-SMD/ LED's avg.**
23	PWB 1/2 lay 3,75 kg/m²	3,3	6-Electronics	**49-PWB 1/2 lay 3.75kg/m2**
24	PWB 6 lay 4,5 kg/m²	7,0	6-Electronics	**50-PWB 6 lay 4.5 kg/m2**
25	Solder SnAg4Cu0,5	2,1	6-Electronics	**52-Solder SnAg4Cu0.5**
26	Cardboard	98,0	7-Misc.	**56-Cardboard**
27				

The environmental impact here is similar to the environmental impact of the desktop PC (corrected by a factor of 1.5/35). For the sake of illustration, the values of the server proportion and of the thin client were added together and recalculated. This produced the following result.

Table 6-12: Pro-rata environmental impact from the production of a server for thin clients; calculations according to MEEUP[32]

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS — EuP EcoReport: RAW OUTPUTS — Assessment of Environmental Impact

Nr: 0 — Product: Office Desktop PC — Date: 2008-Feb-06 — Author: Übertrag Anhang 2 EuP-

MATERIALS EXTRACTION & PRODUCTION

nr	Product: component	wght in g	cat.	material	Energy: GER MJ	Energy: electr MJ	Energy: feedst MJ	Water: water (proces ltr.	Water: water (cool) ltr.	Waste: haz. Waste g	Waste: non-haz. Waste g	Emissions to Air: GWP kg CO2eq	AD g SO2eq	VOC mg	POP ng i-Teq	HM mg Ni eq	PAH mg Ni eq	PM g	to Water: Metal mg Hg/20eq	EUP mg PO4 eq
1	LDPE	10,543	1-BlkPlastics	1-LDPE	0,82	0,14	0,54	0,03	0,47	0,05	0,47	0,02	0,08	0,01	0,00	0,00	0,00	0,01	0,00	0,28
2	ABS	16,318	1-BlkPlastics	10-ABS	1,55	0,11	0,75	0,15	2,69	0,16	1,50	0,05	0,29	0,00	0,00	0,00	0,03	0,05	0,03	10,28
3	PA 6	5,9006	2-TecPlastics	11-PA 6	0,71	0,09	0,23	0,09	1,29	0,11	1,04	0,05	0,23	0,00	0,00	0,00	0,00	0,03	0,29	11,05
4	PC	11,325	2-TecPlastics	12-PC	1,32	0,17	0,43	0,16	1,29	0,11	2,00	0,06	0,29	0,00	0,00	0,00	0,00	0,08	0,00	5,71
5	Epoxy	4,1957	2-TecPlastics	14-Epoxy	0,59	0,10	0,18	0,08	1,61	0,08	1,71	0,03	0,18	0,00	0,00	0,00	0,00	0,06	0,00	40,49
6	Flex PUR	0,0643	2-TecPlastics	16-Flex PUR	0,01	0,00	0,00	0,00	0,02	0,00	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,37
7	Steel sheet galvanized	270,53	3-Ferro	21-St sheet galv.	9,20	0,62	0,02	0,00	0,00	0,00	465,72	0,76	2,02	0,04	7,03	0,96	0,02	0,73	0,96	17,63
8	Steel tube / profile	4,5643	3-Ferro	22-St tube/profile	0,08	0,02	0,00	0,00	0,00	0,00	3,65	0,01	0,02	0,00	0,05	0,01	0,00	0,00	0,01	0,17
9	Cast iron	20,679	3-Ferro	23-Cast iron	0,21	0,00	0,00	0,03	0,08	0,00	6,52	0,02	0,07	0,00	0,12	0,04	0,00	0,29	0,02	0,54
10	Ferrite	0	3-Ferro	24-Ferrite	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
11	Stainless 18/8 coil	0,4071	3-Ferro	25-Stainless 18/8 coil	0,03	0,00	0,00	0,03	0,00	0,00	0,41	0,00	0,02	0,00	0,00	0,06	0,00	0,00	0,04	0,95
12	Al sheet/ extrusion	13,48	4-Non-ferro	26-Al sheet/extrusion	2,60	0,00	0,00	0,00	0,00	0,00	52,84	0,14	0,91	0,00	0,07	0,05	1,30	0,23	0,47	0,07
13	Al diecast	0,6429	4-Non-ferro	27-Al diecast	0,04	0,00	0,00	0,00	0,00	0,00	0,48	0,00	0,01	0,00	0,02	0,00	0,01	0,00	0,00	0,00
14	Cu winding wire	11,014	4-Non-ferro	28-Cu winding wire	1,57	0,00	0,00	0,00	0,00	0,01	220,73	0,08	3,35	0,00	0,04	0,62	0,06	0,03	0,07	1,74
15	Cu wire	14,293	4-Non-ferro	29-Cu wire	1,67	0,00	0,00	0,00	0,00	0,00	286,03	0,09	4,17	0,00	0,05	0,79	0,08	0,04	1,34	2,21
16	Cu tube/sheet	2,85	4-Non-ferro	30-Cu tube/sheet	0,15	0,00	0,00	0,00	0,00	0,00	22,84	0,01	0,18	0,00	0,03	0,09	0,02	0,00	0,11	0,18
17	Powder coating	0,0694	5-Coating	39-powder coating	0,02	0,00	0,00	0,00	0,03	0,00	0,03	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,67
18	Big caps & coils	20,679	6-Electronics	44-big caps & coils	7,93	0,00	0,00	0,72	1,14	0,41	12,42	0,45	2,93	0,00	0,04	0,16	4,23	0,74	1,53	0,15
19	Slots / ext. Ports	13,286	6-Electronics	45-slots / ext. ports	2,49	0,79	0,00	0,99	3,39	0,23	4,09	0,13	2,45	0,00	0,02	0,50	0,03	0,17	0,42	85,95
20	Integrated Circuits, 5% Silicon, Au	2,9571	6-Electronics	46-IC's avg., 5% Si, Au	16,29	15,85	0,00	14,84	0,00	0,74	15,32	1,25	8,24	0,20	0,14	1,32	0,04	0,22	11,06	63,52
21	Integrated Circuits, 1% Silicon	4,0929	6-Electronics	47-IC's avg., 1% Si	3,58	2,76	0,01	2,50	0,42	2,64	7,16	0,24	3,34	0,00	0,04	0,76	0,01	0,10	0,04	17,58
22	SMD & LEDs avg.	8,2929	6-Electronics	48-SMD/ LED's avg.	24,62	23,93	0,00	7,67	0,00	1,08	23,48	1,38	13,44	0,06	0,12	3,50	0,04	0,42	0,12	18,21
23	PWB 1/2 lay 3,75 kg/m²	3,3429	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	0,94	0,50	0,03	0,57	0,26	5,79	8,78	0,04	0,71	0,01	0,01	0,12	0,01	0,02	0,05	12,32
24	PWB 6 lay 4,5 kg/m²	6,9643	6-Electronics	50-PWB 6 lay 4.5 kg/m2	2,56	1,02	0,06	3,38	0,53	13,17	28,37	0,11	2,76	0,01	0,04	0,49	0,05	0,26	0,87	17,01
25	Solder SnAg4Cu0,5	2,0571	6-Electronics	52-Solder SnAg4Cu0.5	0,48	0,40	0,00	0,14	0,00	0,01	0,47	0,02	0,13	0,00	0,00	0,01	0,00	0,00	0,00	0,01
26	Cardboard	97,993	7-Misc.	56-Cardboard	2,74	0,20	1,57	0,69	0,00	0,00	5,13	0,07	0,10	0,00	0,00	0,00	0,00	0,00	0,00	8,43
	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	0	82,17	46,70	3,82	32,08	13,23	24,61	1171,20	5,03	45,93	0,33	7,85	9,48	5,94	5,94	3,49	17,45

6.2 Manufacturing phase

The materials listed in Section 6.1 still have to be added. This requires further energy, which is calculated with specified values according to the MEEUP method. The only parameter that can be varied is the proportion of ferrous scrap. However, this was left at 25 %.

6.2.1 Desktop PC

The following table shows emissions during the manufacturing phase for desktop PCs. The most environmentally intensive step is assembling the printed circuit boards which are then installed in the computers. Final assembly is included in the distribution phase.

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Table 6-13: Manufacturing phase for a desktop PC (according to Annex 2 EuP study)

MANUFACTURING	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	1128,1	0	20	46,08	27,74	1,59	0,42	13,09	0,00	144,39	2,56	11,02	0,00	0,00	0,00	0,01	1,70	0,00	26,94
202	Foundries Fe/Cu/Zn (fixed)	482,5	0	34	1,06	0,64	0,04	0,01	0,30	0,00	3,32	0,06	0,25	0,00	0,00	0,00	0,00	0,04	0,00	0,62
203	Foundries Al/Mg (fixed)	15	0	35	0,10	0,06	0,00	0,00	0,03	0,00	0,31	0,01	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,06
204	Sheetmetal Manufacturing (fixed)	6702,8	0	36	101,41	61,05	3,49	0,92	28,80	0,00	317,76	5,63	24,26	0,01	0,00	0,00	0,00	3,74	0,00	40,01
205	PWB Manufacturing (fixed)	1343,5	0	53	172,62	4,31	6,41	15,83	48,04	5,67	143,47	11,45	65,83	4,17	0,13	1,18	3,47	20,20	0,57	952,83
206	Other materials (Manufacturing already in	3080,6	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	1675,7	0,25	37	20,07	8,23	0,03	0,00	0,00	0,10	301,91	1,34	6,01	0,15	18,04	42,27	0,01	0,86	0,02	0,38
	TOTAL	12753			341,34	102,02	11,57	17,18	90,26	5,78	911,17	21,04	107,41	4,33	18,17	43,44	3,50	26,55	0,60	1020,84

6.2.2 Notebook

The following table shows the emissions during the manufacturing phase of a notebook. The most environmentally intensive step is assembly of the printed circuit boards.

Table 6-14: Manufacturing phase, notebook (according to Annex 2 EuP study)

MANUFACTURING	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	851,8	0	20	34,80	20,95	1,20	0,32	9,88	0,00	109,03	1,93	8,32	0,00	0,00	0,00	0,01	1,28	0,00	20,34
202	Foundries Fe/Cu/Zn (fixed)	0	0	34	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
203	Foundries Al/Mg (fixed)	121,67	0	35	0,79	0,48	0,03	0,01	0,22	0,00	2,48	0,04	0,19	0,00	0,00	0,00	0,00	0,03	0,00	0,46
204	Sheetmetal Manufacturing (fixed)	542,33	0	36	8,21	4,94	0,28	0,07	2,33	0,00	25,71	0,46	1,96	0,00	0,00	0,00	0,00	0,30	0,00	3,24
205	PWB Manufacturing (fixed)	800,56	0	53	102,86	2,57	3,82	9,43	28,63	3,38	85,49	6,82	39,23	2,48	0,08	0,70	2,07	12,04	0,34	567,77
206	Other materials (Manufacturing already in	1462,2	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	135,58	0,25	37	1,62	0,67	0,00	0,00	0,00	0,01	24,43	0,11	0,49	0,01	1,46	3,42	0,00	0,07	0,00	0,03
	TOTAL	3778,6			148,28	29,60	5,33	9,83	41,06	3,39	247,14	9,36	50,19	2,50	1,54	4,12	2,08	13,72	0,34	591,84

6.2.3 LCD monitor 17"

The following table shows the emissions during the manufacturing phase of an LCD monitor. The most environmentally intensive steps are assembly of the printed circuit boards, the plastics and the metal materials.

Table 6-15: Manufacturing phase, 17" LCD monitor (according to Annex 2, EuP study)

MANUFACTURING	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	2250,7	0	20	91,94	55,35	3,17	0,83	26,11	0,00	288,09	5,10	21,99	0,01	0,00	0,00	0,03	3,39	0,00	53,74
202	Foundries Fe/Cu/Zn (fixed)	1165	0	34	2,56	1,54	0,09	0,02	0,73	0,00	8,02	0,14	0,61	0,00	0,00	0,00	0,00	0,09	0,00	1,50
203	Foundries Al/Mg (fixed)	0	0	35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
204	Sheetmetal Manufacturing (fixed)	1893	0	36	28,64	17,24	0,99	0,26	8,13	0,00	89,74	1,59	6,85	0,00	0,00	0,00	0,00	1,06	0,00	11,30
205	PWB Manufacturing (fixed)	158,6	0	53	20,38	0,51	0,76	1,87	5,67	0,67	16,94	1,35	7,77	0,49	0,02	0,14	0,41	2,38	0,07	112,48
206	Other materials (Manufacturing already in	1340,4	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	473,25	0,25	37	5,67	2,32	0,01	0,00	0,00	0,03	85,26	0,38	1,70	0,04	5,10	11,94	0,00	0,24	0,01	0,11
	TOTAL	6807,7			149,18	76,96	5,01	2,98	40,64	0,70	488,04	8,56	38,93	0,54	5,11	12,08	0,44	7,17	0,07	179,13

6.2.4 CRT monitor 17"

The following table shows the emissions during the manufacturing phase of a CRT monitor. The most environmentally intensive steps are assembly of the printed circuit boards and the plastics.

Table 6-16: Manufacturing phase, 17″ CRT monitor (according to Annex 2, EuP study)

MANUFACTURING	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	2411,6	0	20	98,52	59,31	3,39	0,89	27,97	0,00	308,69	5,47	23,57	0,01	0,00	0,00	0,03	3,63	0,00	57,59
202	Foundries Fe/Cu/Zn (fixed)	0	0	34	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
203	Foundries Al/Mg (fixed)	0	0	35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
204	Sheetmetal Manufacturing (fixed)	140	0	36	2,12	1,28	0,07	0,02	0,60	0,00	6,64	0,12	0,51	0,00	0,00	0,00	0,00	0,08	0,00	0,84
205	PWB Manufacturing (fixed)	237,5	0	53	30,52	0,76	1,13	2,80	8,49	1,00	25,36	2,02	11,64	0,74	0,02	0,21	0,61	3,57	0,10	168,44
206	Other materials (Manufacturing already in	13608	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	35	0,25	37	0,42	0,17	0,00	0,00	0,00	0,00	6,31	0,03	0,13	0,00	0,38	0,88	0,00	0,02	0,00	0,01
	TOTAL	16398			131,57	61,52	4,60	3,71	37,07	1,01	346,99	7,64	35,84	0,75	0,40	1,09	0,64	7,30	0,10	226,87

6.2.5 Thin client

The following table shows the emissions during the manufacturing phase of an IGEL 3210 Compact. The most environmentally intensive steps are assembly of the printed circuit boards and processing the metal materials.

Table 6-17: Manufacturing phase, IGEL 3210 Compact (calculated according to MEEUP)

MANUFACTURING	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	200,71	0	20	8,20	4,94	0,28	0,07	2,33	0,00	25,69	0,45	1,96	0,00	0,00	0,00	0,00	0,30	0,00	4,79
202	Foundries Fe/Cu/Zn (fixed)	0	0	34	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
203	Foundries Al/Mg (fixed)	0	0	35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
204	Sheetmetal Manufacturing (fixed)	1483,3	0	36	22,44	13,51	0,77	0,20	6,37	0,00	70,32	1,25	5,37	0,00	0,00	0,00	0,00	0,83	0,00	8,85
205	PWB Manufacturing (fixed)	248,83	0	53	31,97	0,80	1,19	2,93	8,90	1,05	26,57	2,12	12,19	0,77	0,02	0,22	0,64	3,74	0,11	176,47
206	Other materials (Manufacturing already in	1490,3	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	370,82	0,25	37	4,44	1,82	0,01	0,00	0,00	0,02	66,81	0,30	1,33	0,03	3,99	9,35	0,00	0,19	0,00	0,08
	TOTAL	3423,2			67,05	21,06	2,25	3,21	17,60	1,07	189,39	4,12	20,85	0,81	4,02	9,57	0,65	5,06	0,11	190,20

6.2.6 Pro rata calculation of the terminal server

The values correspond to those of the office desktop PC with a correction factor of 1.5/35.

Table 6-18: Pro rata environmental impact; manufacturing phase of a server (calculated according to MEEUP)

MANUFACTURING	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	48,346	0	20	1,97	1,19	0,07	0,02	0,56	0,00	6,19	0,11	0,47	0,00	0,00	0,00	0,00	0,07	0,00	1,15
202	Foundries Fe/Cu/Zn (fixed)	20,679	0	34	0,05	0,03	0,00	0,00	0,01	0,00	0,14	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,03
203	Foundries Al/Mg (fixed)	0,6429	0	35	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
204	Sheetmetal Manufacturing (fixed)	287,26	0	36	4,35	2,62	0,15	0,04	1,23	0,00	13,62	0,24	1,04	0,00	0,00	0,00	0,00	0,16	0,00	1,71
205	PWB Manufacturing (fixed)	57,579	0	53	7,40	0,18	0,27	0,68	2,06	0,24	6,15	0,49	2,82	0,18	0,01	0,05	0,15	0,87	0,02	40,84
206	Other materials (Manufacturing already in	132,03	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	71,816	0,25	37	0,86	0,35	0,00	0,00	0,00	0,00	12,94	0,06	0,26	0,01	0,77	1,81	0,00	0,04	0,00	0,02
	TOTAL	546,54			14,63	4,37	0,50	0,74	3,87	0,25	39,05	0,90	4,60	0,19	0,78	1,86	0,15	1,14	0,03	43,75

6.3 Distribution phase

For the distribution phase it is assumed that the environmental impact is proportional to the volume of the end product. The volumes were taken from a previous study [UMSICHT, 2006]. The second factor, which MEEUP includes in the distribution phase is final assembly.

From these values the emissions for the transportation routes are generated automatically in the Excel table created by VHK [MEEUP, 2005].

6.3.1 Desktop PC

A desktop PC with a packaged volume of 0.0783 m³ produces the emissions listed in the table below.

Table 6-19: Distribution phase for a desktop PC (according to MEEUP calculation)

DISTRIBUTION

	Product					Energy			Water		Waste		Emissions to Air							to Water	
nr			cat.	NDX		GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
						MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
				61	0	51,50	0,00	0,00	0,00	0,00	1,02	51,36	4,52	12,00	0,05	0,29	2,62	2,62	0,26	0,08	1,36
208	Is it an ICT or Consumer Electronics product <15 I		YES	59	1	231,94	0,22	2,22	0,00	0,00	2,05	103,21	18,12	63,50	3,08	0,58	5,25	3,35	70,75	0,16	2,74
209	Is it an installed appliance (e.g. boiler)?		NO	60	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				62	1	39,12	0,00	0,00	0,00	0,00	0,50	25,23	2,30	6,58	0,39	0,14	1,29	0,67	16,81	0,04	0,67
210	Volume of packaged final product in m3	in m3	0,0783	63	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				64	1	4,62	0,00	0,00	0,00	0,00	0,09	4,29	0,32	1,02	0,00	0,02	0,22	0,01	0,02	0,01	0,11
	TOTAL					327,18	0,22	2,22	0,00	0,00	3,66	184,09	25,25	83,10	3,52	1,04	9,37	6,65	87,85	0,29	4,89

6.3.2 Notebook

The notebook has a packaged volume of 40 cm x 38 cm x 20 cm or 0.0304 m³.

Table 6-20: Distribution phase, notebook (according to MEEUP calculation)

DISTRIBUTION

	Product					Energy			Water		Waste		Emissions to Air							to Water	
nr			cat.	NDX		GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
						MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
				61	0	51,50	0,00	0,00	0,00	0,00	1,02	51,36	4,52	12,00	0,05	0,29	2,62	2,62	0,26	0,08	1,36
208	Is it an ICT or Consumer Electronics product <15 I		YES	59	1	90,05	0,09	0,86	0,00	0,00	0,80	40,07	7,03	24,65	1,19	0,23	2,04	1,30	27,47	0,06	1,06
209	Is it an installed appliance (e.g. boiler)?		NO	60	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				62	1	15,19	0,00	0,00	0,00	0,00	0,19	9,80	0,89	2,55	0,15	0,06	0,50	0,26	6,53	0,02	0,26
210	Volume of packaged final product in m3	in m3	0,0304	63	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				64	1	1,79	0,00	0,00	0,00	0,00	0,03	1,67	0,12	0,40	0,00	0,01	0,08	0,00	0,01	0,00	0,04
	TOTAL					158,53	0,09	0,86	0,00	0,00	2,04	102,89	12,57	39,60	1,40	0,58	5,24	4,18	34,26	0,16	2,73

6.3.3 LCD monitor 17"

The 17" LCD monitor has a packaged volume of 45 cm x 43 cm x 13 cm or 0.0252 m³.

Table 6-21: Distribution phase, 17" LCD monitor (according to MEEUP calculation)

DISTRIBUTION

	Product					Energy			Water		Waste		Emissions to Air							to Water	
nr			cat.	NDX		GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
						MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
				61	0	51,50	0,00	0,00	0,00	0,00	1,02	51,36	4,52	12,00	0,05	0,29	2,62	2,62	0,26	0,08	1,36
208	Is it an ICT or Consumer Electronics product <15 I		YES	59	1	74,65	0,07	0,72	0,00	0,00	0,66	33,22	5,83	20,44	0,99	0,19	1,69	1,08	22,77	0,05	0,88
209	Is it an installed appliance (e.g. boiler)?		NO	60	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				62	1	12,59	0,00	0,00	0,00	0,00	0,16	8,12	0,74	2,12	0,13	0,05	0,41	0,21	5,41	0,01	0,22
210	Volume of packaged final product in m3	in m3	0,0252	63	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				64	1	1,49	0,00	0,00	0,00	0,00	0,03	1,38	0,10	0,33	0,00	0,01	0,07	0,00	0,01	0,00	0,04
	TOTAL					140,22	0,07	0,72	0,00	0,00	1,87	94,08	11,20	34,88	1,17	0,53	4,79	3,91	28,45	0,15	2,50

6.3.4 CRT monitor 17"

The 17" CRT monitor has a packaged volume of 58 cm x 48 cm x 45 cm or 0.125 m³.

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Table 6-22: Distribution phase 17" CRT monitor (according to MEEUP calculation)

DISTRIBUTION	Product					Energy			Water		Waste		Emissions to Air							to Water	
nr			cat.	NDX		GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
						MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
				61	0	51,50	0,00	0,00	0,00	0,00	1,02	51,36	4,52	12,00	0,05	0,29	2,62	2,62	0,26	0,08	1,36
208	Is it an ICT or Consumer Electronics product <15		YES	59	1	370,28	0,35	3,55	0,00	0,00	3,27	164,76	28,92	101,38	4,91	0,93	8,38	5,36	112,95	0,26	4,38
209	Is it an installed appliance (e.g. boiler)?		NO	60	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				62	1	62,45	0,00	0,00	0,00	0,00	0,80	40,28	3,66	10,50	0,63	0,23	2,05	1,06	26,84	0,06	1,07
210	Volume of packaged final product in m3	in m3	0,125	63	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				64	1	7,37	0,00	0,00	0,00	0,00	0,14	6,85	0,50	1,63	0,01	0,04	0,35	0,01	0,03	0,01	0,18
	TOTAL					491,60	0,35	3,55	0,00	0,00	5,23	263,25	37,62	125,50	5,60	1,49	13,40	9,05	140,09	0,41	6,99

6.3.5 Thin client

For the IGEL 3210 Compact Thin Client a packaged volume of 15.6 dm^3 = 0.0156 m^3 was measured. This produces the following figures in the distribution phase.

Table 6-23: Distribution phase, thin client

DISTRIBUTION	Product					Energy			Water		Waste		Emissions to Air							to Water	
nr			cat.	NDX		GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
						MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
				61	0	51,50	0,00	0,00	0,00	0,00	1,02	51,36	4,52	12,00	0,05	0,29	2,62	2,62	0,26	0,08	1,36
208	Is it an ICT or Consumer Electronics product <15		YES	59	1	46,21	0,04	0,44	0,00	0,00	0,41	20,56	3,61	12,65	0,61	0,12	1,05	0,67	14,10	0,03	0,55
209	Is it an installed appliance (e.g. boiler)?		NO	60	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				62	1	7,79	0,00	0,00	0,00	0,00	0,10	5,03	0,46	1,31	0,08	0,03	0,26	0,13	3,35	0,01	0,13
210	Volume of packaged final product in m3	in m3	0,0156	63	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				64	1	0,92	0,00	0,00	0,00	0,00	0,02	0,85	0,06	0,20	0,00	0,00	0,04	0,00	0,00	0,00	0,02
	TOTAL					106,42	0,04	0,44	0,00	0,00	1,55	77,80	8,65	26,16	0,74	0,44	3,96	3,42	17,71	0,12	2,06

6.3.6 Pro rata calculation of the terminal server

The volume of the server was measured as 0.1608 m^3. This volume was again adjusted by a factor of 1.5/35. This makes the volume very small, but the values (e.g. GWP) hardly fall, in other words, final assembly is probably calculated with fixed values.

Table 6-24: Pro rata environmental impact of server; distribution phase

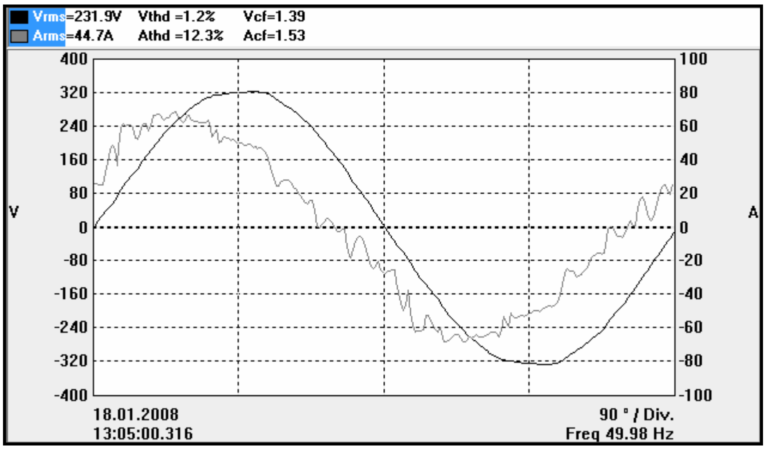
DISTRIBUTION	Product					Energy			Water		Waste		Emissions to Air							to Water	
nr			cat.	NDX		GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
						MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
				61	0	51,50	0,00	0,00	0,00	0,00	1,02	51,36	4,52	12,00	0,05	0,29	2,62	2,62	0,26	0,08	1,36
208	Is it an ICT or Consumer Electronics product <15		YES	59	1	18,80	0,02	0,18	0,00	0,00	0,17	8,37	1,47	5,15	0,25	0,05	0,43	0,27	5,74	0,01	0,22
209	Is it an installed appliance (e.g. boiler)?		NO	60	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				62	1	3,17	0,00	0,00	0,00	0,00	0,04	2,05	0,19	0,53	0,03	0,01	0,10	0,05	1,36	0,00	0,05
210	Volume of packaged final product in m3	in m3	0,006347368	63	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				64	1	0,37	0,00	0,00	0,00	0,00	0,01	0,35	0,03	0,08	0,00	0,00	0,02	0,00	0,00	0,00	0,01
	TOTAL					73,85	0,02	0,18	0,00	0,00	1,23	62,12	6,21	17,76	0,33	0,35	3,17	2,94	7,36	0,10	1,65

6.4 Operation phase

6.4.1 Desktop PC

Based on the real time view, while the performance was being measured, it became clear that electrical current is not exactly sinusoidal due to the influences of harmonic waves.

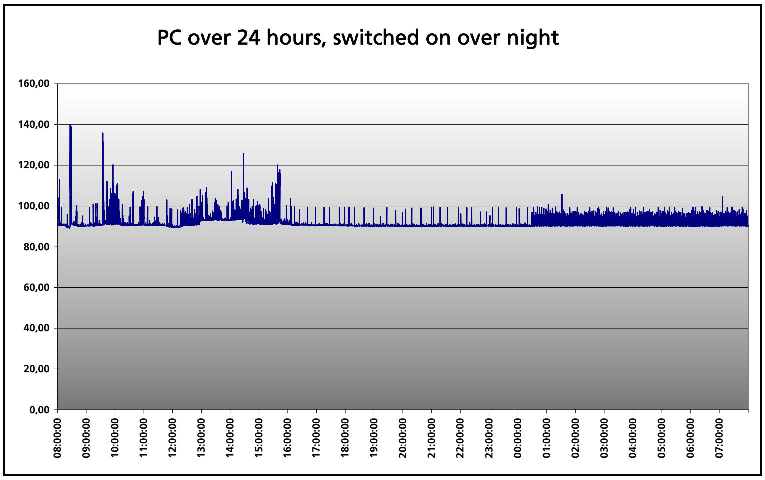
Figure 6-1: Measurement of voltage and current on a desktop PC



Although power supply units with a nominal rating of 50 W or 75 W (depending on the device category) must have a power-factor correction (PFC) according to EN 61000-3-2, this cannot completely prevent phase shift and thus a deviation between the effective and apparent power. In the systems that were measured the power factor during operation was in the range of 0.80-0.84. Current measuring instruments, which only record apparent power, would show power consumption – in relation to the effective power – that is 17-25 % too high.

In the first measurement over 24 hours the PC was not switched off. It was seen that the operating devices have peaks of up to 150 W. However, these short-term peaks have only a marginal effect on the average value during working time or over 24 hours (cf. Figure 6-2).

Figure 6-2: PC system 2 over 24 hours, switched on overnight



On the whole it was seen that during typical office work, PCs use approximately the same amount of power, regardless whether someone is working on them or not. The oldest system in the test field, which is used only by light users, has the lowest power consumption.

Table 6-25: Power consumption, desktop PC continuously switched on

Device	Average value, during working hours [W]	Average value over 24 hours [W]
PC 1	66.1	65.4
PC 2	92.4	91.4
PC 3	90.5	89.8

The oldest system being tested, PC 1, consumes on average 3.5 W in »soft-off« mode, the newer system use only about 2.4 W. If the systems are switched off overnight, average power consumption can be reduced by up to 64 % over 24 hours.

Table 6-26: Power consumption, desktop PC switched off overnight (»soft-off«)

Device	Average value, during working hours [W]	Average value over 24 hours [W]
PC 1	66.1	28.5
PC 2	92.4	33.6
PC 3	90.5	34.3

Several PC models are already available on the market with components and configuration geared to a low energy usage, which, according to type, consume only 9-52 W power in »idle« mode (cf. [Benz, 2008] and [Windeck, 2008-1]). But on a market average, all desktop PCs currently being purchased have higher power consumption. For example, the calculation model in the EuP report is based on average values of **78.2 W in »idle« mode** and **2.7 W in »soft-off«** (cf. [IVF, 2007], p140ff). These values are based on the basis year 2005. As PC systems are used for up to six years and since devices are still being marketed with above-average power consumption, these values are still regarded as a representative market average and are used for the calculation model in the following. Assuming the working day has nine hours, an **average value of 31.0 W over 24 hours** is assumed in case the desktop PC is shut down outside of working time.

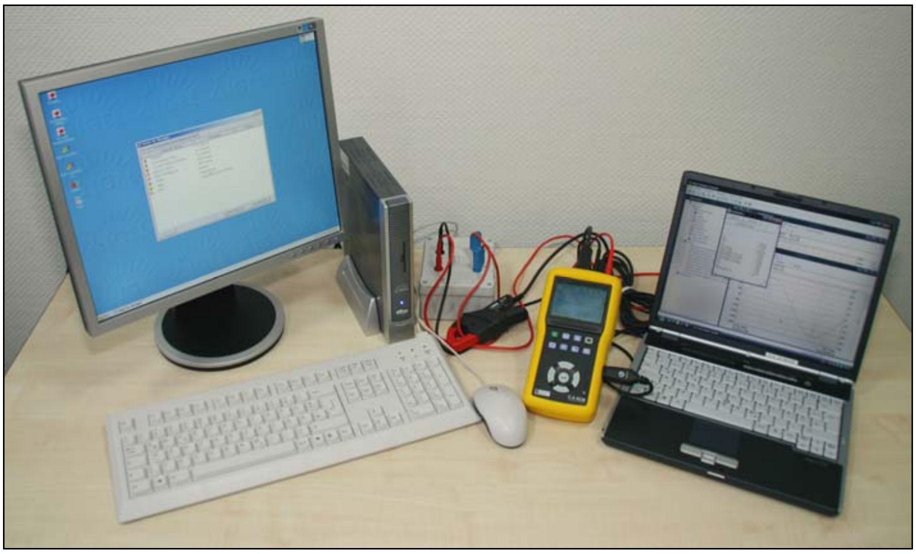
6.4.2 Notebook

For notebooks the EuP report assumes average values of **22.0 W in »idle« mode** and **1.2 W in »soft-off«** (cf. [IVF, 2007], p. 143ff) assuming that the notebook is operated stationary with an external monitor and that the internal screen is switched off. With 25.8 W and 0.82 W the notebook which was measured in our study is close to the average values.

6.4.3 Thin client

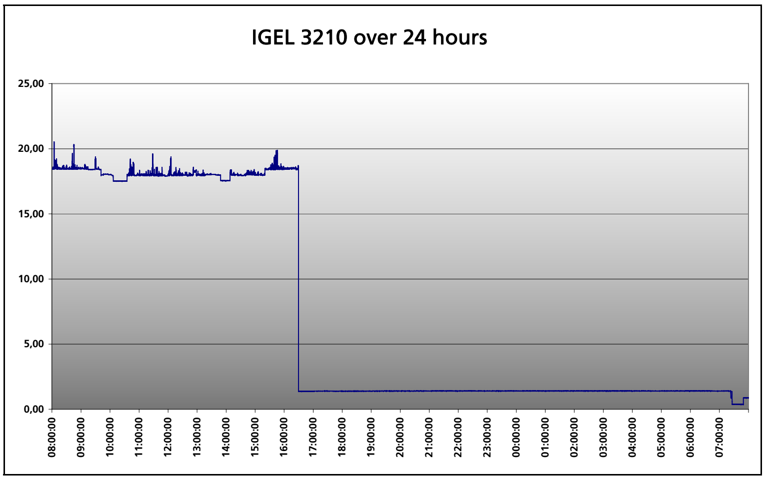
There are no literature sources available that refer to the power consumption of thin clients, which meant that we could use only the results of our measurements within the scope of the calculation model. Several thin clients of the same type were measured for 24 hours and average values were then taken from these measurement series. According to EN 61000-3-2, no power factor correction is specified for the 22 W power unit of the thin client we measured. The average power factor during operation is 0.5. Current measuring instruments, which measure only apparent power, would show power consumption – in relation to the effective power – that is 100 % too high

Figure 6-3: Evaluation of the power measurement (Photo: Fraunhofer UMSICHT)



Although the devices consumed up to 2.5 W in operation or when displaying moving pictures, these peaks had only a marginal effect on the average values. The devices that were measured consumed on average **18.3 W in »idle« mode** and **1.4 W in »soft-off«** mode. As the devices were switched off overnight, the **average value over 24 hours was 7.5 W**. These values will be considered accordingly in the calculation model.

Figure 6-4: IGEL 3210 LX Compact over 24 hours, in »soft-off« mode overnight



6.4.4 Pro rata calculation of the terminal server

No literature sources dealing with the power consumption of servers especially in the role of a terminal server were available, which meant that we could use only the results of our own measurements within the scope of the calculation model.

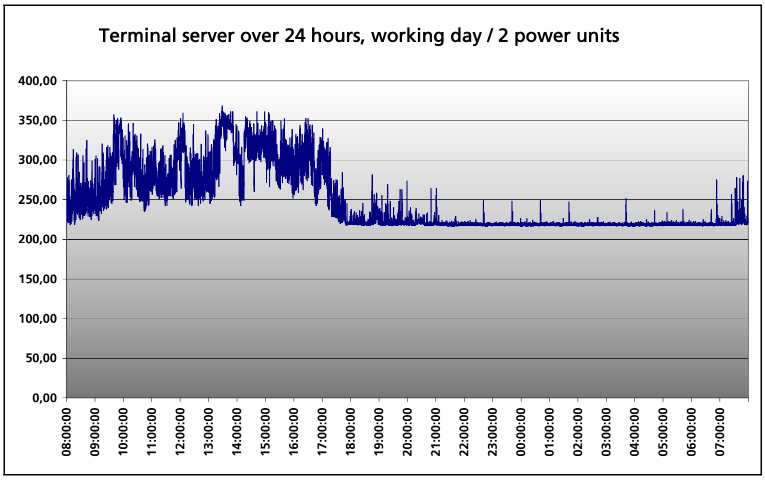
In our measurements of the terminal servers it was seen that the efficiency of the complete system drops when two redundant power units are used instead of a single power unit. In this case the terminal server consumed approx. 16 per cent more energy (cf. Table 6-27).

Table 6-27: Power consumption, terminal server

Server	Average value, working hours [W]	Average value, 24 hours [W]
1 power unit	238.2	212.3
2 power units	284.7	246.6

During the day the server consumes up to 370 W energy. Over the whole 24 hours the **average consumption is 246.6 W**. On free days (weekend, bank holidays) the server runs in **»idle«** mode the entire time. In this case the average consumption was **214.9 W**. These values will be used in the following and added to the clients with the factor 1/35.

Figure 6-5: Terminal server over 24 hours/2 power units



6.4.5 Monitors

The random measurements of monitors produced the following values for the four types that were investigated:

Table 6-28: Power consumption, different monitors

Monitor	Operation [W]	»Soft-off« [W]
17“ CRT	76.3	0.3
19“ CRT	93.6	0.2
17“ TFT	20.8	0.7
19“ TFT	31.0	0.7

It must be remembered that with CRT monitors the power factor is between 0.93 and 0.96 and for flat screens between 0.56 and 0.57. Current measuring instruments that measure only apparent power would show power consumption – in relation to the effective power – that is 75 % too high in the case of TFT monitors.

In the EuP report, average values were recorded only for 17 inch monitors (cf. [IVF, 2007], p. 143ff):

Table 6-29: Average values for power consumption of monitors, EuP report

Monitor	Operation [W]	»Soft-off« [W]
17“ CRT	69.5	1.5
17“ TFT	31.4	0.8

As the market average was mapped within the scope of the EuP report, these values form the basis for further calculations, even if individual random samples show lower values for the test devices. In relation to nine hours working time per day the average value over 24 hours is assumed to be **27.0 W for CRT monitors** and **12.3 W for flat screens**.

6.5 Recycling/disposal

The assumptions for the disposal phase were defined in the section on methodology.

6.5.1 Desktop PC

Hence, for the office desktop PC we get the results shown in the table below. In almost all areas, resource conservation or emission reduction can be observed (e.g. energy and water consumption). Naturally, disposal increases the amount of waste. Environmental impact can be seen in the area of heavy metals (in water and in the air) and in terms of persistent organic pollutants. These values can probably be attributed to incineration processes. The table lists the additional impacts, which are then offset with a credit.

Table 6-30: Environmental impact of disposal/recycling of an office desktop PC; calculation according to [MEEUP, 2005]

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	value		NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
	Substances released during Product Life and Landfill																			
227	Refrigerant in the product (Click & select)	0	g	1-none																
228	Percentage of fugitive & dumped refriger:	0										0,00								
229	Mercury (Hg) in the product	0	g Hg	0																
230	Percentage of fugitive & dumped mercury	0	0	0												0,00				
	Disposal: Environmental Costs perkg final	SUBTOTAL!			157,83	0,00	0,00	0,00	0,00	1687,03	782,06	11,77	23,47	0,43	5,43	43,28	0,00	203,07	13,20	754,54
231	Landfill (fraction products not recovered)	637,63	0,05	88-fixed	43,56	0,00	0,00	0,00	0,00	0,00	781,69	3,25	6,38	0,18	5,38	12,75	0,00	56,72	3,62	206,96
232	Incineration (plastics & PWB not re-used/r	1687	g	91-fixed	113,53	0,00	0,00	0,00	0,00	1687,02	0,00	8,46	16,87	0,24	0,05	30,37	0,00	142,93	9,58	547,57
233	Plastics: Re-use & Recycling ("cost"-side)	112,81	g	92-fixed	0,73	0,00	0,00	0,00	0,00	0,01	0,37	0,05	0,23	0,02	0,00	0,16	0,00	3,42	0,00	0,01
	Re-use, Recycling Benefit	SUBTOTAL!		0	190,93	78,28	3,53	70,60	16,56	87,92	227,33	13,03	66,60	0,97	0,85	9,87	8,14	3,18	44,78	641,48
234	Plastics: Re-use, Closed Loop Recycling (	11,281	0,01	4	0,62	0,06	0,45	0,04	0,34	0,04	0,24	0,02	0,05	0,00	0,00	0,00	0,00	0,01	0,00	1,39
235	Plastics: Materials Recycling (please edit%	101,53	0,09	4	5,06	0,37	2,68	0,24	2,03	0,22	1,43	0,10	0,28	0,00	0,00	0,00	0,02	0,04	0,00	8,35
236	Plastics: Thermal Recycling (please edit%	1015,3	0,9	72	80,27	0,00	0,00	0,00	0,00	0,00	0,00	5,99	7,50	0,10	0,00	0,00	0,00	0,13	0,00	0,00
237	Electronics: PWB Easy to Disassemble ? ((	671,75	YES	98	104,99	77,85	0,41	70,31	14,19	87,65	225,66	6,92	58,76	0,87	0,85	9,87	8,11	3,01	44,78	631,73
238	Metals & TV Glass & Misc. (95% Recycling)	9766,9	0	fixed	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL				-33,11	-78,28	-3,53	-70,60	-16,56	1599,11	554,73	-1,26	-43,12	-0,54	4,58	33,41		-8,14	199,89	-31,58

6.5.2 Notebook

With the notebook we also see resource conservation or emission reduction in all areas (e.g. energy and water consumption). The table lists the additional impacts, which are then offset with a credit. Compared to the desktop PC the savings are less, as less material was installed in the production phase.

Table 6-31: Environmental impact of disposal/recycling of a notebook; calculation according to [MEEUP, 2005]

DISPOSAL/RECYCLING																				
	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	value		NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
	Substances released during Product Life and Landfill																			
227	Refrigerant in the product (Click & select)	0	g	1-none																
228	Percentage of fugitive & dumped refriger:	0										0,00								
229	Mercury (Hg) in the product	0	g Hg	0																
230	Percentage of fugitive & dumped mercury	0	0	0												0,00				
	Disposal: Environmental Costs perkg final	SUBTOTAL!			91,99	0,00	0,00	0,00	0,00	1166,91	231,89	6,86	13,73	0,23	1,63	24,91	0,00	118,25	7,70	440,08
231	Landfill (fraction products not recovered)	188,93	0,05	88-fixed	12,91	0,00	0,00	0,00	0,00	0,00	231,62	0,96	1,89	0,05	1,59	3,78	0,00	16,81	1,07	61,32
232	Incineration (plastics & PWB not re-used/r	1166,9	g	91-fixed	78,53	0,00	0,00	0,00	0,00	1166,90	0,00	5,85	11,67	0,16	0,04	21,00	0,00	98,86	6,63	378,75
233	Plastics: Re-use & Recycling ("cost"-side)	85,18	g	92-fixed	0,55	0,00	0,00	0,00	0,00	0,01	0,28	0,04	0,17	0,01	0,00	0,12	0,00	2,58	0,00	0,01
	Re-use, Recycling Benefit	SUBTOTAL!		0	112,30	46,71	2,60	42,11	10,25	52,43	135,73	7,61	39,51	0,58	0,51	5,88	4,85	1,90	26,68	383,79
234	Plastics: Re-use, Closed Loop Recycling (	8,518	0,01	4	0,46	0,05	0,34	0,03	0,26	0,03	0,18	0,01	0,04	0,00	0,00	0,00	0,00	0,00	0,00	1,05
235	Plastics: Materials Recycling (please edit%	76,662	0,09	4	3,82	0,28	2,02	0,18	1,53	0,17	1,08	0,08	0,22	0,00	0,00	0,00	0,01	0,03	0,00	6,31
236	Plastics: Thermal Recycling (please edit%	766,62	0,9	72	45,46	0,00	0,00	0,00	0,00	0,00	0,00	3,39	4,25	0,06	0,00	0,00	0,00	0,07	0,00	0,00
237	Electronics: PWB Easy to Disassemble ? ((	400,28	YES	98	62,56	46,39	0,24	41,90	8,46	52,23	134,47	4,13	35,01	0,52	0,51	5,88	4,83	1,79	26,68	376,44
238	Metals & TV Glass & Misc. (95% Recycling)	2019,9	0	fixed	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL				-20,31	-46,71	-2,60	-42,11	-10,25	1114,48	96,17	-0,75	-25,79	-0,35	1,12	19,02		-4,85	116,35	-18,99

6.5.3 LCD monitor 17"

With the LCD monitor, resource conservation and reduced emissions are not evident in all areas. In recycling, more energy is used than is recovered. There are savings in the areas of water consumption and particulate matter.

Table 6-32: Environmental impact of disposal/recycling of a 17" LCD monitor; calculation according to [MEEUP, 2005]

DISPOSAL/RECYCLING																				
	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	value		NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
	Substances released during Product Life and Landfill																			
227	Refrigerant in the product (Click & select)	0	g	1-none																
228	Percentage of fugitive & dumped refriger:	0										0,00								
229	Mercury (Hg) in the product	0	g Hg	0																
230	Percentage of fugitive & dumped mercury	0	0	0												0,00				
	Disposal: Environmental Costs perkg final	SUBTOTAL!			166,37	0,00	0,00	0,00	0,00	2104,92	418,02	12,40	24,90	0,42	2,94	45,02	0,00	215,43	13,88	793,71
231	Landfill (fraction products not recovered)	340,38	0,05	88-fixed	23,26	0,00	0,00	0,00	0,00	0,00	417,29	1,74	3,40	0,10	2,87	6,81	0,00	30,28	1,93	110,48
232	Incineration (plastics & PWB not re-used/r	2104,9	g	91-fixed	141,65	0,00	0,00	0,00	0,00	2104,90	0,00	10,56	21,05	0,30	0,06	37,89	0,00	178,33	11,95	683,21
233	Plastics: Re-use & Recycling ("cost"-side)	225,07	g	92-fixed	1,46	0,00	0,00	0,00	0,00	0,01	0,73	0,10	0,45	0,03	0,00	0,33	0,00	6,82	0,00	0,02
	Re-use, Recycling Benefit	SUBTOTAL!		0	118,50	10,05	6,28	8,87	6,40	10,87	29,96	8,12	16,46	0,23	0,10	1,17	1,01	0,59	5,29	94,02
234	Plastics: Re-use, Closed Loop Recycling (	22,507	0,01	4	1,23	0,12	0,89	0,08	0,68	0,07	0,47	0,03	0,09	0,00	0,00	0,00	0,01	0,01	0,00	2,78
235	Plastics: Materials Recycling (please edit%	202,56	0,09	4	10,10	0,74	5,34	0,49	4,05	0,45	2,85	0,20	0,57	0,00	0,00	0,00	0,04	0,08	0,00	16,67
236	Plastics: Thermal Recycling (please edit%	2025,6	0,9	72	94,78	0,00	0,00	0,00	0,00	0,00	0,00	7,07	8,86	0,12	0,00	0,00	0,00	0,15	0,00	0,00
237	Electronics: PWB Easy to Disassemble ? ((	79,3	YES	98	12,39	9,19	0,05	8,30	1,68	10,35	26,64	0,82	6,94	0,10	0,10	1,17	0,96	0,36	5,29	74,58
238	Metals & TV Glass & Misc. (95% Recycling)	4178,5	0	fixed	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL				47,87	-10,05	-6,28	-8,87	-6,40	2094,05	388,05	4,27	8,44	0,20	2,84	43,86		-1,01	214,84	8,60

6.5.4 CRT monitor 17"

With the CRT monitor, resource conservation and reduced emissions are not evident in all areas. In recycling, more energy is used than is recovered. There are savings in the areas of water consumption and particulate matter.

Table 6-33: Environmental impact of disposal/recycling of a 17" CRT monitor; calculation according to [MEEUP, 2005]

DISPOSAL/RECYCLING

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	value		NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
	Substances released during Product Life and Landfill																			
227	Refrigerant in the product (Click & select)	0	g	1-none																
228	Percentage of fugitive & dumped refriger:	0										0,00								
229	Mercury (Hg) in the product	0	g Hg	0																
230	Percentage of fugitive & dumped mercury	0	0	0												0,00				
	Disposal: Environmental Costs perkg final	SUBTOTAL!			211,64	0,00	0,00	0,00	0,00	2289,22	1005,90	15,77	31,57	0,59	6,99	57,95	0,00	274,19	17,65	1009,17
231	Landfill (fraction products not recovered)	819,88	0,05	88-fixed	56,02	0,00	0,00	0,00	0,00	0,00	1005,12	4,18	8,20	0,23	6,91	16,40	0,00	72,93	4,65	266,12
232	Incineration (plastics & PWB not re-used/r	2289,2	g	91-fixed	154,05	0,00	0,00	0,00	0,00	2289,21	0,00	11,49	22,89	0,32	0,07	41,21	0,00	193,95	13,00	743,03
233	Plastics: Re-use & Recycling ("cost"-side)	241,16	g	92-fixed	1,57	0,00	0,00	0,00	0,00	0,02	0,78	0,11	0,48	0,03	0,00	0,35	0,00	7,31	0,00	0,02
	Re-use, Recycling Benefit	SUBTOTAL!		0	161,74	14,68	6,75	13,04	7,57	16,06	43,45	11,25	23,35	0,32	0,15	1,75	1,49	0,83	7,92	132,51
234	Plastics: Re-use, Closed Loop Recycling (p	24,116	0,01	4	1,31	0,13	0,95	0,09	0,72	0,08	0,51	0,04	0,10	0,00	0,00	0,00	0,01	0,01	0,00	2,98
235	Plastics: Materials Recycling (please edit%	217,05	0,09	4	10,82	0,79	5,72	0,52	4,34	0,48	3,05	0,21	0,61	0,00	0,00	0,00	0,04	0,08	0,00	17,86
236	Plastics: Thermal Recycling (please edit%	2170,5	0,9	72	131,05	0,00	0,00	0,00	0,00	0,00	0,00	9,78	12,25	0,17	0,00	0,00	0,00	0,21	0,00	0,00
237	Electronics: PWB Easy to Disassemble ? ((	118,75	YES	98	18,56	13,76	0,07	12,43	2,51	15,50	39,89	1,22	10,39	0,15	0,15	1,75	1,43	0,53	7,92	111,68
238	Metals & TV Glass & Misc. (95% Recycling)	13061	0	fixed	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL				49,90	-14,68	-6,75	-13,04	-7,57	2273,17	962,45	4,52	8,23	0,26	6,84	56,21		-1,49	273,36	9,74

6.5.5 Thin client

The results for the thin client are shown in the table below. In almost all areas, resource conservation and a reduction in emissions is evident (e.g. energy and water consumption).

Table 6-34: Environmental impact of disposal/recycling of an Igel Compact; calculation according to [MEEUP, 2005]

DISPOSAL/RECYCLING

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	value		NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
	Substances released during Product Life and Landfill																			
227	Refrigerant in the product (Click & select)	0	g	1-none																
228	Percentage of fugitive & dumped refriger:	0										0,00								
229	Mercury (Hg) in the product	0	g Hg	0																
230	Percentage of fugitive & dumped mercury	0	0	0												0,00				
	Disposal: Environmental Costs perkg final	SUBTOTAL!			32,35	0,00	0,00	0,00	0,00	305,05	209,89	2,41	4,80	0,09	1,45	8,94	0,00	41,68	2,70	154,57
231	Landfill (fraction products not recovered)	171,16	0,05	88-fixed	11,69	0,00	0,00	0,00	0,00	0,00	209,83	0,87	1,71	0,05	1,44	3,42	0,00	15,23	0,97	55,55
232	Incineration (plastics & PWB not re-used/r	305,05	g	91-fixed	20,53	0,00	0,00	0,00	0,00	305,05	0,00	1,53	3,05	0,04	0,01	5,49	0,00	25,84	1,73	99,01
233	Plastics: Re-use & Recycling ("cost"-side)	20,071	g	92-fixed	0,13	0,00	0,00	0,00	0,00	0,00	0,07	0,01	0,04	0,00	0,00	0,03	0,00	0,61	0,00	0,00
	Re-use, Recycling Benefit	SUBTOTAL!		0	45,17	14,50	0,63	13,07	3,05	16,28	42,09	3,15	13,25	0,19	0,16	1,83	1,51	0,60	8,29	118,74
234	Plastics: Re-use, Closed Loop Recycling (p	2,0071	0,01	4	0,11	0,01	0,08	0,01	0,06	0,01	0,04	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,25
235	Plastics: Materials Recycling (please edit%	18,064	0,09	4	0,90	0,07	0,48	0,04	0,36	0,04	0,25	0,02	0,05	0,00	0,00	0,00	0,00	0,01	0,00	1,49
236	Plastics: Thermal Recycling (please edit%	180,64	0,9	72	24,71	0,00	0,00	0,00	0,00	0,00	0,00	1,84	2,31	0,03	0,00	0,00	0,00	0,04	0,00	0,00
237	Electronics: PWB Easy to Disassemble ? ((	124,41	YES	98	19,44	14,42	0,08	13,02	2,63	16,23	41,79	1,28	10,88	0,16	0,16	1,83	1,50	0,56	8,29	117,00
238	Metals & TV Glass & Misc. (95% Recycling)	2824,9	0	fixed	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL				-12,81	-14,49	-0,63	-13,07	-3,05	288,77	167,80	-0,73	-8,45	-0,10	1,29	7,11		-1,51	41,07	-5,59

6.5.6 Pro rata calculation of the terminal server

The values are similar to those of the office desktop PC after adjustment (*1.5/35).

Table 6-35: Pro rata environmental impact from disposal/recycling of a terminal server; calculation according to [MEEUP, 2005]

DISPOSAL/RECYCLING

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	value		NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
	Substances released during Product Life and Landfill																			
227	Refrigerant in the product (Click & select)	0	g	1-none																
228	Percentage of fugitive & dumped refriger:	0										0,00								
229	Mercury (Hg) in the product	0	g Hg	0																
230	Percentage of fugitive & dumped mercury	0	0	0												0,00				
	Disposal: Environmental Costs perkg final	SUBTOTAL!			6,76	0,00	0,00	0,00	0,00	72,30	33,52	0,50	1,01	0,02	0,23	1,85	0,00	8,70	0,57	32,34
231	Landfill (fraction products not recovered)	27,327	0,05	88-fixed	1,87	0,00	0,00	0,00	0,00	0,00	33,50	0,14	0,27	0,01	0,23	0,55	0,00	2,43	0,16	8,87
232	Incineration (plastics & PWB not re-used/r	72,301	g	91-fixed	4,87	0,00	0,00	0,00	0,00	72,30	0,00	0,36	0,72	0,01	0,00	1,30	0,00	6,13	0,41	23,47
233	Plastics: Re-use & Recycling ("cost"-side)	4,8346	g	92-fixed	0,03	0,00	0,00	0,00	0,00	0,00	0,02	0,00	0,01	0,00	0,00	0,01	0,00	0,15	0,00	0,00
	Re-use, Recycling Benefit	SUBTOTAL!		0	8,18	3,35	0,15	3,03	0,71	3,77	9,74	0,56	2,85	0,04	0,04	0,42	0,35	0,14	1,92	27,49
234	Plastics: Re-use, Closed Loop Recycling (p	0,4835	0,01	4	0,03	0,00	0,02	0,00	0,01	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06
235	Plastics: Materials Recycling (please edit%	4,3512	0,09	4	0,22	0,02	0,11	0,01	0,09	0,01	0,06	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,36
236	Plastics: Thermal Recycling (please edit%	43,512	0,9	72	3,44	0,00	0,00	0,00	0,00	0,00	0,00	0,26	0,32	0,00	0,00	0,00	0,00	0,01	0,00	0,00
237	Electronics: PWB Easy to Disassemble ? ((	28,789	YES	98	4,50	3,34	0,02	3,01	0,61	3,76	9,67	0,30	2,52	0,04	0,04	0,42	0,35	0,13	1,92	27,07
238	Metals & TV Glass & Misc. (95% Recycling)	418,58	0	fixed	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL				-1,42	-3,35	-0,15	-3,03	-0,71	68,53	23,77	-0,05	-1,85	-0,02	0,20	1,43		-0,35	8,57	-1,35

6.6 Summary and evaluation

In this evaluation the focus is on the greenhouse gas relevance of IT equipment. Hence, in the following only the GWP (Global Warming Potential) is considered.

6.6.1 Monitors

As explained in Section 6.4.5, the average power consumption on working days was assumed to be 27.0 W for CRT monitors and 12.3 W for LCD monitors. On the other days, stand-by power in »soft-off« was assumed to be 1.5 W and 0.8 W. Assuming 220 working days per year, the **annual consumption is**:

CRT monitor	220 days x 24 h x 27.0 W
	+ 145 days x 24 h x 1.5 W = 147.78 kWh

TFT monitor	220 days x 24 h x 12.3 W
	+ 145 days x 24 h x 0.8 W = 67.73 kWh

This is calculated according to the German electricity mix in 0.61 kg CO_2eq per 1 kWh, extrapolated for an operation phase of **five** years and used in the following summary. The values for the other phases are taken from the MEEUP study:

Table 6-36: Global warming potential (GWP) in kg CO_2eq for monitors

	CRT monitor	LCD monitor
Manufacturing phase	41.96	46.34
Production phase	7.64	8.56
Distribution phase	37.62	11.2
Operation phase	450.73	206.58
Disposal phase	4.52	4.27
Total:	**542.47**	**276.95**

It can be seen that the operation phase dominates all the other phases. This is followed, with a large gap, by the production phase. Here, the distribution phase (which also includes final assembly of the computer) is surprisingly high.

If we assume 5 years' usage, the LCD monitor is better by a factor of about 2.

6.6.2 Desktop PC and notebook

According to Section 6.4.1 a PC, which is not switched off, consumes continuously 78.2 W. Taking 365 days, this produces an **annual consumption** of:

PC (»idle«)	365 days x 24 h x 78.2 W = 685.03 kWh

In the following, this case is considered with a share of 1/3. If the PC is switched off regularly, with power consumption of 2.7 W in »soft-off« mode the average value on working days drops to 31.0 W. This gives us the following **annual consumption**:

PC (»soft-off«)	220 days x 24 h x 31.0 W
	+ 145 days x 24 h x 2.7 W = 173.08 kWh

In the following, this case is considered with a share of 2/3, which produces the following **average value**:

PC ø	1/3 x 685.03 kWh	
	+ 2/3 x 173.08 kWh =	343.73 kWh

For notebooks that always use energy saving mode, according to Section 6.4.2, 22.0 W is assumed on average for operation (»idle«) and 1.2 W for »soft-off«. This gives us an average value of 9 W over 24 hours for working days. At 220 working days per year, we get the following **annual consumption**:

Notebook	220 days x 24 h x 9.0 W	
	+ 145 days x 24 h x 1.2 W =	51.70 kWh

The values are calculated according to the German electricity mix in 0.61 kg CO_2eq per 1 kWh, extrapolated for an operation phase of **five** years and used in the following summary. The values for the other phases are taken from the MEEUP study:

Table 6-37: Global warming potential (GWP) in kg CO_2eq for desktop PCs and notebooks

	Desktop PC	Notebook
Manufacturing phase	117.33	71.15
Production phase	21.04	9.36
Distribution phase	25.25	12.57
Operation phase	1 048.38	157.69
Disposal phase	-1.26	-0.75
Total:	**1 210.74**	**250.02**

As the VDU Directive requires an external monitor also for notebooks, this is not considered in the following in direct comparisons of different desktop equipment.

In the disposal phase there is a small environmental credit resulting from the utilization of plastics and printed circuit boards. In reality the credit is higher, but this was already taken into account in the production phase (as described in the methodology).

6.6.3 Thin client and proportion of the terminal server

According to Section 6.2.5 the thin client that we measured consumes 18.3 W in operation (»idle«) and 1.4 W in »soft-off« mode. The *measured* average value is 7.5 W over 24 hours on a working day. Assuming 220 working days per year, we calculate the following **annual consumption**:

Thin client	220 days x 24 h x 7.5 W	
	+ 145 days x 24 h x 1.4 W =	44.47 kWh

The terminal server that was measured uses on average 246.6 W in 24 hours and 214.9 W on free days. With 220 working days in the year we calculate the following **annual consumption**:

Server	220 days x 24 h x 246.6 W
	+ 145 days x 24 h x 214.9 W = 2,049.90 kWh

As air conditioning is needed for the server in the data centre, the annual consumption is doubled and produces a value of 4,099.80 W. The values are calculated according to the German electricity mix in 0.61 kg CO_2eq per 1 kWh and extrapolated for an operation phase of **five** years and are used as such in the following summary. The values of the other phases are taken according to the MEEUP study. The server is added pro rata to the clients with a factor of 1/35:

Table 6-38: Global warming potential (GWP) in kg CO_2eq of thin client and thin client incl. server share

	Thin Client	Calculated server share (factor 1,5/35)	Thin Client incl. calculated share of terminal server
Manufacturing phase	37.33	5.03	42.36
Production phase	4.12	0.9	5.02
Distribution phase	8.65	6.21	14.86
Operation phase	135.63	357.27	492.9
Disposal phase	-0.73	-0.05	-0.78
Total:	**185.00**	**369.36**	**554.36**

According to the MEEUP evaluation framework the utilization rate is 95 %. This produces a credit in the disposal phase, as materials can be fed back to the supply chain.

Figure 6-6: Recycling electrical scrap (Photo: IGEL Technology GmbH)

According to information from IGE Hennemann Recycling GmbH & Co. KG, which handles recycling of IGEL Thin Clients in Germany, the total utilization rate for PCs and thin clients is 99 %. This means that almost 100 % of the device material can be fed back to the material cycle.

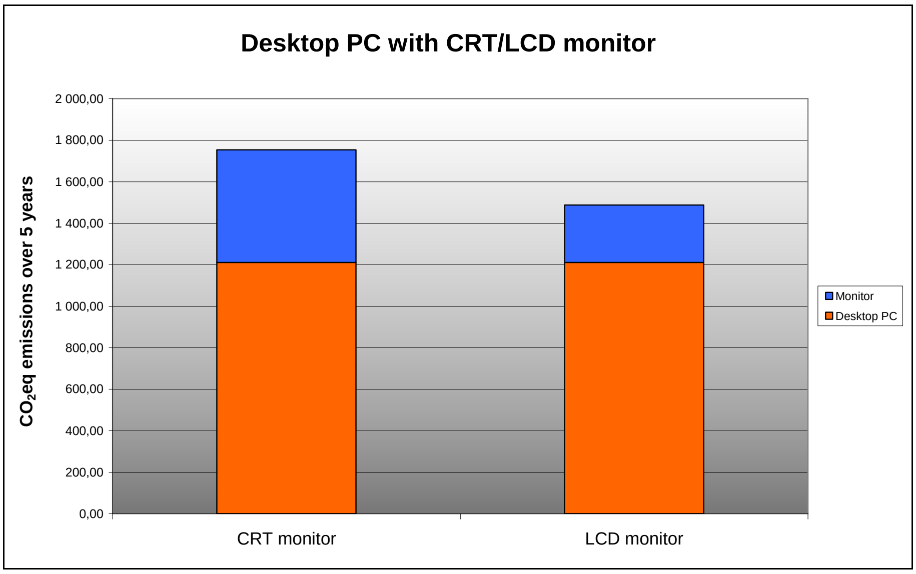
7 Interpretation of the results

The aim of this section is to put the determined CO_2eq emissions from the different devices in relation to each other and to interpret various magnitudes in terms of their use in companies.

7.1 Desktop system and monitor

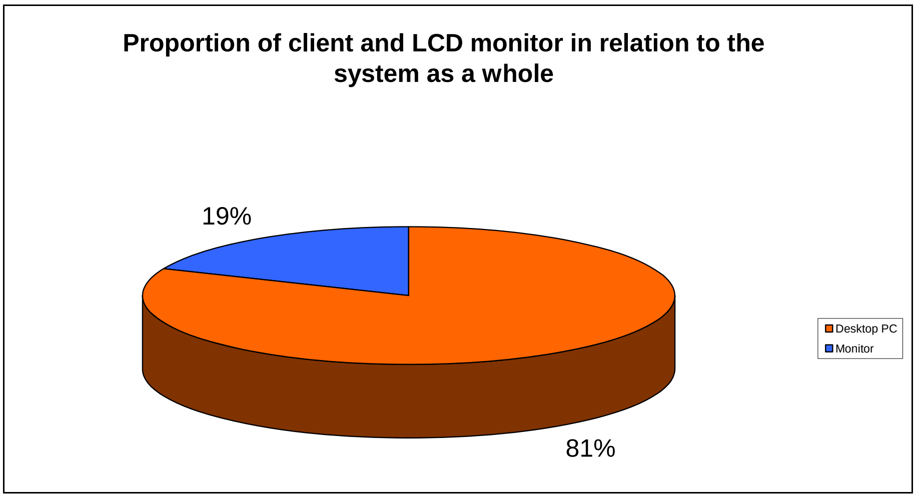
Together with a desktop PC, changing from a CRT to an LCD monitor can reduce CO_2eq emissions for the complete system by more than 15 % over five years.

Figure 7-1: CO2eq emissions, comparison between CRT/LCD monitors



In the scenario involving a PC and LCD monitor, 81 % of the entire emissions can be attributed to the PC.

Figure 7-2: Proportion of PC and monitor in relation to total emissions of the workstation

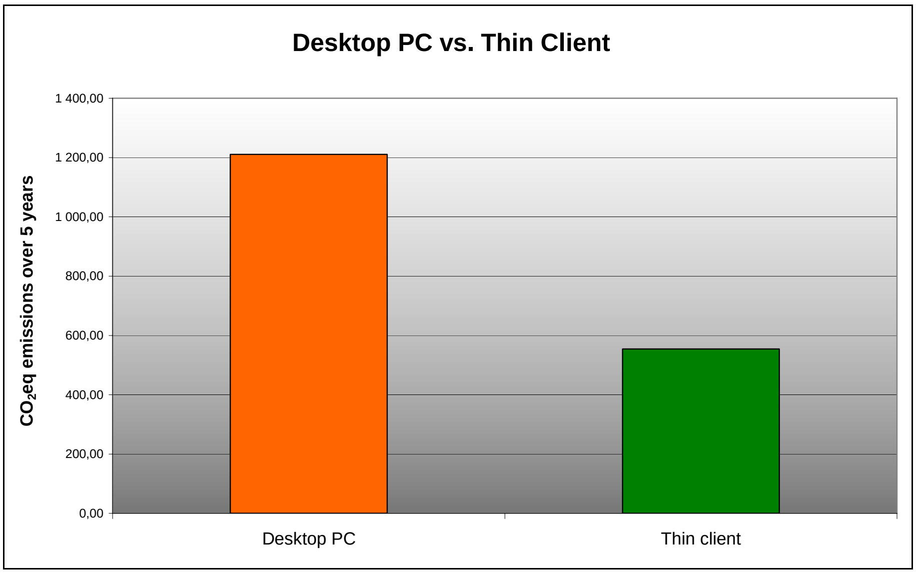


It can thus be deduced that it would be environmentally sensible to change from CRT monitors to LCD monitors. Apart from the fact that this change has already been made at many workplaces and that almost only LCD monitors are available on the market, the high proportion of emissions attributed to the desktop PCs compared to the system as a whole is noticeable. Accordingly, different desktops will be compared in the following.

7.2 Desktop PC vs. thin client

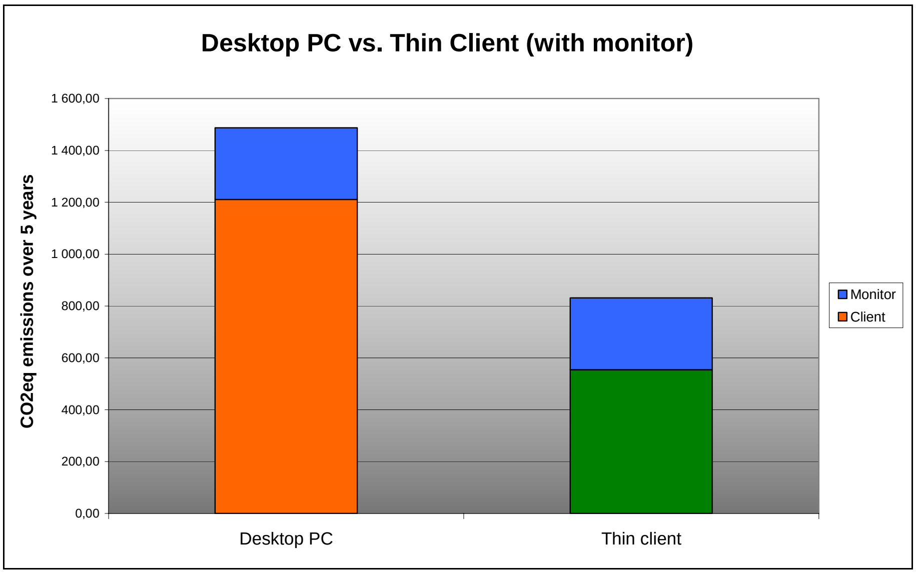
If a desktop PC is replaced by a thin client and terminal server, the emissions of the workstation system drop by more than 54 %.

Figure 7-3: Desktop PC vs. thin client, CO_2eq emissions over five years



In relation to a complete system with LCD monitor the savings potential is 44 %.

Figure 7-4: Desktop PC vs. thin client (incl. monitor), CO_2eq emissions over five years



7.3 Notebook

When used as a stationary device a notebook saves 79 % of CO_2eq emissions compared to a PC and approx. 55 % compared to a thin client and server. This result must be relatives because a differentiated investigation of the use of notebooks was not the focus of this study. Rather, for the purpose of the study it was assumed that notebooks are used exclusively as stationary devices. However, because of their technical design, notebooks are intended explicitly for mobile use and are generally used as intended. Consequently, in a detailed investigation completely different usage behavior would have to be mapped and evaluated according to the specific company and deployment. For instance, if the notebook is used frequently as a mobile device, the power consumption varies considerably according to the configuration of the energy schema. Batteries are also frequently charged and uncharged. Hence, in the eco balance over the life cycles, disposal and procurement of additional batteries would have to be considered.

In addition, when various operation models are recommended from the end customer's viewpoint, ecological and economical aspects must be taken into account. For example, within the scope of the economic viability analysis it was identified that desktop PCs incur approx. 1/3 more overall costs than a similar server-based computing infrastructure. When notebooks are used, the overall costs would increase further due to the higher purchase price. Besides, especially in case of mobile use, increased security requirements would have to be considered, which may mean the implementation of technologies for hard disk encryption or other security procedures, such as logging on via biometric methods, SmartCards, etc. which would incur additional costs. Due to the increased security requirements the complete deployment of notebooks in sensitive areas such as public authorities, banks and insurance companies is not advisable.

7.4 Calculation example: SME

In terms of use in a small to medium-sized enterprise with 300 workplaces the use of thin clients over a five-year usage phase would save more than **148 t CO_2eq** of emissions if 75 % of the workplaces could be changed over to thin clients. A VW Golf[33] could drive more than **1,093,000 km** and thus circle the earth 27 times with this volume of emissions.

7.5 Calculation example: large company

If the savings potential is interpolated to a large company with 10,000 workstations to be supported, more than **4,923 t CO_2eq** would be saved in such an environment over a five-year usage period if 75 % of the PC workstations were replaced with thin clients.

Assuming an annual distance of **20,000 km,** a fleet of **364 cars** of the above type could be driven for **five years** with this level of CO_2eq emissions.

[33] VW Golf 1.9 TDI, 90 PS, 135 g CO_2/km

8 Macroeconomic perspective

In addition to the monetary savings potentials created for certain companies through the use of thin clients the macroeconomic connections are also especially relevant in terms of the environmental impacts. Using statistical market data this section will investigate the potential that could arise for the economies in Europe, and especially Germany, if the use of thin client technology were to become more widespread.

For example, the European Information Technology Observatory (EITO), founded by the industry association BITKOM, expects the number of new computers sold in Europe[34] in 2007 to rise by 9.6 % over the previous year and to exceed 60 million in real figures. For 2008 it is expected that this figure will grow by a further 9.1 % to more than 66 million devices (cf. Table 8-1 and Figure 8-1).

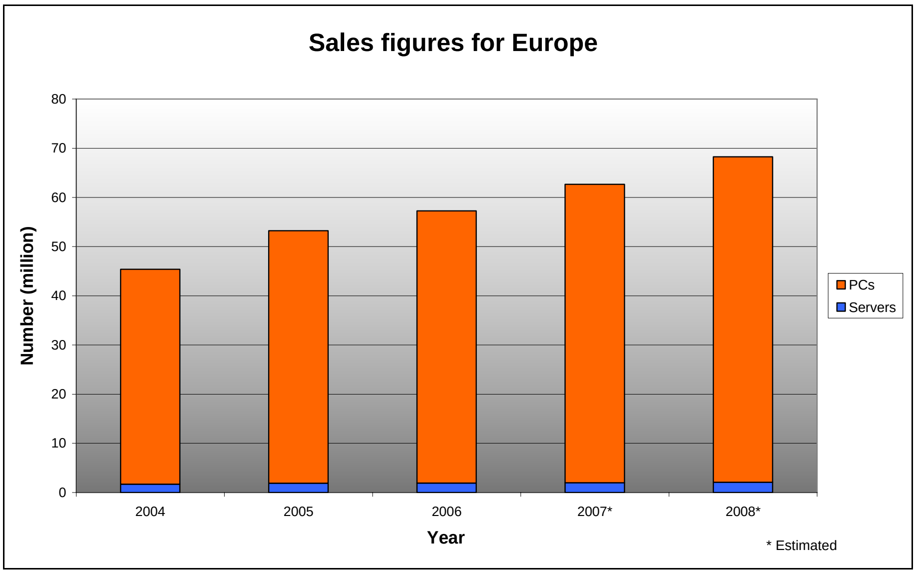
Table 8-1: Sales figures for PCs and servers in Europe (Source: EITO, 2007)

Device type	2004	2005	2006	2007*	2008*
Server	1,703,617	1,885,830	1,914,131	1,985,173	2,070,241
PC	43,708,414	51,324,592	55,359,236	60,666,179	66,178,405

* Estimated

34 In this survey »Europe« includes Norway, Switzerland and the EU-25 countries Belgium, Denmark, Germany, Estonia, Finland, France, Greece, Ireland, Italy, Latvia, Lithuania, Luxemburg, Malta, Netherlands, Austria, Poland, Portugal, Sweden, Slovakia, Slovenia, Spain, Czech Republic, United Kingdom, Hungary and Cyprus.

Figure 8-1: Sales figures for PCs and servers in Europe (Source: EITO, 2007)



In terms of the proportions of the EU-15 countries[35] EITO also differentiates according to stationary desktop PC and portable equipment, such as notebooks and tablet PCs. With similar growth rates to the overall market it can be seen that the share of mobile devices will exceed 50 % in 2007 and will continue to grow in 2008 (cf. Table 8-2 and Figure 8-2).

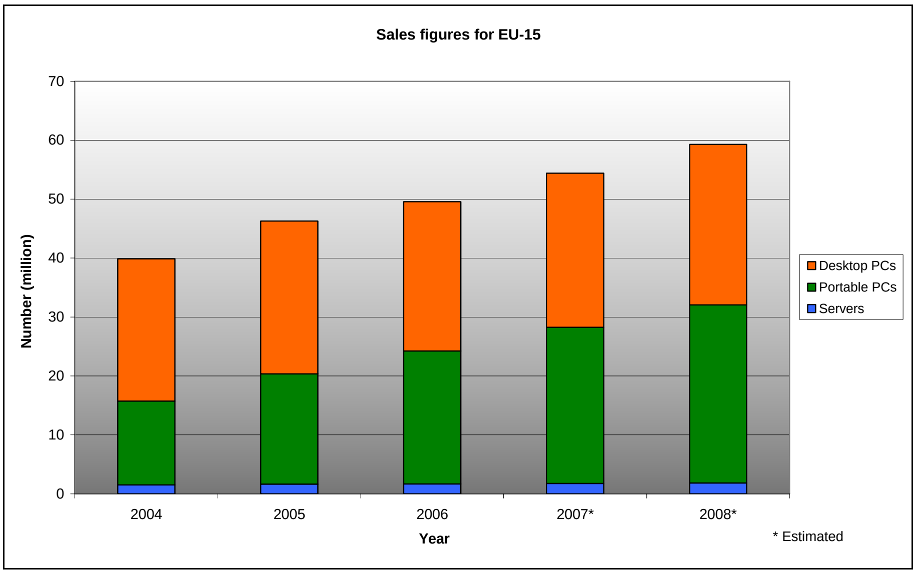
Table 8-2: Sales figures for PCs and servers in the EU-15 countries (Source: EITO, 2007)

Device type	2004	2005	2006	2007*	2008*
Server	1,509,648	1,654,766	1,679,510	1,749,217	1,825,523
PC, total	38,376,512	44,634,847	47,897,483	52,667,047	57,469,686
- Portable PC	14,246,168	18,687,374	22,548,578	26,530,578	30,240,037
- Desktop PC	24,130,344	25,947,473	25,348,905	26,136,469	27,229,649

* Estimated

35 The »EU-15« region includes the following countries: Belgium, Denmark, Germany, Finland, France, Greece, Ireland, Italy, Luxemburg, Netherlands, Austria, Portugal, Sweden, Spain, United Kingdom

Figure 8-2: Sales figures for PCs and servers in the EU-15 countries (Source: EITO, 2007)



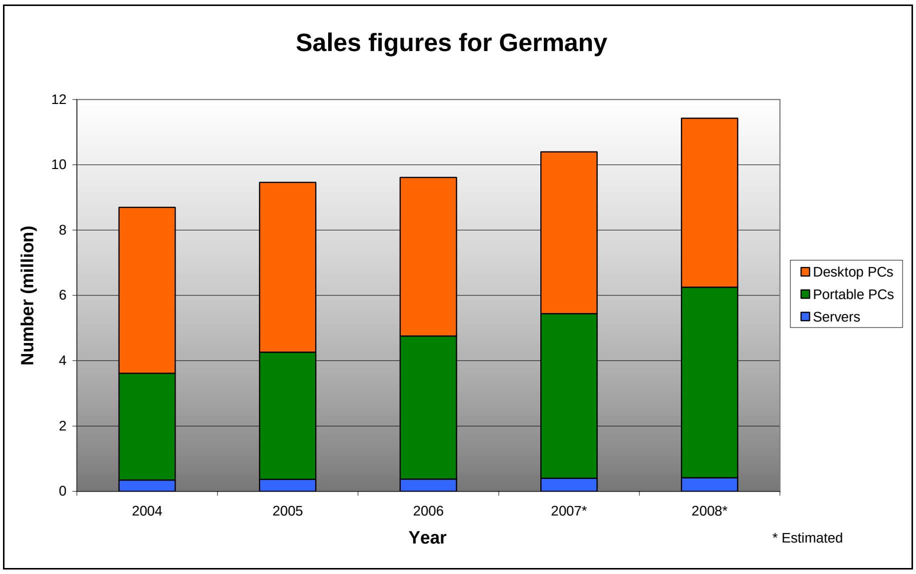
These relationships and growth rates can also be transferred to the German market. Here, for 2007 it is expected that about 10 million new PCs will be sold, approximately 50 % of these will be stationary devices. In 2008 this figure is expected to rise to more than 11 million PCs, with about 47 % of these being stationary devices (cf. Table 8-3 and Figure 8-3).

Table 8-3: Sales figures for PCs and servers in Germany (Source: EITO, 2007)

Device type	2004	2005	2006	2007*	2008*
Server	343,435	368,364	375,546	398,121	411,204
PC, total	8,352,413	9,091,467	9,236,588	9,995,558	11,016,752
- Portable PC	3,271,431	3,893,841	4,380,815	5,041,478	5,843,147
- Desktop PC	5,080,982	5,197,626	4,855,773	4,954,080	5,173,605

* Estimated

Figure 8-3: Sales figures for PCs and servers in Germany (Source: EITO, 2007)



Compared to this, market research company IDC expects only 3.3 million thin clients to be sold worldwide in 2008; 1.1 million of these in »Western Europe«[36].

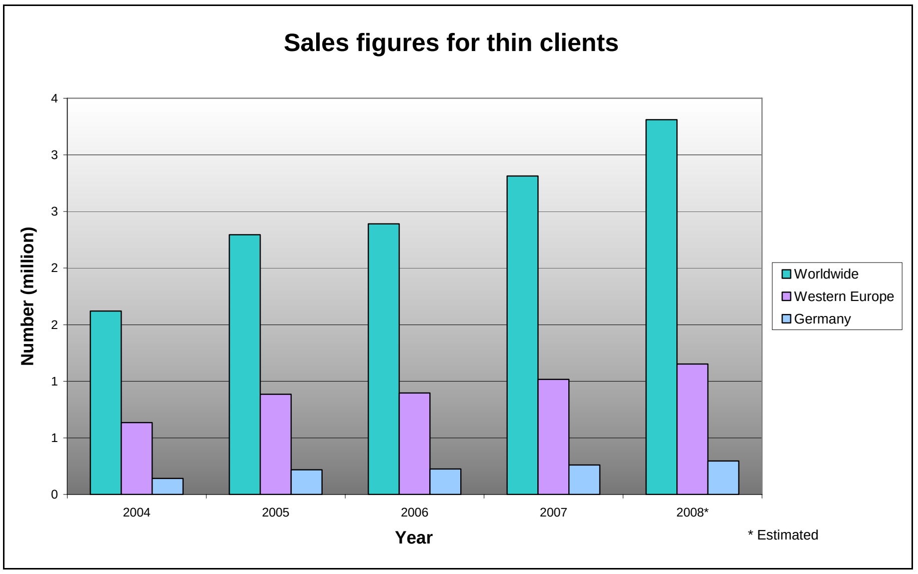
Table 8-4: Sales figures for thin clients (Source: IDC, 2008)

Region	2004	2005	2006	2007	2008*
Worldwide	1,620,371	2,294,799	2,390,831	2,813,177	3,311,393
Western Europe	634,706	885,732	895,886	1,016,399	1,152,675
Germany	141,410	217,972	224,472	260,167	296,558

* Estimated

36 »Western Europe« includes Norway, Switzerland and the EU-15 countries.

Figure 8-4: Sales figures for thin clients (Source: IDC, 2008)



8.1 Comparison

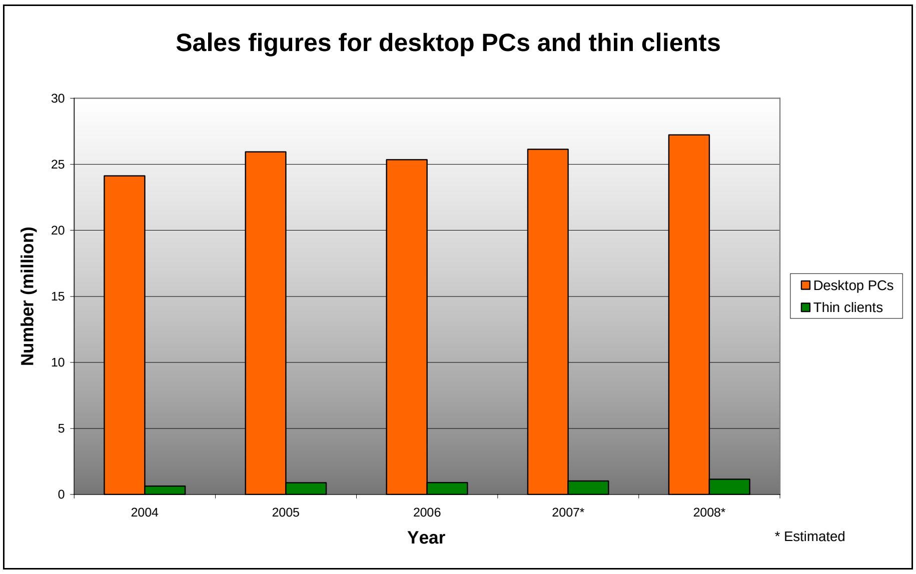
The market for thin clients is growing faster than that for desktop PCs – but at a much lower level. In the comparable regions of »EU-15« and »Western Europe« in 2008 more than 27 million new desktop PCs will be sold, compared to just 1.2 million thin clients. This is just 4.3 % of the number of PCs (cf. Table 8-5 and Figure 8-5).

Table 8-5: Comparison of new desktop PCs and thin clients

Device type	2004	2005	2006	2007	2008
Desktop PC	24,130,344	25,947,473	25,348,905	26,136,469	27,229,649*
Thin Clients	634,706	885,732	895,886	1,016,399*	1,152,675*

* Estimated

Figure 8-5: Comparison of new desktop PCs and thin clients



It must be remembered that thin clients are used almost exclusively in companies, while the majority of PCs are bought by private households. For example, in 2005 approx. 43 % of desktop PCs were deployed in companies. This proportion is expected to drop to about 40 % in 2008 (cf. [IVF, 2007], p. 69).

It must also be considered that because of technical requirements not all PCs used in companies can be substituted by thin clients. All applications cannot yet be mapped by terminal servers. This applies especially to power-hungry applications in the areas of graphical design, CAD and multimedia. As all screen content has to be transferred from the terminal server to the client via a network, it is not yet possible to edit video data on a thin client fluently in real time. Programmers who need extended rights to develop new applications have to use desktop systems. Consequently, in the following calculations it will be conservatively assumed that only 75 % of desktop PCs used in companies – or 30 % of the total PCs sold – can be replaced by thin clients.

8.2 Savings potential

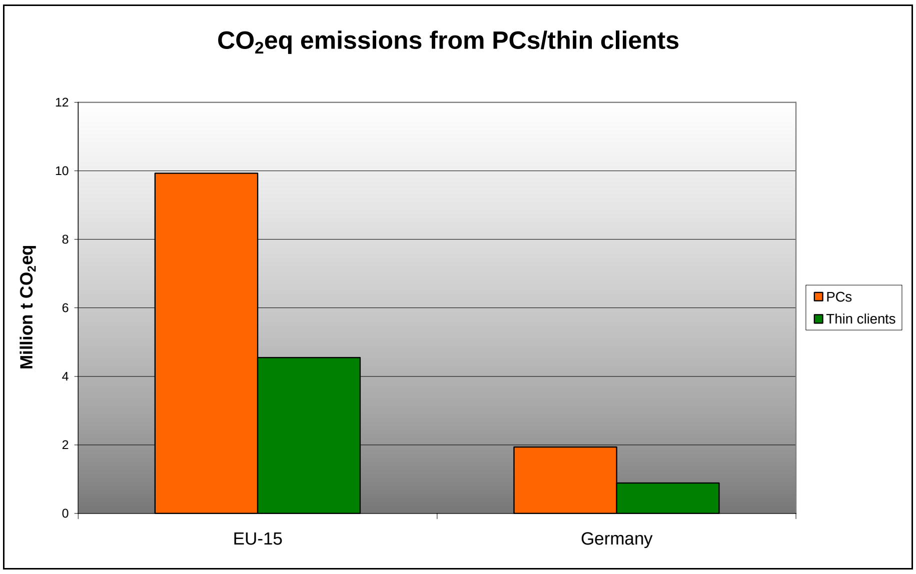
Based on the above considerations, we get the following substitution potential in the corporate environment, broken down by region:

Table 8-6: Substitution potential by region

Region	New desktop PCs	Share	Substitution potential in the corporate environment
EU-15	27.2 million	30 %	8.2 million
Germany	5.2 million	30 %	1.6 million

With the current state of the art, this means that in the EU-15 countries at least 8.2 million of the new desktop PCs sold could be replaced by thin clients; in Germany this figure would be 1.6 million. Based on the values determined in Section 6, this would mean savings of **5,382,000 t CO_2eq** in the EU-15 countries and **1,050,000 t CO_2eq** in Germany over a five-year usage period[37].

Figure 8-6: CO2eq emissions from PCs/thin clients in Germany and the EU-15 over 5 years



More savings potential will be possible in future as the functional scope of Terminal Services increases (cf. Sect. 9), which will enable more applications to be covered by thin clients. On the other hand, the efficiency of the hardware and software on the servers will also increase. The relevant technologies and developments are presented in the following section.

37 This calculation is based on the German electricity mix.

9 Future optimization potential

This section presents technologies and current developments that could help cover a wider range of applications with thin clients and server-based computing in future. Possibilities to optimize the utilization factor and efficiency of the respective infrastructures will also be identified.

9.1 64-bit computing

As the performance values of terminal servers show, an increase in user sessions on a 32-bit operating system (x86) is generally not limited by the processor but by the main memory (cf. Sect. 5.1.4). This is more relevant for new server systems, as processors with two or more processor cores have become established as the standard. In other words, measured by the computing capacity that is available these systems could execute many more user sessions simultaneously if the main memory was not limited. But the x86 editions of Windows Server™ can address only 4 GB max. of main memory[38]. The address space that can be used by the operating system kernel is also limited to just 2 GB. This address space particularly includes the storage areas for parts of the operating system and drivers that cannot be swapped during runtime (non-paged pool), parts that can be swapped (paged pool), a directory where swapped components can be administered (page table entries), and a directory to administer all opened files (system cache). If one of these storage areas is exhausted, the stability of the server is at risk, even if sufficient free resources are otherwise available (cf. [Microsoft, 2005], pp. 9-10).

[38] This limit can be extended with Physical Address Extension (PAE) if this is supported by the processor and operating system. (http://www.microsoft.com/whdc/system/platform/server/PAE/PAEdrv.mspx). For instance, in the Enterprise Edition, Windows Server™ 2003 can support up to 32 GB main memory. Since, with the use of PAE, the memory cannot be addressed directly but only indirectly via software, the performance of a x86 system deteriorates the more main memory in excess of 4 GB is used (cf. [Microsoft, 2005], p. 7).

Table 9-1: Memory management on x86 and x64 platforms (Source: Microsoft)

Property	x86 (32-bit)	x64 (64-bit)
Max. size of the main memory	4 GB	16 TB
Max. size of the swap file	16 TB	512 TB
Virtual address space of the kernel	2 GB	8 TB
Paged pool	470 MB	128 GB
Non-paged pool	256 MB	128 GB
System page table entries (PTE)	~900 MB	128 GB
System cache	1 GB	1 TB

The 64-bit variants (x64) of the Windows® operating systems promise some help: not only can they address significantly more main memory, but they also provide much more storage area to swap parts of the system and manage open files (cf. Table 9-1). Case reports confirm the potential considerable performance improvement with suitably sized server hardware (cf. [Citrix, 2007]).

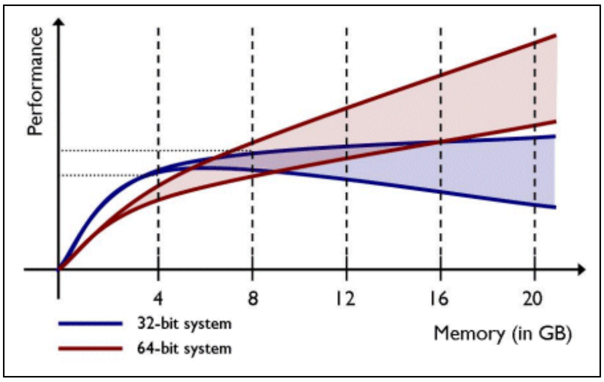
However, from this technical data it cannot automatically be deduced that a x64 operating system is superior to its x86 counterpart in all cases. As a joint study carried out by Microsoft and Hewlett-Packard (cf. [Microsoft, 2005]) has shown, this depends in fact on the hardware and application software that is used. For instance, many standard software products are available only as 32-bit versions. Deploying 32-bit applications on a 64-bit operating system leads to inefficient memory use. Microsoft and HP expect 50-100 per cent higher storage requirements for the 64-bit platform and up to 20 per cent higher processor load (cf. [Microsoft, 2005], pp. 12-17), as the processors are loaded additionally with translating from 32-bit to 64-bit data structures. These results are backed by a technical white paper from terminal server expert Dr. Bernhard Tritsch, who determined lower performance for identical server hardware with less than 16 GB running on a x64 operating system than on a x86 operating system (cf. [Tritsch, 2007-1]). Another study into the scalability of typical office programs identified up to 100 % higher assignment of memory space for some programs, which resulted in up to 50 % higher requirements for the user sessions (cf. Table 9-2 and [Tritsch, 2007-2], p. 15ff).

Table 9-3: Average memory requirements for 32-bit applications on 32-bit and 64-bit systems

	x86 (32-bit)	x64 (64-bit)	Increase
Microsoft Excel 2003	6.7 MB	13.6 MB	103 %
Microsoft PowerPoint 2003	1.8-2.2 MB	1.8-2.9 MB	18 %
Microsoft Word 2003	20.0 MB	26.0-27.0 MB	33 %
Session in total	30.0 MB	45.0 MB	50 %
Microsoft Excel 2007	16.0 MB	23.8 MB	49 %
Microsoft PowerPoint 2007	4.0 MB	3.8-7.0 MB	35 %
Microsoft Word 2007	22.0 MB	26.0 MB	18 %
Session in total	40.0 MB	55.0 MB	38 %

From these key figures we can see that, as a rule, x64 operating systems demonstrate their benefits only on suitable sized server hardware. Only systems with 4-8 processor cores and more than 16 GB memory in combination with a 64-bit operating system can be used more efficiently and allow more user sessions to be supported (cf. Figure 9-1).

Figure 9-1: Scalability of 32 and 64-bit systems (Source: [Tritsch, 2007-1])



Thus, the results of this study cannot simply be mapped on 64-bit systems. Therefore, if this topic is handled further, the focus should be on the question of how electricity consumption and general material and energy intensity of an IT infrastructure change if numerous small 32-bit terminal servers are replaced by fewer, more powerful 64-bit systems or BladeCenters[39].

In addition to direct use as a basis for Terminal Services, large 64-bit servers and BladeCenters can also be used as virtualization platforms, for example, to ex-

39 BladeCenters or blade servers are a chassis for numerous compact server trays that allow a much higher packing density than conventional server racks in 19" format (cf. http://www.heise.de/glossar/entry/86274f7572789b17)

pand the principle of server-based computing to areas in which thin clients cannot yet be used due to technical restrictions (cf. following section).

9.2 Virtualization

The various approaches to virtualize complete operating system instances or individual applications promise to save server hardware and energy in the data centre. The corresponding technologies are already available or will become established within the next one or two years. In a further evaluation of the ecological aspects of IT infrastructures the effects of virtualization technologies on the overall system should be considered. A distinction can be made between application streaming and application, server and desktop virtualization.

9.2.1 Application virtualization

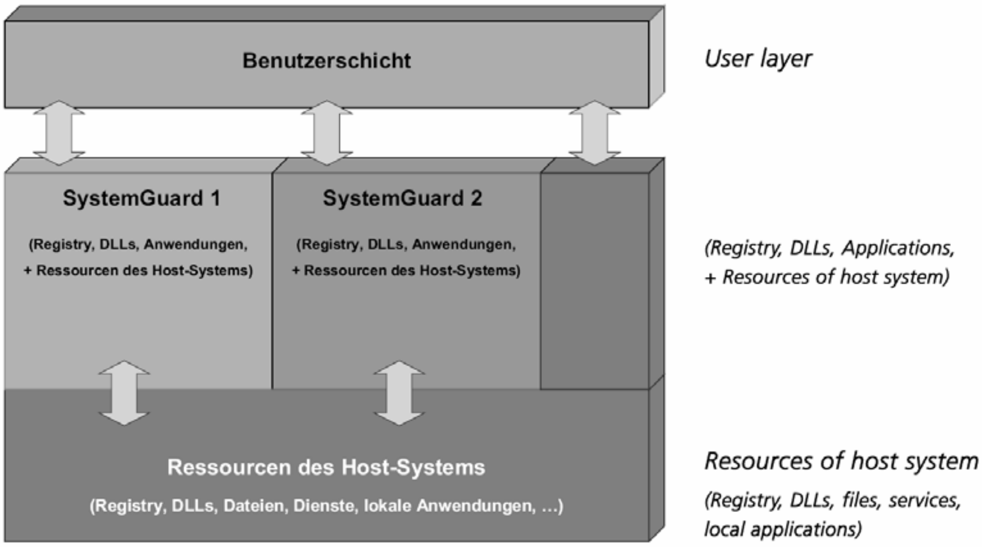
Virtualization of applications is an alternative to conventional local installation. If an application is installed locally on an operating system, it often anchors itself deep in the system. In case of installation on the Windows® platform, files are not only copied in the program directory, such as »C:\Programs\<Name of the application>«, but other files, such as function libraries and drivers, are also copied into the paths »C:\Windows« or »C:\Windows\System32«. This also applies to settings that the application writes in the registry.

Hence, it is difficult to uninstall an application from the system completely and without leaving any superfluous files. In practice it is also complicated or even impossible to run different programs that need different versions of a function library parallel to each other on a system. The same applies to different versions of an application. For instance, due to unavoidable interactions, with conventional installation it is not possible to install Microsoft® Office 2003 and Office 2007 or Internet Explorer 6 and 7 at the same time.

In the past, this has made it necessary to split terminal server farms into so-called »server silos«. Applications that are incompatible with each other are separated in the different silos. A process such as this even allows different program versions to be offered parallel to each other, but generally this leads to inefficient use of the resources. Numerous physical server systems are needed, although measured against the required computing performance, fewer systems would be sufficient. Material and energy intensity of the complete solution increases.

Virtualizing an application means installing it in an environment isolated from the operating system, in a so-called »sandbox«. This environment provides the application with a transparent view of the operating system resources (cf. Figure 9-2). Hence, the application is able to have write access to the registry and to save or change data in the system directory. Access is redirected by the virtualization solution. From the viewer's aspect the »sandbox« aggregates the operating system and the view which is virtualized for the application into a complete view. For example, an application can be assigned write rights in the system directory during runtime without actually having to allow it to access the operating system level. Applications that could only be executed in the past with administrator privileges can now also be deployed for normal user accounts, which increases the security and stability of the system.

Figure 9-2: Application virtualization with SoftGrid® (Source: [Lüdemann, 2007])



From ecological aspects, application virtualization promises to transfer programs to terminal servers which, in the past, needed standalone systems separated from the network for security reasons. Server silos can also be consolidated on fewer physical systems. The potential of these developments should be investigated and quantified in more detail when this topic is analyzed again in the future.

9.2.2 Application streaming

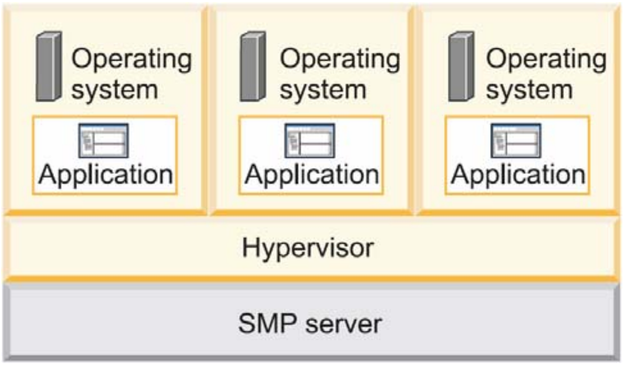
So-called application streaming is not so much a virtualization technology as a form of software distribution, which can show its full potential especially in combination with application virtualization. As known from conventional systems for automatic software distribution the applications are packeted. However, these packets are not installed permanently on the local client, but are executed in an isolated manner in a virtualized environment. The packets are optimized for transfer in the network and are then transferred to the client in such a way that the application can already be started before the complete packet is loaded. The client caches the packet locally so that the program can also be executed even if the network connection is interrupted.

This approach is a supplement to the known terminal server approach, as clients can also be provided centrally with applications that have no permanent connection to the network. The focus of future investigations should be the extent to which mobile clients could be provided with software completely or partially via streaming and whether it is possible to optimize the clients' hardware by replacing local hard disks with flash memories or solid-state disks in future, which only load the software that is required at the specific time via streaming.

9.2.3 Server virtualization

Virtualization of server instances can now be seen as an established standard on the market. The corresponding software products, such as the ones offered by Citrix Systems, VMware and Microsoft, abstract from the underlying hardware, using an instance known as a hypervisor and thus allow multiple operating systems to run simultaneously.

Figure 9-3: Virtualization with hypervisor (Source: IBM)



In terms of the ecological aspects the question must be asked whether it would be possible to consolidate multiple physical servers on one powerful piece of hardware and thus utilize the hardware capacity more efficiently. The energy and resource intensities of an infrastructure based on virtualization technologies must be evaluated.

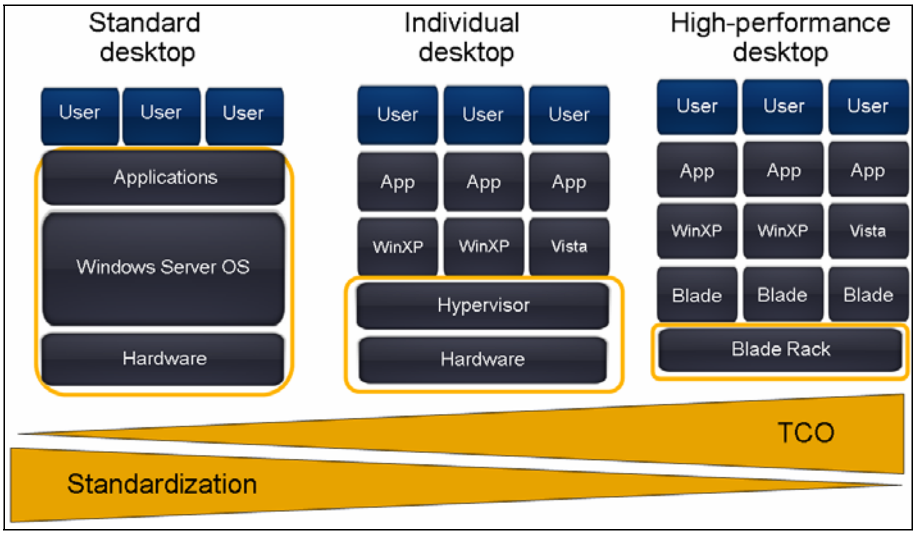
9.2.4 Desktop virtualization

There are two different forms of desktop virtualization. On the one hand, the term could refer to virtualization *on the* desktop and, on the other, to virtualization *of* desktops. Virtualization *on the* desktop means using a complete PC workstation as a host system to make multiple physical desktop systems for each employee superfluous. This should especially benefit developers and all employees who need different platforms. For instance, Windows® and Linux® or Windows® and Mac OS® could be consolidated on one hardware system.

But from an IT strategy aspect there is more potential in virtualization *of* desktops. This means moving resources into the data centre and central management. The traditional form of the **standard desktop**, the deployment of terminal servers and thin clients has already been investigated in this study and significant ecological and economical advantages were identified.

However, we know the current technological limitations – that especially power users cannot be completely provided with special software and higher performance demands in this manner. Against this background, technologies like Citrix XenDesktop™ are a promising extension of the terminal server concept. Instead of hosting multiple users sessions on one operating system with virtualization, it is possible to provide an **individual desktop** for each user on the server; in other words, a separate operating system instance, assuming special software requires this because, for example, it was not developed for multi-user operation, there are incompatibilities due to different versions or special security requirements do not allow it. If the criterion is maximum performance, this could also be mapped centrally via a **high-performance desktop** by not only giving every user a separate operating system instance but also dedicated hardware in the form of a blade in a blade server. In all cases a suitable device would be a thin client backed by various server systems in the data centre.

Figure 9-4: Different forms of desktop virtualization (Source: Citrix Systems)



In this way the use of thin clients could be extended to workplaces that, due to technical limitations, in the past required desktop PCs. It can be expected that with a change from the standard desktop to a high-performance desktop the material and energy intensities as well as running costs would increase, while the achievable degree of standardization would decrease (cf. Figure 9-4). Hence, future investigations in regard to ecological aspects should focus on how the different operating concepts behave compared to a conventional client-server solution on dedicated hardware. The objective of this should be to obtain a complete balance for a corresponding IT infrastructure so that recommendations for action can be derived for the sustainable development of future working environments.

9.3 Energy saving options at the workplace

Progress has been made in terms of energy saving potential at the workplace by thin client manufacturers and by traditional PC producers. This can, in part, be attributed to the increasingly restrictive limit values of voluntary labeling, such as the Energy Star, which are integrated in national procurement guidelines and thus become obligatory.

If all new computers had the Energy Star 4.0 categories A (50 watts, »idle«) and B (65 watts, »idle«) and consistently used energy saving modes, such as Suspend to RAM (STR) and Suspend to Disk (STD), these systems would use less energy than today's terminal server technology. However, this requires advances in the hardware and, especially, in the drivers, as in practice computers »awakening« from energy saving mode often do not function reliably, or an active computer incorrectly goes into idle mode although applications are still active [König, 2008]. Besides implementing technical boundary conditions, users must also be sensitized to use energy saving modes.

Within the scope of future ecological evaluation, energy-efficient PCs should be compared with advances in the development of thin clients. There are already some devices available on the market that just consume about 5 watts in operation. In addition, under the name of »zero clients« a new category of devices is being developed that need no local operating system and which, in combination with streaming technologies and virtualization on the server side could considerably reduce the total energy requirement of an IT infrastructure even more.

9.4 Citrix® PowerSmart

With its »Citrix® PowerSmart Utility for Presentation Server™«[40] Citrix developed a free help program for terminal servers. This is used to monitor the server with the objective of shutting down previously defined unused servers and restarting them at the start of the normal working hours.

The software is currently at the beta test stage and initially supports only HP servers. It is planned to extend the functionality to include servers that run as virtual machines. With this technology it would be possible to significantly reduce the energy consumption of a terminal server infrastructure and thus the share to be apportioned to the individual workstations.

40 http://www.citrix.com/powersmart

9.5 Thin clients in private households/»Web 2.0«

If thin clients are also to be used in the private sphere, naturally the corresponding server services are needed. However, operating a separate terminal server for one to five clients per household would be impractical from both ecological and economical aspects. If thin clients are also to become established here, the providers must offer suitable products. This could be the deployment of native Windows applications, traditional Terminal Services or suitable online services.

Suitable products, which implement traditional office applications, collaboration and groupware tools on a web basis, are currently being developed under the keyword »Web 2.0«. Examples of this are the online applications »Google Text & Tables«[41] and »Microsoft Office Live«[42] which is in the beta stage. When these platforms have passed through the beta phase, they can handle normal office requirements and can be operated with a thin client. Some of the hurdles that have to be overcome are of a technical and legal nature. After all, for a product such as this to be accepted it must be continuously available and be supplemented by additional services such as online backup and archiving. In addition, in terms of data protection, customers need the legal certainty that their information is treated confidentially by the respective provider. On the other hand, end customers must accept that their data is no longer stored locally. Although it is unlikely that PCs will be completely replaced in this way, it does represent an alternative product for users who want only to use basic office applications and web sites.

41 http://docs.google.com
42 http://www.officelive.com

10 Recommendations for action and outlook

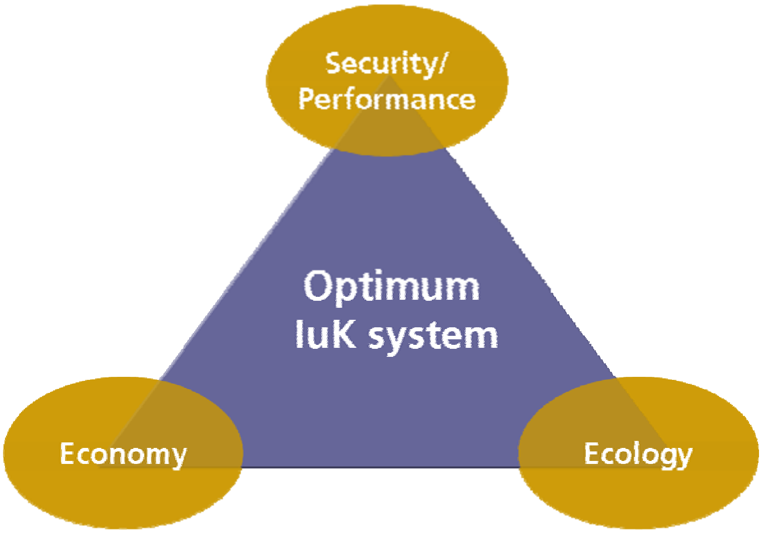
In the first environmental study carried out for IGEL Technology GmbH in 2006 it was decided that the biggest information gap in the ecological comparison between thin clients and PCs, but also in the ecological evaluation of computer components in general, was the bad data situation in terms of material and energy consumption in production and recycling/disposal. Much of this gap was closed with the methods and data developed within the scope of the 2007 EU project »Personal Computers (desktops and laptops) and Computer Monitors« [IVP, 2007], in which the corresponding data fundamentals were published with a lot of details. Important work for a strategic »Thin Clients« sustainability concept was carried out on the research side.

To summarize it can be said that from an ecological aspect and on the basis of the assumptions made here, the thin client systems from IGEL that were investigated here fare much better than the PC systems, but they are beaten by notebook systems which are used as workstations. However, only **one** decision-making criterion was considered – the ecological criterion.

But if you also consider the criteria of *economy* and *security/performance* – which would probably be the main criteria in any the economic decision process (cf. Fig. 10-1), this produces a completely different picture:

- Notebook systems are more expensive, more difficult to administer and require more maintenance than thin client systems.
- In terms of »central data security and backup« notebook systems have disadvantages and cannot be used as desktop systems in some industries.
- Notebooks are generally used in a completely different way to stationary desktop systems.
- Because of their mobility, technical features and general attraction notebooks are often stolen, which is usually associated with loss of sensitive or confidential data.

Figure 10-1: Decision-making triangle for optimum ICT systems



In other words, if we consider the decision-making triangle in Fig. 10-1 in relation to choosing optimum information and communication technology (ITC) systems, the overall strengths of the thin clients become obvious. This leads to a situation where, considering all three decision-making criteria, they are the preferred ITC system instead of PC or notebook systems.

In spite of this advantage, thin client systems receive little consideration in the procurement processes of companies and public authorities[43], which is reflected in the small market shares in comparison to conventional ITC systems. Even in the above-mentioned EU project, thin clients were considered only marginally. From a qualitative aspect the »image« of thin client systems amongst decision makers and users of ITC systems is still lagging behind that of PCs and notebooks.

But if progress in the direction of green IT goals is in the interest of public authorities, agreements should be made to include thin client systems in the **procurement guidelines** of public institutions (cf. Fig. 10-2). In this way the government could live up to its model role and, at the same time, help improve the widespread image of thin client systems and make them a preferred ITC solution. An **image campaign**, on the other hand, would have to be started in the marketing and PR area and be initiated by producers of thin client systems themselves.

[43] It can be assumed that thin clients do not yet play a part in the procurement processes in private households.

Figure 10-2: Environmental effects of infrastructure measures (Source: Computer Zeitung No. 6 / 04.02.08)

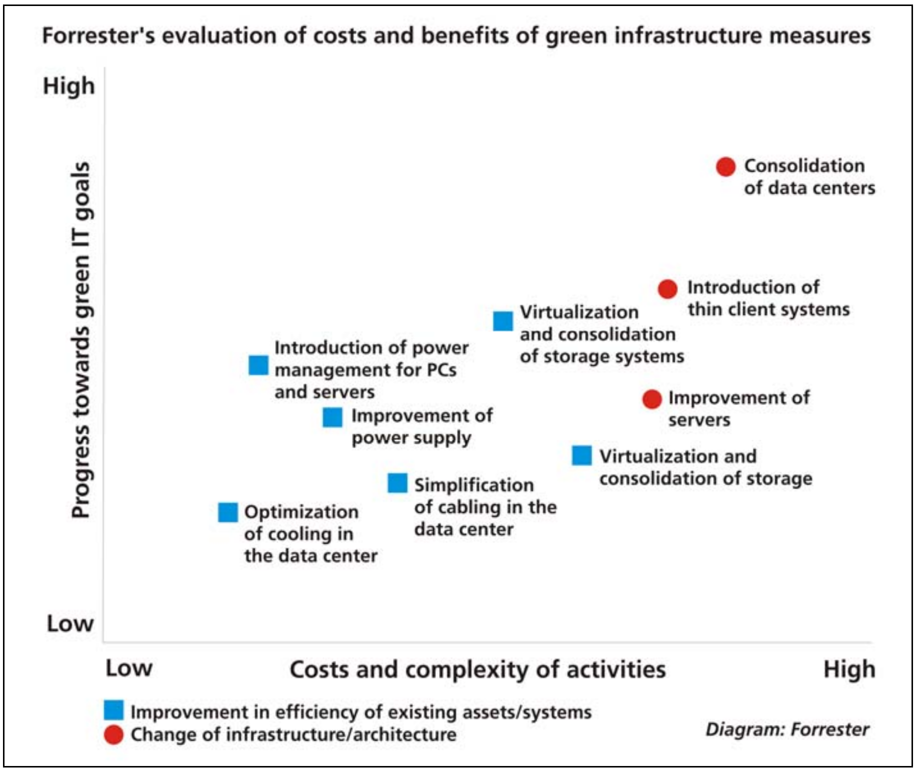


Fig. 10-2 shows that considerable ecological potentials can be expected to make IT infrastructures generally more efficient: for example, with energy-saving software and hardware systems and a reduction in the required cooling requirements (air conditioning) in data centers. Admittedly, together with the introduction of thin clients this assumes more expensive and more complex activities in the beginning, but, at the same time, much higher environmental effects can be expected than by simply optimizing existing components or systems.

In spite of this holistic, rather long-term development, the thin clients themselves also have ecological optimization potential; for instance, in regard to particularly environmentally relevant components (e.g. Cu/Ni/Cr coating on the rear panel).

The calculation results of this ecological comparison are based on plausible assumptions and user scenarios, many of which have been verified in practice. This produces a model with parameters, which can be »adjusted« specifically to suit the particular application. Knowledge of the influence of the parameter values (sensitivity analysis) on the results would be an important step towards increasing the resilience of the ecological comparison.

All investigations in this study refer to thin clients from IGEL Technology GmbH. Hence, the results of the ecological comparison apply only to these devices and cannot be generalized. It may be practical to investigate thin clients from competitors in collaboration with other manufacturers and, perhaps, BITKOM in order to obtain an expressive, resilient, overall result[44]. In this connection, the staff involved in the EU study should be contacted to compare the methodology, data and results. The thin client investigations could thus be presented in an international context and discourse. Perhaps these projects could be integrated into larger R&D programs under the auspices of the German federal government or the EU.

Against this background, recommendations for action for a strategic sustainability concept »Thin Clients« 2008 can be put into concrete terms as follows:

Table 10-2: Specific recommendations for action for a strategic sustainability concept »Thin Clients 2008«

Recommendations→ / Area ↓	Specific actions
Perception and propagation of thin clients	▪ Place thin client systems in procurement guidelines ▪ Carry out model projects with public institutions
Image	▪ Marketing/PR campaign to »raise awareness« in broad-based strata of the population (also decision makers) ▪ Explain the thin client concept on a level that is generally understood (perhaps with BITKOM)
Ecological optimization of thin clients (medium-term)	▪ Design for environment – LC-oriented* → Replace especially environmentally relevant components, reduce the amount of material ▪ Energy efficiency – LC-oriented* ▪ Energy-saving default settings in thin clients
Ecological optimization of the entire IT infrastructure (longer-term)	▪ Energy-saving software and hardware systems for networks ▪ Reduce the number of network components ▪ Reduce the necessary cooling requirements in data centers
Research and development	▪ Sensitivity analysis for a model for an ecological comparison of thin clients ▪ Investigate competitors' thin client systems ▪ Extend contact and cooperate with partners of the EU study to compare methodology, data and results ▪ Develop larger R&D projects (national, EU-level)

* LC: Life Cycle

44 In many cases, thin clients have very different features, simply due to industry-specific solutions (e.g. with or without smartcard reader).

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13 Abbreviations and list of symbols

A	Ampere
Fig.	Figure
ABS	Acrylonitrile butadiene styrene (plastic)
AP	Acidification potential, measured in SO_2 equivalents
Big caps & coils	Capacitors and coils (electronic elements to convert electrical current)
cm	Centimeter
CD-RW	Compact Disc – ReWritable
CF	Compact Flash
CO_2	Carbon dioxide
CO_2eq	CO_2 equivalent
CRT	Cathode Ray Tube (CRT monitor)
Deca-DBE	Deca-brominated diphenyl ether (flame retardant)
DVD-ROM	Digital Versatile Disk – Read Only Memory
DVD-RW	Digital Versatile Disc – ReWriteable
ElektroG	German Electrical and Electronic Equipment Act
EPA	Environmental Protection Agency (US authority)
EPS	Expanded polystyrene
ERP	Enterprise Resource Planning
etc.	Et cetera
EuP	Energy using products
EU	European Union
EUP	Eutrophication potential
FHC	Fluorinated hydrocarbon
GB	Gigabyte
GER	Gross energy requirement, measured in MJ
GHz	Gigahertz
GUI	Graphical User Interface
GWP	Global Warming Potential
h	Hour
HFC	Hydrofluorocarbon
ICA	Independent Computing Architecture
IDE	Integrated Drive Electronics

IPCC	Intergovernmental Panel on Climate Change
Hg	Mercury
HM	Heavy metals
HP	Hewlett-Packard
kg	Kilogram
km	Kilometer
KrW-/AbfG	German Closed Substance Cycle and Waste Management Act
kW	Kilowatt
l	Liter
LCD	Liquid Crystal Display, corresponds to TFT screens
LDPE	Low Density Polyethylene (plastic)
LED	Light Emitting Diode
M	Mega
MB	Megabyte
m^3	Cubic meter
mA	Milliampere
nag	Nanogram
mg	Milligram
mm	Millimeter
PA 6	Polyamide (plastic)
PAH	Polycyclic Aromatic Hydrocarbons
PC	Personal Computer
PC	Polycarbonate (plastic)
PCB	Printed Circuit Board
PF	Power Factor
PM	Particulate Matter
POP	Persistent Organic Pollutants
ppm	Parts per million
PTE	Page Table Entries
PUR	Polyurethane (plastic)
PWB	Printed Wiring Board
RAM	Random Access Memory
RDP	Remote Desktop Protocol
RoHS	Restriction of the use of certain hazardous substances in electrical and electronic equipment

rpm	Rounds per minute
SATA	Serial Advanced Technology Attachment
SBC	Server Based Computing
SDRAM	Synchronous Dynamic Random Access Memory
SMD	Surface-mounted Device (e.g. resistors and capacitors)
SO_2	Sulfur dioxide
SO_2eq	SO_2 equivalent (acidification potential)
STD	Suspend to Disk
STR	Suspend to RAM
t	Metric ton
T	Tera
TCO	Tjänstemännens Central Organisation
TCP/IP	Transmission Control Protocol/Internet Protocol
TEHG	German Greenhouse Gas Emission Entitlements Trading Act
TEQ	Toxicity equivalent (here, for example dioxins and furans are evaluated according to their toxicity, so that a total can be formed)
TFT	Thin Film Transistor (flat screen)
incl.	Including
UBA	German Federal Environment Agency
VA	Volt ampere (apparent power)
cf.	Compare
VOC	Volatile Organic Compounds
W	Watt (effective power)
WEEE	Waste from Electric and Electronic Equipment
e.g.	For example
%	Per cent
Σ	Total
Ø	Average
"	Inch (2.54 cm), e.g. 17" monitor

14 Annex

The Annex contains enlarged versions of the tables given in chapter 6.

Table 6-2: Environmental impact caused by the production of an office desktop PC; calculations according to MEEUP[45]

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS

EuP EcoReport: RAW OUTPUTS
Assessment of Environmental Impact

Nr: 0 **Product:** Office Desktop PC **Date:** 2008-Feb-06 **Author:** Übertrag Anhang 2 EuP-

MATERIALS EXTRACTION & PRODUCTION

Product					Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	material	GER	electr	feedst	water (proces	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	LDPE	246	1-BlkPlastics	1-LDPE	19,14	3,27	12,68	0,74	11,07	1,09	10,87	0,47	1,83	0,12	0,00	0,00	0,03	0,23	0,00	6,55
2	ABS	380,75	1-BlkPlastics	10-ABS	36,18	2,65	17,43	3,54	62,82	3,81	35,00	1,26	6,77	0,00	0,00	0,00	0,69	1,10	0,74	239,81
3	PA 6	137,68	2-TecPlastics	11-PA 6	16,45	2,08	5,36	2,20	30,15	2,62	24,27	1,18	5,38	0,00	0,00	0,00	0,06	0,74	6,75	257,78
4	PC	264,25	2-TecPlastics	12-PC	30,87	3,93	10,04	3,70	30,12	2,64	46,65	1,43	6,72	0,00	0,00	0,00	0,10	1,77	0,04	133,19
5	Epoxy	97,9	2-TecPlastics	14-Epoxy	13,78	2,40	4,17	1,86	37,59	1,86	39,80	0,65	4,30	0,00	0,00	0,00	0,01	1,47	0,00	944,72
6	Flex PUR	1,5	2-TecPlastics	16-Flex PUR	0,16	0,03	0,06	0,11	0,45	0,05	0,82	0,01	0,05	0,00	0,00	0,00	0,03	0,01	0,01	8,53
7	Steel sheet galvanized	6312,3	3-Ferro	21-St sheet galv.	214,62	14,38	0,47	0,00	0,00	0,00	10866,75	17,85	47,12	0,86	164,12	22,37	0,44	17,09	22,41	411,37
8	Steel tube / profile	106,5	3-Ferro	22-St tube/profile	1,81	0,49	-0,02	0,00	0,00	0,00	85,27	0,15	0,38	0,01	1,28	0,28	0,00	0,11	0,17	4,08
9	Cast iron	482,5	3-Ferro	23-Cast iron	4,83	0,07	-0,03	0,63	1,77	0,00	152,16	0,51	1,56	0,06	2,90	0,96	0,01	6,76	0,44	12,66
10	Ferrite	0	3-Ferro	24-Ferrite	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
11	Stainless 18/8 coil	9,5	3-Ferro	25-Stainless 18/8 coil	0,59	0,09	0,04	0,72	0,08	0,00	9,50	0,06	0,53	0,00	0,07	1,41	0,00	0,08	0,82	22,12
12	Al sheet/ extrusion	314,53	4-Non-ferro	26-Al sheet/extrusion	60,59	0,00	0,00	0,00	0,00	0,00	1232,96	3,25	21,17	0,02	1,57	1,14	30,36	5,32	11,01	1,56
13	Al diecast	15	4-Non-ferro	27-Al diecast	0,83	0,00	0,00	0,00	0,00	0,00	11,25	0,05	0,23	0,00	0,50	0,01	0,27	0,06	0,10	0,02
14	Cu winding wire	257	4-Non-ferro	28-Cu winding wire	36,68	0,00	0,00	0,00	0,00	0,21	5150,28	1,89	78,09	0,01	1,02	14,53	1,42	0,78	1,66	40,66
15	Cu wire	333,5	4-Non-ferro	29-Cu wire	38,87	0,00	0,00	0,00	0,00	0,08	6674,00	2,07	97,42	0,00	1,25	18,36	1,79	0,95	31,38	51,53
16	Cu tube/sheet	66,5	4-Non-ferro	30-Cu tube/sheet	3,39	0,00	0,00	0,00	0,00	0,00	532,93	0,18	4,16	0,00	0,68	2,20	0,36	0,10	2,50	4,12
17	Powder coating	1,62	5-Coating	39-powder coating	0,58	0,10	0,07	0,03	0,62	0,03	0,80	0,03	0,10	0,00	0,00	0,00	0,00	0,02	0,00	15,64
18	Big caps & coils	482,5	6-Electronics	44-big caps & coils	184,93	0,00	0,00	16,72	26,54	9,46	289,76	10,46	68,43	0,06	1,04	3,70	98,74	17,18	35,81	3,44
19	Slots / ext. Ports	310	6-Electronics	45-slots / ext. ports	57,99	18,39	0,00	23,14	79,16	5,30	95,38	3,11	57,15	0,00	0,43	11,78	0,60	4,02	9,86	2005,62
20	Integrated Circuits, 5% Silicon, Au	69	6-Electronics	46-IC's avg., 5% Si, Au	380,14	369,73	0,00	346,17	0,00	17,38	357,52	29,22	192,33	4,68	3,37	30,81	1,01	5,03	258,06	1482,19
21	Integrated Circuits, 1% Silicon	95,5	6-Electronics	47-IC's avg., 1% Si	83,48	64,29	0,29	58,40	9,89	61,56	166,96	5,62	77,95	0,00	0,94	17,67	0,28	2,31	0,92	410,30
22	SMD & LEDs avg.	193,5	6-Electronics	48-SMD/ LED's avg.	574,47	558,36	0,00	179,07	0,00	25,29	547,78	32,32	313,56	1,45	2,90	81,60	0,88	9,83	2,85	424,83
23	PWB 1/2 lay 3,75 kg/m²	78	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	21,92	11,74	0,67	13,26	5,99	135,19	204,78	0,88	16,67	0,18	0,21	2,82	0,28	0,40	1,15	287,54
24	PWB 6 lay 4,5 kg/m²	162,5	6-Electronics	50-PWB 6 lay 4.5 kg/m2	59,67	23,75	1,39	78,82	12,48	307,42	661,91	2,55	64,35	0,17	0,83	11,38	1,12	6,02	20,38	396,95
25	Solder SnAg4Cu0,5	48	6-Electronics	52-Solder SnAg4Cu0.5	11,23	9,30	0,00	3,37	0,00	0,22	10,94	0,56	3,10	0,00	0,06	0,16	0,09	0,07	0,00	0,29
26	Cardboard	2286,5	7-Misc.	56-Cardboard	64,02	4,57	36,58	16,11	0,00	0,11	119,62	1,61	2,38	0,00	0,03	0,08	0,01	0,03	0,03	196,78
	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	0	1 917,21	1089,61	89,19	748,60	308,74	574,30	27327,97	117,33	1071,72	7,63	183,20	221,27	138,57	138,57	81,46	407,10

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Table 6-4: Environmental impact from the production of a notebook; calculations according to MEEUP[46]

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ECO-DESIGN OF ENERGY-USING PRODUCTS — EuP EcoReport: RAW OUTPUTS — Assessment of Environmental Impact

Nr: 0 — **Product:** Laptops at home — **Date:** 2008-Feb-06 — **Author:** Übertrag Anhang 2 EuP-

MATERIALS EXTRACTION & PRODUCTION

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	material	GER	electr	feedst	water (proces	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	LDPE	43	1-BlkPlastics	1-LDPE	3,35	0,57	2,22	0,13	1,94	0,19	1,90	0,08	0,32	0,02	0,00	0,00	0,01	0,04	0,00	1,14
2	PP	4	1-BlkPlastics	4-PP	0,29	0,03	0,21	0,02	0,16	0,02	0,11	0,01	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,66
3	PS	2,6667	1-BlkPlastics	5-PS	0,23	0,01	0,13	0,01	0,47	0,00	0,06	0,01	0,05	0,00	0,00	0,00	0,32	0,00	0,00	0,15
4	EPS	50,333	1-BlkPlastics	6-EPS	4,21	0,17	2,41	0,29	8,86	0,05	1,91	0,14	0,91	0,00	0,00	0,00	3,06	0,09	0,00	6,27
5	PVC	23,333	1-BlkPlastics	8-PVC	1,32	0,26	0,54	0,26	1,45	0,12	1,57	0,05	0,35	0,00	0,00	0,00	0,00	0,07	0,07	7,33
6	ABS	141,83	1-BlkPlastics	10-ABS	13,48	0,99	6,49	1,32	23,40	1,42	13,04	0,47	2,52	0,00	0,00	0,00	0,26	0,41	0,28	89,33
7	PA 6	280,54	2-TecPlastics	11-PA 6	33,53	4,24	10,92	4,49	61,44	5,33	49,45	2,40	10,95	0,00	0,00	0,00	0,11	1,51	13,75	525,25
8	PC	267,1	2-TecPlastics	12-PC	31,20	3,97	10,15	3,74	30,45	2,67	47,16	1,44	6,79	0,00	0,00	0,00	0,10	1,79	0,04	134,62
9	PMMA	36,333	2-TecPlastics	13-PMMA	4,00	0,48	1,52	0,36	0,94	0,05	3,81	0,22	1,58	0,00	0,00	0,00	0,00	0,19	0,10	75,14
10	Epoxy	2,6667	2-TecPlastics	14-Epoxy	0,38	0,07	0,11	0,05	1,02	0,05	1,08	0,02	0,12	0,00	0,00	0,00	0,00	0,04	0,00	25,73
11	Stell sheet galvanized	489,23	3-Ferro	21-St sheet galv.	16,63	1,11	0,04	0,00	0,00	0,00	842,22	1,38	3,65	0,07	12,72	1,73	0,03	1,32	1,74	31,88
12	Al sheet/ extrusion	37,9	4-Non-ferro	26-Al sheet/extrusion	7,30	0,00	0,00	0,00	0,00	0,00	148,57	0,39	2,55	0,00	0,19	0,14	3,66	0,64	1,33	0,19
13	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
14	Cu wire	60	4-Non-ferro	29-Cu wire	6,99	0,00	0,00	0,00	0,00	0,01	1200,72	0,37	17,53	0,00	0,22	3,30	0,32	0,17	5,65	9,27
15	Cu tube/sheet	15,2	4-Non-ferro	30-Cu tube/sheet	0,77	0,00	0,00	0,00	0,00	0,00	121,81	0,04	0,95	0,00	0,16	0,50	0,08	0,02	0,57	0,94
16	MgZn5 cast	121,67	4-Non-ferro	33-MgZn5 cast	19,69	0,00	0,00	14,42	1,59	0,68	582,31	2,24	5,48	0,01	3,33	0,32	5,93	1,11	2,18	0,44
17	Powder coating	4,7933	5-Coating	39-powder coating	1,71	0,29	0,20	0,09	1,84	0,10	2,36	0,09	0,30	0,00	0,00	0,01	0,00	0,07	0,00	46,27
18	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
19	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
20	LCD screnn m² (viewable screen size)	63,167	6-Electronics	42-LCD per m2 scrn	225,08	143,39	0,00	2,84	42,32	0,06	3,28	11,64	3,74	0,03	0,02	0,05	0,01	0,04	0,02	0,00
21	Big caps & coils	501	6-Electronics	44-big caps & coils	192,03	0,00	0,00	17,36	27,56	9,82	300,87	10,86	71,05	0,06	1,08	3,84	102,53	17,84	37,19	3,58
22	Slots / external Ports	132,93	6-Electronics	45-slots / ext. ports	24,87	7,88	0,00	9,92	33,95	2,27	40,90	1,33	24,51	0,00	0,19	5,05	0,26	1,72	4,23	860,02
23	Integrated Circuits, 5% Silicon, Au	46,833	6-Electronics	46-IC's avg., 5% Si, Au	258,02	250,95	0,00	234,96	0,00	11,79	242,66	19,83	130,54	3,17	2,29	20,91	0,69	3,41	175,16	1006,02
24	Integrated Circuits, 1% Silicon	31,167	6-Electronics	46-IC's avg., 5% Si, Au	171,71	167,01	0,00	156,37	0,00	7,85	161,49	13,20	86,87	2,11	1,52	13,92	0,46	2,27	116,56	669,50
25	SMD & LED avg	50,267	6-Electronics	47-IC's avg., 1% Si	43,94	33,84	0,15	30,74	5,21	32,40	87,88	2,96	41,03	0,00	0,49	9,30	0,15	1,21	0,48	215,96
26	PWB 1/2 lay 3,75 kg/m2	4,8	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	1,35	0,72	0,04	0,82	0,37	8,32	12,60	0,05	1,03	0,01	0,01	0,17	0,02	0,02	0,07	17,69
27	PWB 6 lay 4,5 kg/m²	76,867	6-Electronics	50-PWB 6 lay 4.5 kg/m2	28,22	11,24	0,66	37,28	5,90	145,42	313,10	1,21	30,44	0,08	0,39	5,39	0,53	2,85	9,64	187,77
28	Solder SnAg4Cu0,5	6,9667	6-Electronics	52-Solder SnAg4Cu0.5	1,63	1,35	0,00	0,49	0,00	0,03	1,59	0,08	0,45	0,00	0,01	0,02	0,01	0,01	0,00	0,04
29	Glass for lamps	0,6667	7-Misc.	54-Glass for lamps	0,01	0,01	0,00	0,01	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
30	Cardboard	921	7-Misc.	56-Cardboard	25,79	1,84	14,74	6,49	0,00	0,04	48,18	0,65	0,96	0,00	0,01	0,03	0,00	0,01	0,01	79,26
31	Glass for LCD	362,33	7-Misc.	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
32	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	0	1 117,72	630,41	50,51	522,45	248,86	228,70	4230,64	71,15	444,69	5,57	22,63	64,69	118,54	118,54	36,88	369,06

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Table 6-6: Environmental impact from the production of a 17" LCD monitor; calculations according to MEEUP[47]

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS — EuP EcoReport: RAW OUTPUTS, Assessment of Environmental Impact

Nr: 0 | Product: | Date: 08.02.08 | Author: Copy Annex II of EuP St

MATERIALS EXTRACTION & PRODUCTION

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	material	GER	electr	feedst	water (proces	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	LDPE	164	1-BlkPlastics	1-LDPE	12,76	2,18	8,45	0,49	7,38	0,73	7,25	0,31	1,22	0,08	0,00	0,00	0,02	0,15	0,00	4,37
2	EPS	278,7	1-BlkPlastics	6-EPS	23,32	0,94	13,32	1,59	49,05	0,26	10,55	0,75	5,05	0,00	0,00	0,00	16,96	0,50	0,00	34,73
3	PVC	42,8	1-BlkPlastics	8-PVC	2,42	0,48	0,98	0,47	2,65	0,21	2,87	0,09	0,64	0,00	0,00	0,00	0,00	0,12	0,12	13,44
4	ABS	679,1	1-BlkPlastics	10-ABS	64,53	4,72	31,08	6,32	112,05	6,79	62,43	2,25	12,07	0,00	0,00	0,00	1,23	1,97	1,32	427,73
5	PA 6	422,22	2-TecPlastics	11-PA 6	50,46	6,39	16,43	6,76	92,47	8,02	74,42	3,61	16,48	0,00	0,00	0,00	0,17	2,28	20,70	790,51
6	PC	384,75	2-TecPlastics	12-PC	44,94	5,72	14,62	5,39	43,86	3,85	67,93	2,07	9,78	0,00	0,00	0,00	0,14	2,58	0,06	193,92
7	PMMA	152,85	2-TecPlastics	13-PMMA	16,84	2,00	6,39	1,50	3,97	0,21	16,01	0,92	6,66	0,00	0,00	0,00	0,00	0,78	0,43	316,10
8	E-glass fibre	119,75	2-TecPlastics	18-E-glass fibre	7,88	2,53	1,29	6,50	32,49	0,84	37,27	0,40	3,49	0,00	0,00	0,00	0,01	0,98	5,67	377,38
9	Armid fibre	6,5	2-TecPlastics	19-Aramid fibre	1,67	0,53	0,27	1,38	6,88	0,18	7,89	0,09	0,74	0,00	0,00	0,00	0,00	0,21	1,20	79,89
10	Steel sheet galvanized	1854	3-Ferro	21-St sheet galv.	63,04	4,22	0,14	0,00	0,00	0,00	3191,70	5,24	13,84	0,25	48,20	6,57	0,13	5,02	6,58	120,82
11	Al sheet/ extrusion	39	4-Non-ferro	26-Al sheet/extrusion	7,51	0,00	0,00	0,00	0,00	0,00	152,88	0,40	2,62	0,00	0,19	0,14	3,76	0,66	1,37	0,19
12	Cu wire	189,6	4-Non-ferro	29-Cu wire	22,10	0,00	0,00	0,00	0,00	0,05	3794,28	1,18	55,38	0,00	0,71	10,44	1,02	0,54	17,84	29,30
13	Powder coating	1,03	5-Coating	39-powder coating	0,37	0,06	0,04	0,02	0,40	0,02	0,51	0,02	0,06	0,00	0,00	0,00	0,00	0,02	0,00	9,94
14	LCD screen m² (viewable screen size)	91,3	6-Electronics	42-LCD per m2 scrn	325,32	207,25	0,00	4,11	61,17	0,09	4,75	16,83	5,40	0,04	0,03	0,07	0,01	0,05	0,03	0,00
15	Big caps & coils	41,35	6-Electronics	44-big caps & coils	15,85	0,00	0,00	1,43	2,27	0,81	24,83	0,90	5,86	0,01	0,09	0,32	8,46	1,47	3,07	0,30
16	Slots /ext. ports	36,55	6-Electronics	45-slots / ext. ports	6,84	2,17	0,00	2,73	9,33	0,62	11,25	0,37	6,74	0,00	0,05	1,39	0,07	0,47	1,16	236,47
17	Integrated Circuits, 5% Silcon, Au	12,85	6-Electronics	46-IC's avg., 5% Si, Au	70,79	68,86	0,00	64,47	0,00	3,24	66,58	5,44	35,82	0,87	0,63	5,74	0,19	0,94	48,06	276,03
18	Integrated Circuits, 1% Silicon	20,35	6-Electronics	47-IC's avg., 1% Si	17,79	13,70	0,06	12,44	2,11	13,12	35,58	1,20	16,61	0,00	0,20	3,76	0,06	0,49	0,20	87,43
19	SMD & LEDs avg	10,7	6-Electronics	48-SMD/ LED's avg.	31,77	30,88	0,00	9,90	0,00	1,40	30,29	1,79	17,34	0,08	0,16	4,51	0,05	0,54	0,16	23,49
20	PWB 1/2 lay 3,75 kg/m²	30	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	8,43	4,52	0,26	5,10	2,30	52,00	78,76	0,34	6,41	0,07	0,08	1,08	0,11	0,15	0,44	110,59
21	PWB 6 lay 4,5 kg/m²	19,6	6-Electronics	50-PWB 6 lay 4.5 kg/m2	7,20	2,86	0,17	9,51	1,51	37,08	79,84	0,31	7,76	0,02	0,10	1,37	0,13	0,73	2,46	47,88
22	Solder SnAg4Cu0,5	7,55	6-Electronics	52-Solder SnAg4Cu0.5	1,77	1,46	0,00	0,53	0,00	0,03	1,72	0,09	0,49	0,00	0,01	0,03	0,01	0,01	0,00	0,05
23	Glass for lamps	26	7-Misc.	54-Glass for lamps	0,42	0,34	0,00	0,22	0,00	0,01	0,35	0,02	0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,01
24	Cardboard	650	7-Misc.	56-Cardboard	18,20	1,30	10,40	4,58	0,00	0,03	34,01	0,46	0,68	0,00	0,01	0,02	0,00	0,01	0,01	55,94
25	Office paper	54,5	7-Misc.	57-Office paper	2,18	0,33	1,47	4,15	0,00	0,02	3,68	0,03	0,27	0,01	0,00	0,01	0,00	0,09	0,00	288,22
26	Misc glass	307,6	7-Misc.	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
27	Cast iron	1165	3-Ferro	23-Cast iron	11,65	0,16	-0,07	1,51	4,26	0,00	367,39	1,23	3,77	0,14	6,99	2,31	0,02	16,31	1,06	30,56
	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	0	836,04	363,58	105,31	151,09	434,16	129,61	8165,00	46,34	235,29	1,58	57,46	37,77	32,56	32,56	37,07	111,93

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Table 6-8: Environmental impact from the production of a 17"CRT monitor; calculations according to MEEUP[48]

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS — EuP EcoReport: RAW OUTPUTS — Assessment of Environmental Impact

Nr: 0 — Product: — Date: 08.02.08 — Author: Copy Annex II of EuP St

MATERIALS EXTRACTION & PRODUCTION

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	material	GER	electr	feedst	water (proces	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	EPS	165	1-BlkPlastics	6-EPS	13,80	0,56	7,89	0,94	29,04	0,15	6,25	0,45	2,99	0,00	0,00	0,00	10,04	0,30	0,00	20,56
2	PVC	43,8	1-BlkPlastics	8-PVC	2,48	0,49	1,00	0,48	2,72	0,22	2,94	0,09	0,66	0,00	0,00	0,00	0,00	0,13	0,12	13,75
3	ABS	1754,8	1-BlkPlastics	10-ABS	166,74	12,20	80,32	16,32	289,54	17,55	161,31	5,83	31,18	0,00	0,00	0,00	3,17	5,09	3,40	1105,25
4	PA 6	447,47	2-TecPlastics	11-PA 6	53,48	6,77	17,41	7,16	98,00	8,50	78,88	3,83	17,47	0,00	0,00	0,00	0,18	2,42	21,93	837,79
5	PC	0,55	2-TecPlastics	12-PC	0,06	0,01	0,02	0,01	0,06	0,01	0,10	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,28
6	Steel sheet galvanized	126	3-Ferro	21-St sheet galv.	4,28	0,29	0,01	0,00	0,00	0,00	216,91	0,36	0,94	0,02	3,28	0,45	0,01	0,34	0,45	8,21
7	Al sheet / extrusion	14	4-Non-ferro	26-Al sheet/extrusion	2,70	0,00	0,00	0,00	0,00	0,00	54,88	0,14	0,94	0,00	0,07	0,05	1,35	0,24	0,49	0,07
8	Cu wire	222,2	4-Non-ferro	29-Cu wire	25,90	0,00	0,00	0,00	0,00	0,05	4446,67	1,38	64,91	0,00	0,83	12,23	1,20	0,63	20,91	34,33
9	Powder coating	6,03	5-Coating	39-powder coating	2,15	0,37	0,26	0,11	2,32	0,12	2,97	0,11	0,38	0,00	0,00	0,01	0,00	0,09	0,00	58,20
10	CRT screen m² (nominal screen size)	90,2	6-Electronics	43-CRT per m2 scrn	285,84	192,22	0,00	26,18	0,00	4,42	222,61	15,42	97,15	72,25	1,26	84,16	0,00	254,63	1,26	56,80
11	Big caps & coils	37,5	6-Electronics	44-big caps & coils	14,37	0,00	0,00	1,30	2,06	0,74	22,52	0,81	5,32	0,00	0,08	0,29	7,67	1,34	2,78	0,27
12	Slots / external ports	40	6-Electronics	45-slots / ext. ports	7,48	2,37	0,00	2,99	10,21	0,68	12,31	0,40	7,37	0,00	0,06	1,52	0,08	0,52	1,27	258,79
13	Integrated Circuits, 5 % Silicon, Au	17	6-Electronics	46-IC's avg., 5% Si, Au	93,66	91,09	0,00	85,29	0,00	4,28	88,08	7,20	47,38	1,15	0,83	7,59	0,25	1,24	63,58	365,18
14	Integrated Circuits, 1 % Silicon	13,5	6-Electronics	47-IC's avg., 1% Si	11,80	9,09	0,04	8,25	1,40	8,70	23,60	0,79	11,02	0,00	0,13	2,50	0,04	0,33	0,13	58,00
15	SMD & LEDs avg	12,5	6-Electronics	48-SMD/ LED's avg.	37,11	36,07	0,00	11,57	0,00	1,63	35,39	2,09	20,26	0,09	0,19	5,27	0,06	0,64	0,18	27,44
16	PWB 1/2 lay 3,75 kg/m²	96	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	26,98	14,45	0,82	16,32	7,37	166,39	252,03	1,08	20,52	0,22	0,26	3,47	0,34	0,49	1,42	353,90
17	PWB 6 lay 4,5 kg/m²	23,5	6-Electronics	50-PWB 6 lay 4.5 kg/m2	8,63	3,43	0,20	11,40	1,80	44,46	95,72	0,37	9,31	0,02	0,12	1,65	0,16	0,87	2,95	57,40
18	Solder SnAg4Cu0,5	11	6-Electronics	52-Solder SnAg4Cu0.5	2,57	2,13	0,00	0,77	0,00	0,05	2,51	0,13	0,71	0,00	0,01	0,04	0,02	0,02	0,00	0,07
19	Glass for lamps	6,5	7-Misc.	54-Glass for lamps	0,11	0,08	0,00	0,06	0,00	0,00	0,09	0,01	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00
20	Cardboard	1880	7-Misc.	56-Cardboard	52,64	3,76	30,08	13,25	0,00	0,09	98,36	1,32	1,95	0,00	0,02	0,06	0,01	0,02	0,02	161,80
21	Office paper	280	7-Misc.	57-Office paper	11,20	1,68	7,56	21,32	0,00	0,09	18,91	0,16	1,41	0,06	0,01	0,03	0,00	0,46	0,01	1480,75
22	Misc glass	11110	7-Misc.	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
23	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	0	824,00	377,05	145,61	223,72	444,52	258,14	5843,03	41,96	341,90	73,83	7,16	119,31	24,58	24,58	269,78	120,92

Table 6-10: Environmental impact from the production of an Igel Compact; calculations according to MEEUP[49]

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS — EuP EcoReport: RAW OUTPUTS — Assessment of Environmental Impact

Nr: 0 — Product: 0 — Date: 00.01.00 — Author: 0

MATERIALS EXTRACTION & PRODUCTION

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	material	GER	electr	feedst	water (proces	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	M/B	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
2	PCB	112	6-Electronics	50-PWB 6 lay 4.5 kg/m2	41,12	16,37	0,96	54,33	8,60	211,88	456,21	1,76	44,35	0,11	0,57	7,85	0,77	4,15	14,05	273,59
3	Conn CF	2,48	6-Electronics	45-slots / ext. ports	0,46	0,15	0,00	0,19	0,63	0,04	0,76	0,02	0,46	0,00	0,00	0,09	0,00	0,03	0,08	16,04
4	Socket DDR2	5,4	6-Electronics	45-slots / ext. ports	1,01	0,32	0,00	0,40	1,38	0,09	1,66	0,05	1,00	0,00	0,01	0,21	0,01	0,07	0,17	34,94
5	Socket BIOS	1	6-Electronics	45-slots / ext. ports	0,19	0,06	0,00	0,07	0,26	0,02	0,31	0,01	0,18	0,00	0,00	0,04	0,00	0,01	0,03	6,47
6	IC SI164	0,25	6-Electronics	47-IC's avg., 1% Si	0,22	0,17	0,00	0,15	0,03	0,16	0,44	0,01	0,20	0,00	0,00	0,05	0,00	0,01	0,00	1,07
7	IC VT1612A	1	6-Electronics	47-IC's avg., 1% Si	0,87	0,67	0,00	0,61	0,10	0,64	1,75	0,06	0,82	0,00	0,01	0,19	0,00	0,02	0,01	4,30
8	IC W83697	2	6-Electronics	47-IC's avg., 1% Si	1,75	1,35	0,01	1,22	0,21	1,29	3,50	0,12	1,63	0,00	0,02	0,37	0,01	0,05	0,02	8,59
9	IC ICS9P936AF	0,22	6-Electronics	47-IC's avg., 1% Si	0,19	0,15	0,00	0,13	0,02	0,14	0,38	0,01	0,18	0,00	0,00	0,04	0,00	0,01	0,00	0,95
10	IC TTL SN74LVC2G74	0,0043	6-Electronics	47-IC's avg., 1% Si	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
11	IC TTL 74HC14	0,0043	6-Electronics	47-IC's avg., 1% Si	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
12	IC TTL SN74AHC1G125DBVR	0,0043	6-Electronics	47-IC's avg., 1% Si	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,02
13	IC UTL75232L	0,235	6-Electronics	47-IC's avg., 1% Si	0,21	0,16	0,00	0,14	0,02	0,15	0,41	0,01	0,19	0,00	0,00	0,04	0,00	0,01	0,00	1,01
14	IC CPU Eden 600MHz	2	6-Electronics	46-IC's avg., 5% Si, Au	11,02	10,72	0,00	10,03	0,00	0,50	10,36	0,85	5,57	0,14	0,10	0,89	0,03	0,15	7,48	42,96
15	IC NB	2	6-Electronics	46-IC's avg., 5% Si, Au	11,02	10,72	0,00	10,03	0,00	0,50	10,36	0,85	5,57	0,14	0,10	0,89	0,03	0,15	7,48	42,96
16	IC SB	2	6-Electronics	46-IC's avg., 5% Si, Au	11,02	10,72	0,00	10,03	0,00	0,50	10,36	0,85	5,57	0,14	0,10	0,89	0,03	0,15	7,48	42,96
17	IC PHY	1	6-Electronics	46-IC's avg., 5% Si, Au	5,51	5,36	0,00	5,02	0,00	0,25	5,18	0,42	2,79	0,07	0,05	0,45	0,01	0,07	3,74	21,48
18	IC ICS952906FT	0,721	6-Electronics	47-IC's avg., 1% Si	0,63	0,49	0,00	0,44	0,07	0,46	1,26	0,04	0,59	0,00	0,01	0,13	0,00	0,02	0,01	3,10
19	IC LM385BDR02.5	0,3	6-Electronics	47-IC's avg., 1% Si	0,26	0,20	0,00	0,18	0,03	0,19	0,52	0,02	0,24	0,00	0,00	0,06	0,00	0,01	0,00	1,29
20	IC PWM RT8214OS SOIC-8P	0,3	6-Electronics	47-IC's avg., 1% Si	0,26	0,20	0,00	0,18	0,03	0,19	0,52	0,02	0,24	0,00	0,00	0,06	0,00	0,01	0,00	1,29
21	IC PWM ISL9501CV	0,5	6-Electronics	47-IC's avg., 1% Si	0,44	0,34	0,00	0,31	0,05	0,32	0,87	0,03	0,41	0,00	0,00	0,09	0,00	0,01	0,00	2,15
22	IC Regulator	0,609	6-Electronics	47-IC's avg., 1% Si	0,53	0,41	0,00	0,37	0,06	0,39	1,06	0,04	0,50	0,00	0,01	0,11	0,00	0,01	0,01	2,62
23	IC others	0,02	6-Electronics	47-IC's avg., 1% Si	0,02	0,01	0,00	0,01	0,00	0,01	0,03	0,00	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,09
24	SMT AVR	8,944	6-Electronics	48-SMD/ LED's avg.	26,55	25,81	0,00	8,28	0,00	1,17	25,32	1,49	14,49	0,07	0,13	3,77	0,04	0,45	0,13	19,64
25	TRANS	0,054	6-Electronics	47-IC's avg., 1% Si	0,05	0,04	0,00	0,03	0,01	0,03	0,09	0,00	0,04	0,00	0,00	0,01	0,00	0,00	0,00	0,23
26	DIODE	0,465	6-Electronics	48-SMD/ LED's avg.	1,38	1,34	0,00	0,43	0,00	0,06	1,32	0,08	0,75	0,00	0,01	0,20	0,00	0,02	0,01	1,02
27	FUSE	0,0672	6-Electronics	48-SMD/ LED's avg.	0,20	0,19	0,00	0,06	0,00	0,01	0,19	0,01	0,11	0,00	0,00	0,03	0,00	0,00	0,00	0,15
28	BEADS	0,47	6-Electronics	48-SMD/ LED's avg.	1,40	1,36	0,00	0,43	0,00	0,06	1,33	0,08	0,76	0,00	0,01	0,20	0,00	0,02	0,01	1,03
29	INDUCTOR	9,03	6-Electronics	44-big caps & coils	3,46	0,00	0,00	0,31	0,50	0,18	5,42	0,20	1,28	0,00	0,02	0,07	1,85	0,32	0,67	0,06
30	COMMON CHOKE	0,25	6-Electronics	48-SMD/ LED's avg.	0,74	0,72	0,00	0,23	0,00	0,03	0,71	0,04	0,41	0,00	0,00	0,11	0,00	0,01	0,00	0,55
31	CONNS	48,3	6-Electronics	45-slots / ext. ports	9,04	2,86	0,00	3,61	12,33	0,83	14,86	0,48	8,90	0,00	0,07	1,84	0,09	0,63	1,54	312,49
32	IC FLASH	1,145	6-Electronics	47-IC's avg., 1% Si	1,00	0,77	0,00	0,70	0,12	0,74	2,00	0,07	0,93	0,00	0,01	0,21	0,00	0,03	0,01	4,92
33	DIP CAPS	31,65	6-Electronics	44-big caps & coils	12,13	0,00	0,00	1,10	1,74	0,62	19,01	0,69	4,49	0,00	0,07	0,24	6,48	1,13	2,35	0,23
34	THERMISTERS	2	6-Electronics	48-SMD/ LED's avg.	5,94	5,77	0,00	1,85	0,00	0,26	5,66	0,33	3,24	0,01	0,03	0,84	0,01	0,10	0,03	4,39
35	CRYSTAL/OSC	2	6-Electronics	48-SMD/ LED's avg.	5,94	5,77	0,00	1,85	0,00	0,26	5,66	0,33	3,24	0,01	0,03	0,84	0,01	0,10	0,03	4,39
36	BUZZER	2	6-Electronics	45-slots / ext. ports	0,37	0,12	0,00	0,15	0,51	0,03	0,62	0,02	0,37	0,00	0,00	0,08	0,00	0,03	0,06	12,94
37	Battery	3	6-Electronics	44-big caps & coils	1,15	0,00	0,00	0,10	0,17	0,06	1,80	0,07	0,43	0,00	0,01	0,02	0,61	0,11	0,22	0,02
38	Card	13,2	6-Electronics	98-controller board	10,32	7,65	0,04	6,91	1,39	8,61	22,17	0,68	5,77	0,09	0,08	0,97	0,80	0,30	4,40	62,07
39	Solder SMT	3,17	6-Electronics	52-Solder SnAg4Cu0.5	0,74	0,61	0,00	0,22	0,00	0,01	0,72	0,04	0,20	0,00	0,00	0,01	0,01	0,00	0,00	0,02
40	Solder DIP	9,6	6-Electronics	52-Solder SnAg4Cu0.5	2,25	1,86	0,00	0,67	0,00	0,04	2,19	0,11	0,62	0,00	0,01	0,03	0,02	0,01	0,00	0,06
41	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
42	CASE base	450	3-Ferro	21-St sheet galv.	15,30	1,03	0,03	0,00	0,00	0,00	774,68	1,27	3,36	0,06	11,70	1,60	0,03	1,22	1,60	29,33
43	Case cover	450	3-Ferro	21-St sheet galv.	15,30	1,03	0,03	0,00	0,00	0,00	774,68	1,27	3,36	0,06	11,70	1,60	0,03	1,22	1,60	29,33
44	Power Supply	165	6-Electronics	98-controller board	128,94	95,61	0,50	86,35	17,43	107,65	277,14	8,50	72,16	1,06	1,05	12,12	9,96	3,70	55,00	775,85
45	Inner case	436	3-Ferro	21-St sheet galv.	14,82	0,99	0,03	0,00	0,00	0,00	750,58	1,23	3,25	0,06	11,34	1,55	0,03	1,18	1,55	28,41
46	Front panel	50,2	1-BlkPlastics	10-ABS	4,77	0,35	2,30	0,47	8,28	0,50	4,61	0,17	0,89	0,00	0,00	0,00	0,09	0,15	0,10	31,62
47	Cables	56,7	4-Non-ferro	28-Cu winding wire	8,09	0,00	0,00	0,00	0,00	0,05	1136,27	0,42	17,23	0,00	0,23	3,20	0,31	0,17	0,37	8,97
48	Speaker	3,29	3-Ferro	24-Ferrite	0,17	0,01	0,00	0,13	0,00	0,00	8,50	0,01	0,04	0,00	0,13	0,12	0,00	0,01	0,01	0,26
49	Heatsink(AL)	124	3-Ferro	25-Stainless 18/8 coil	7,69	1,20	0,50	9,39	1,05	0,00	124,00	0,77	6,95	0,02	0,95	18,39	0,00	0,98	10,71	288,66
50	Insulator	7,01	1-BlkPlastics	10-ABS	0,67	0,05	0,32	0,07	1,16	0,07	0,64	0,02	0,12	0,00	0,00	0,00	0,01	0,02	0,01	4,42
51	Screws	20	3-Ferro	25-Stainless 18/8 coil	1,24	0,19	0,08	1,51	0,17	0,00	20,00	0,12	1,12	0,00	0,15	2,97	0,00	0,16	1,73	46,56
52	Rear panel	80	5-Coating	40-Cu/Ni/Cr plating	220,72	206,71	0,00	14,96	139,36	4,65	1600,00	9,97	134,07	0,25	31,72	1548,00	0,40	4,23	12,24	7600,35
53	Rubber	3	2-TecPlastics	16-Flex PUR	0,31	0,06	0,12	0,21	0,89	0,10	1,65	0,01	0,10	0,00	0,00	0,00	0,06	0,02	0,01	17,06
54	Power cord	174	4-Non-ferro	28-Cu winding wire	24,83	0,00	0,00	0,00	0,00	0,14	3486,96	1,28	52,87	0,01	0,69	9,83	0,96	0,53	1,13	27,53
55	Smart card reader	24	6-Electronics	98-controller board	18,76	13,91	0,07	12,56	2,54	15,66	40,31	1,24	10,50	0,15	0,15	1,76	1,45	0,54	8,00	112,85
56	Cables	1,6	4-Non-ferro	28-Cu winding wire	0,23	0,00	0,00	0,00	0,00	0,00	32,06	0,01	0,49	0,00	0,01	0,09	0,01	0,00	0,01	0,25
57	Cradle	126,4	1-BlkPlastics	10-ABS	12,01	0,88	5,79	1,18	20,86	1,26	11,62	0,42	2,25	0,00	0,00	0,00	0,23	0,37	0,25	79,61
58	Cradle rubber	0,7	2-TecPlastics	16-Flex PUR	0,07	0,01	0,03	0,05	0,21	0,02	0,38	0,00	0,02	0,00	0,00	0,00	0,01	0,01	0,00	3,98
59	Carton	23,46	7-Misc.	56-Cardboard	0,66	0,05	0,38	0,17	0,00	0,00	1,23	0,02	0,02	0,00	0,00	0,00	0,00	0,00	0,00	2,02
60	BOX	515	7-Misc.	56-Cardboard	14,42	1,03	8,24	3,63	0,00	0,02	26,94	0,36	0,54	0,00	0,01	0,02	0,00	0,01	0,01	44,32
61	BAG	13,4	1-BlkPlastics	1-LDPE	1,04	0,18	0,69	0,04	0,60	0,06	0,59	0,03	0,10	0,01	0,00	0,00	0,00	0,01	0,00	0,36
62	Cushion	420	7-Misc.	56-Cardboard	11,76	0,84	6,72	2,96	0,00	0,02	21,97	0,29	0,44	0,00	0,01	0,01	0,00	0,00	0,01	36,15
63	Paper/Labels	10	7-Misc.	57-Office paper	0,40	0,06	0,27	0,76	0,00	0,00	0,68	0,01	0,05	0,00	0,00	0,00	0,00	0,02	0,00	52,88
64	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	10152,87	671,60	437,62	27,12	255,26	220,82	360,99	9710,58	37,33	426,50	2,48	71,31	1623,18	24,44	24,44	22,73	144,34

Table 6-12: Pro-rata environmental impact from the production of a server for thin clients; calculations according to MEEUP[50]

Version 5 VHK for European Commission 28 Nov. 2005 — Document subject to a legal notice (see below)

ECO-DESIGN OF ENERGY-USING PRODUCTS — EuP EcoReport: RAW OUTPUTS — Assessment of Environmental Impact

Nr: 0 — **Product:** Office Desktop PC — **Date:** 2008-Feb-06 — **Author:** Übertrag Anhang 2 EuP-

MATERIALS EXTRACTION & PRODUCTION

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	material	GER	electr	feedst	water (proces	water (cool)	haz. Waste	non-haz. Waste	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
1	LDPE	10,543	1-BlkPlastics	1-LDPE	0,82	0,14	0,54	0,03	0,47	0,05	0,47	0,02	0,08	0,01	0,00	0,00	0,00	0,01	0,00	0,28
2	ABS	16,318	1-BlkPlastics	10-ABS	1,55	0,11	0,75	0,15	2,69	0,16	1,50	0,05	0,29	0,00	0,00	0,00	0,03	0,05	0,03	10,28
3	PA 6	5,9006	2-TecPlastics	11-PA 6	0,71	0,09	0,23	0,09	1,29	0,11	1,04	0,05	0,23	0,00	0,00	0,00	0,00	0,03	0,29	11,05
4	PC	11,325	2-TecPlastics	12-PC	1,32	0,17	0,43	0,16	1,29	0,11	2,00	0,06	0,29	0,00	0,00	0,00	0,00	0,08	0,00	5,71
5	Epoxy	4,1957	2-TecPlastics	14-Epoxy	0,59	0,10	0,18	0,08	1,61	0,08	1,71	0,03	0,18	0,00	0,00	0,00	0,00	0,06	0,00	40,49
6	Flex PUR	0,0643	2-TecPlastics	16-Flex PUR	0,01	0,00	0,00	0,00	0,02	0,00	0,04	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,37
7	Steel sheet galvanized	270,53	3-Ferro	21-St sheet galv.	9,20	0,62	0,02	0,00	0,00	0,00	465,72	0,76	2,02	0,04	7,03	0,96	0,02	0,73	0,96	17,63
8	Steel tube / profile	4,5643	3-Ferro	22-St tube/profile	0,08	0,02	0,00	0,00	0,00	0,00	3,65	0,01	0,02	0,00	0,05	0,01	0,00	0,00	0,01	0,17
9	Cast iron	20,679	3-Ferro	23-Cast iron	0,21	0,00	0,00	0,03	0,08	0,00	6,52	0,02	0,07	0,00	0,12	0,04	0,00	0,29	0,02	0,54
10	Ferrite	0	3-Ferro	24-Ferrite	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
11	Stainless 18/8 coil	0,4071	3-Ferro	25-Stainless 18/8 coil	0,03	0,00	0,00	0,03	0,00	0,00	0,41	0,00	0,02	0,00	0,00	0,06	0,00	0,00	0,04	0,95
12	Al sheet/ extrusion	13,48	4-Non-ferro	26-Al sheet/extrusion	2,60	0,00	0,00	0,00	0,00	0,00	52,84	0,14	0,91	0,00	0,07	0,05	1,30	0,23	0,47	0,07
13	Al diecast	0,6429	4-Non-ferro	27-Al diecast	0,04	0,00	0,00	0,00	0,00	0,00	0,48	0,00	0,01	0,00	0,02	0,00	0,01	0,00	0,00	0,00
14	Cu winding wire	11,014	4-Non-ferro	28-Cu winding wire	1,57	0,00	0,00	0,00	0,00	0,01	220,73	0,08	3,35	0,00	0,04	0,62	0,06	0,03	0,07	1,74
15	Cu wire	14,293	4-Non-ferro	29-Cu wire	1,67	0,00	0,00	0,00	0,00	0,00	286,03	0,09	4,17	0,00	0,05	0,79	0,08	0,04	1,34	2,21
16	Cu tube/sheet	2,85	4-Non-ferro	30-Cu tube/sheet	0,15	0,00	0,00	0,00	0,00	0,00	22,84	0,01	0,18	0,00	0,03	0,09	0,02	0,00	0,11	0,18
17	Powder coating	0,0694	5-Coating	39-powder coating	0,02	0,00	0,00	0,00	0,03	0,00	0,03	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,67
18	Big caps & coils	20,679	6-Electronics	44-big caps & coils	7,93	0,00	0,00	0,72	1,14	0,41	12,42	0,45	2,93	0,00	0,04	0,16	4,23	0,74	1,53	0,15
19	Slots / ext. Ports	13,286	6-Electronics	45-slots / ext. ports	2,49	0,79	0,00	0,99	3,39	0,23	4,09	0,13	2,45	0,00	0,02	0,50	0,03	0,17	0,42	85,95
20	Integrated Circuits, 5% Silicon, Au	2,9571	6-Electronics	46-IC's avg., 5% Si, Au	16,29	15,85	0,00	14,84	0,00	0,74	15,32	1,25	8,24	0,20	0,14	1,32	0,04	0,22	11,06	63,52
21	Integrated Circuits, 1% Silicon	4,0929	6-Electronics	47-IC's avg., 1% Si	3,58	2,76	0,01	2,50	0,42	2,64	7,16	0,24	3,34	0,00	0,04	0,76	0,01	0,10	0,04	17,58
22	SMD & LEDs avg.	8,2929	6-Electronics	48-SMD/ LED's avg.	24,62	23,93	0,00	7,67	0,00	1,08	23,48	1,38	13,44	0,06	0,12	3,50	0,04	0,42	0,12	18,21
23	PWB 1/2 lay 3,75 kg/m²	3,3429	6-Electronics	49-PWB 1/2 lay 3.75kg/m2	0,94	0,50	0,03	0,57	0,26	5,79	8,78	0,04	0,71	0,01	0,01	0,12	0,01	0,02	0,05	12,32
24	PWB 6 lay 4,5 kg/m²	6,9643	6-Electronics	50-PWB 6 lay 4.5 kg/m2	2,56	1,02	0,06	3,38	0,53	13,17	28,37	0,11	2,76	0,01	0,04	0,49	0,05	0,26	0,87	17,01
25	Solder SnAg4Cu0,5	2,0571	6-Electronics	52-Solder SnAg4Cu0.5	0,48	0,40	0,00	0,14	0,00	0,01	0,47	0,02	0,13	0,00	0,00	0,01	0,00	0,00	0,00	0,01
26	Cardboard	97,993	7-Misc.	56-Cardboard	2,74	0,20	1,57	0,69	0,00	0,00	5,13	0,07	0,10	0,00	0,00	0,00	0,00	0,00	0,00	8,43
	0	0	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL	0	0	0	82,17	46,70	3,82	32,08	13,23	24,61	1171,20	5,03	45,93	0,33	7,85	9,48	5,94	5,94	3,49	17,45

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Table 6-13: Manufacturing phase for a desktop PC (according to Annex 2 EuP study)

MANUFACTURING																				
	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	1128,1	0	20	46,08	27,74	1,59	0,42	13,09	0,00	144,39	2,56	11,02	0,00	0,00	0,00	0,01	1,70	0,00	26,94
202	Foundries Fe/Cu/Zn (fixed)	482,5	0	34	1,06	0,64	0,04	0,01	0,30	0,00	3,32	0,06	0,25	0,00	0,00	0,00	0,00	0,04	0,00	0,62
203	Foundries Al/Mg (fixed)	15	0	35	0,10	0,06	0,00	0,00	0,03	0,00	0,31	0,01	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,06
204	Sheetmetal Manufacturing (fixed)	6702,8	0	36	101,41	61,05	3,49	0,92	28,80	0,00	317,76	5,63	24,26	0,01	0,00	0,00	0,00	3,74	0,00	40,01
205	PWB Manufacturing (fixed)	1343,5	0	53	172,62	4,31	6,41	15,83	48,04	5,67	143,47	11,45	65,83	4,17	0,13	1,18	3,47	20,20	0,57	952,83
206	Other materials (Manufacturing already in	3080,6	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	1675,7	0,25	37	20,07	8,23	0,03	0,00	0,00	0,10	301,91	1,34	6,01	0,15	18,04	42,27	0,01	0,86	0,02	0,38
	TOTAL	12753			341,34	102,02	11,57	17,18	90,26	5,78	911,17	21,04	107,41	4,33	18,17	43,44	3,50	26,55	0,60	1020,84

Table 6-14: Manufacturing phase, notebook (according to Annex 2 EuP study)

MANUFACTURING																				
	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	851,8	0	20	34,80	20,95	1,20	0,32	9,88	0,00	109,03	1,93	8,32	0,00	0,00	0,00	0,01	1,28	0,00	20,34
202	Foundries Fe/Cu/Zn (fixed)	0	0	34	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
203	Foundries Al/Mg (fixed)	121,67	0	35	0,79	0,48	0,03	0,01	0,22	0,00	2,48	0,04	0,19	0,00	0,00	0,00	0,00	0,03	0,00	0,46
204	Sheetmetal Manufacturing (fixed)	542,33	0	36	8,21	4,94	0,28	0,07	2,33	0,00	25,71	0,46	1,96	0,00	0,00	0,00	0,00	0,30	0,00	3,24
205	PWB Manufacturing (fixed)	800,56	0	53	102,86	2,57	3,82	9,43	28,63	3,38	85,49	6,82	39,23	2,48	0,08	0,70	2,07	12,04	0,34	567,77
206	Other materials (Manufacturing already in	1462,2	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	135,58	0,25	37	1,62	0,67	0,00	0,00	0,00	0,01	24,43	0,11	0,49	0,01	1,46	3,42	0,00	0,07	0,00	0,03
	TOTAL	3778,6			148,28	29,60	5,33	9,83	41,06	3,39	247,14	9,36	50,19	2,50	1,54	4,12	2,08	13,72	0,34	591,84

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Table 6-15: Manufacturing phase, 17″ LCD monitor (according to Annex 2, EuP study)

MANUFACTURING																				
	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	2250,7	0	20	91,94	55,35	3,17	0,83	26,11	0,00	288,09	5,10	21,99	0,01	0,00	0,00	0,03	3,39	0,00	53,74
202	Foundries Fe/Cu/Zn (fixed)	1165	0	34	2,56	1,54	0,09	0,02	0,73	0,00	8,02	0,14	0,61	0,00	0,00	0,00	0,00	0,09	0,00	1,50
203	Foundries Al/Mg (fixed)	0	0	35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
204	Sheetmetal Manufacturing (fixed)	1893	0	36	28,64	17,24	0,99	0,26	8,13	0,00	89,74	1,59	6,85	0,00	0,00	0,00	0,00	1,06	0,00	11,30
205	PWB Manufacturing (fixed)	158,6	0	53	20,38	0,51	0,76	1,87	5,67	0,67	16,94	1,35	7,77	0,49	0,02	0,14	0,41	2,38	0,07	112,48
206	Other materials (Manufacturing already in	1340,4	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	473,25	0,25	37	5,67	2,32	0,01	0,00	0,00	0,03	85,26	0,38	1,70	0,04	5,10	11,94	0,00	0,24	0,01	0,11
	TOTAL	6807,7			149,18	76,96	5,01	2,98	40,64	0,70	488,04	8,56	38,93	0,54	5,11	12,08	0,44	7,17	0,07	179,13

Table 6-16: Manufacturing phase, 17″ CRT monitor (according to Annex 2, EuP study)

MANUFACTURING																				
	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	2411,6	0	20	98,52	59,31	3,39	0,89	27,97	0,00	308,69	5,47	23,57	0,01	0,00	0,00	0,03	3,63	0,00	57,59
202	Foundries Fe/Cu/Zn (fixed)	0	0	34	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
203	Foundries Al/Mg (fixed)	0	0	35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
204	Sheetmetal Manufacturing (fixed)	140	0	36	2,12	1,28	0,07	0,02	0,60	0,00	6,64	0,12	0,51	0,00	0,00	0,00	0,00	0,08	0,00	0,84
205	PWB Manufacturing (fixed)	237,5	0	53	30,52	0,76	1,13	2,80	8,49	1,00	25,36	2,02	11,64	0,74	0,02	0,21	0,61	3,57	0,10	168,44
206	Other materials (Manufacturing already in	13608	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	35	0,25	37	0,42	0,17	0,00	0,00	0,00	0,00	6,31	0,03	0,13	0,00	0,38	0,88	0,00	0,02	0,00	0,01
	TOTAL	16398			131,57	61,52	4,60	3,71	37,07	1,01	346,99	7,64	35,84	0,75	0,40	1,09	0,64	7,30	0,10	226,87

Table 6-17: Manufacturing phase, IGEL 3210 Compact (calculated according to MEEUP)

MANUFACTURING																				
	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	200,71	0	20	8,20	4,94	0,28	0,07	2,33	0,00	25,69	0,45	1,96	0,00	0,00	0,00	0,00	0,30	0,00	4,79
202	Foundries Fe/Cu/Zn (fixed)	0	0	34	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
203	Foundries Al/Mg (fixed)	0	0	35	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
204	Sheetmetal Manufacturing (fixed)	1483,3	0	36	22,44	13,51	0,77	0,20	6,37	0,00	70,32	1,25	5,37	0,00	0,00	0,00	0,00	0,83	0,00	8,85
205	PWB Manufacturing (fixed)	248,83	0	53	31,97	0,80	1,19	2,93	8,90	1,05	26,57	2,12	12,19	0,77	0,02	0,22	0,64	3,74	0,11	176,47
206	Other materials (Manufacturing already in	1490,3	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	370,82	0,25	37	4,44	1,82	0,01	0,00	0,00	0,02	66,81	0,30	1,33	0,03	3,99	9,35	0,00	0,19	0,00	0,08
	TOTAL	3423,2			67,05	21,06	2,25	3,21	17,60	1,07	189,39	4,12	20,85	0,81	4,02	9,57	0,65	5,06	0,11	190,20

Table 6-18: Pro rata environmental impact; manufacturing phase of a server (calculated according to MEEUP)

MANUFACTURING																				
	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	wght	cat.	NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	g	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
201	OEM Plastics Manufacturing (fixed)	48,346	0	20	1,97	1,19	0,07	0,02	0,56	0,00	6,19	0,11	0,47	0,00	0,00	0,00	0,00	0,07	0,00	1,15
202	Foundries Fe/Cu/Zn (fixed)	20,679	0	34	0,05	0,03	0,00	0,00	0,01	0,00	0,14	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,03
203	Foundries Al/Mg (fixed)	0,6429	0	35	0,00	0,00	0,00	0,00	0,00	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
204	Sheetmetal Manufacturing (fixed)	287,26	0	36	4,35	2,62	0,15	0,04	1,23	0,00	13,62	0,24	1,04	0,00	0,00	0,00	0,00	0,16	0,00	1,71
205	PWB Manufacturing (fixed)	57,579	0	53	7,40	0,18	0,27	0,68	2,06	0,24	6,15	0,49	2,82	0,18	0,01	0,05	0,15	0,87	0,02	40,84
206	Other materials (Manufacturing already in	132,03	0	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
207	Sheetmetal Scrap (Please adjust percenta	71,816	0,25	37	0,86	0,35	0,00	0,00	0,00	0,00	12,94	0,06	0,26	0,01	0,77	1,81	0,00	0,04	0,00	0,02
	TOTAL	546,54			14,63	4,37	0,50	0,74	3,87	0,25	39,05	0,90	4,60	0,19	0,78	1,86	0,15	1,14	0,03	43,75

Table 6-19: Distribution phase for a desktop PC (according to MEEUP calculation)

DISTRIBUTION																					
	Product					Energy			Water		Waste		Emissions to Air							to Water	
nr			cat.	NDX		GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
						MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
				61	0	51,50	0,00	0,00	0,00	0,00	1,02	51,36	4,52	12,00	0,05	0,29	2,62	2,62	0,26	0,08	1,36
208	Is it an ICT or Consumer Electronics product <15 l		YES	59	1	231,94	0,22	2,22	0,00	0,00	2,05	103,21	18,12	63,50	3,08	0,58	5,25	3,35	70,75	0,16	2,74
209	Is it an installed appliance (e.g. boiler)?		NO	60	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				62	1	39,12	0,00	0,00	0,00	0,00	0,50	25,23	2,30	6,58	0,39	0,14	1,29	0,67	16,81	0,04	0,67
210	Volume of packaged final product in m3	in m3	0,0783	63	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				64	1	4,62	0,00	0,00	0,00	0,00	0,09	4,29	0,32	1,02	0,00	0,02	0,22	0,01	0,02	0,01	0,11
	TOTAL					327,18	0,22	2,22	0,00	0,00	3,66	184,09	25,25	83,10	3,52	1,04	9,37	6,65	87,85	0,29	4,89

Table 6-20: Distribution phase, notebook (according to MEEUP calculation)

DISTRIBUTION																					
	Product					Energy			Water		Waste		Emissions to Air							to Water	
nr			cat.	NDX		GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
						MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
				61	0	51,50	0,00	0,00	0,00	0,00	1,02	51,36	4,52	12,00	0,05	0,29	2,62	2,62	0,26	0,08	1,36
208	Is it an ICT or Consumer Electronics product <15 l		YES	59	1	90,05	0,09	0,86	0,00	0,00	0,80	40,07	7,03	24,65	1,19	0,23	2,04	1,30	27,47	0,06	1,06
209	Is it an installed appliance (e.g. boiler)?		NO	60	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				62	1	15,19	0,00	0,00	0,00	0,00	0,19	9,80	0,89	2,55	0,15	0,06	0,50	0,26	6,53	0,02	0,26
210	Volume of packaged final product in m3	in m3	0,0304	63	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				64	1	1,79	0,00	0,00	0,00	0,00	0,03	1,67	0,12	0,40	0,00	0,01	0,08	0,00	0,01	0,00	0,04
	TOTAL					158,53	0,09	0,86	0,00	0,00	2,04	102,89	12,57	39,60	1,40	0,58	5,24	4,18	34,26	0,16	2,73

Table 6-21: Distribution phase, 17" LCD monitor (according to MEEUP calculation)

DISTRIBUTION																					
	Product					Energy			Water		Waste		Emissions to Air							to Water	
nr			cat.	NDX		GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
						MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
				61	0	51,50	0,00	0,00	0,00	0,00	1,02	51,36	4,52	12,00	0,05	0,29	2,62	2,62	0,26	0,08	1,36
208	Is it an ICT or Consumer Electronics product <15 l	YES		59	1	74,65	0,07	0,72	0,00	0,00	0,66	33,22	5,83	20,44	0,99	0,19	1,69	1,08	22,77	0,05	0,88
209	Is it an installed appliance (e.g. boiler)?	NO		60	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				62	1	12,59	0,00	0,00	0,00	0,00	0,16	8,12	0,74	2,12	0,13	0,05	0,41	0,21	5,41	0,01	0,22
210	Volume of packaged final product in m3	in m3	0,0252	63	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				64	1	1,49	0,00	0,00	0,00	0,00	0,03	1,38	0,10	0,33	0,00	0,01	0,07	0,00	0,01	0,00	0,04
	TOTAL					140,22	0,07	0,72	0,00	0,00	1,87	94,08	11,20	34,88	1,17	0,53	4,79	3,91	28,45	0,15	2,50

Table 6-22: Distribution phase 17" CRT monitor (according to MEEUP calculation)

DISTRIBUTION																					
	Product					Energy			Water		Waste		Emissions to Air							to Water	
nr			cat.	NDX		GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
						MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
				61	0	51,50	0,00	0,00	0,00	0,00	1,02	51,36	4,52	12,00	0,05	0,29	2,62	2,62	0,26	0,08	1,36
208	Is it an ICT or Consumer Electronics product <15 l	YES		59	1	370,28	0,35	3,55	0,00	0,00	3,27	164,76	28,92	101,38	4,91	0,93	8,38	5,36	112,95	0,26	4,38
209	Is it an installed appliance (e.g. boiler)?	NO		60	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				62	1	62,45	0,00	0,00	0,00	0,00	0,80	40,28	3,66	10,50	0,63	0,23	2,05	1,06	26,84	0,06	1,07
210	Volume of packaged final product in m3	in m3	0,125	63	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				64	1	7,37	0,00	0,00	0,00	0,00	0,14	6,85	0,50	1,63	0,01	0,04	0,35	0,01	0,03	0,01	0,18
	TOTAL					491,60	0,35	3,55	0,00	0,00	5,23	263,25	37,62	125,50	5,60	1,49	13,40	9,05	140,09	0,41	6,99

Table 6-23: Distribution phase, thin client

DISTRIBUTION																					
	Product					Energy			Water		Waste		Emissions to Air							to Water	
nr			cat.	NDX		GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
						MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
				61	0	51,50	0,00	0,00	0,00	0,00	1,02	51,36	4,52	12,00	0,05	0,29	2,62	2,62	0,26	0,08	1,36
208	Is it an ICT or Consumer Electronics product <15 l		YES	59	1	46,21	0,04	0,44	0,00	0,00	0,41	20,56	3,61	12,65	0,61	0,12	1,05	0,67	14,10	0,03	0,55
209	Is it an installed appliance (e.g. boiler)?		NO	60	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				62	1	7,79	0,00	0,00	0,00	0,00	0,10	5,03	0,46	1,31	0,08	0,03	0,26	0,13	3,35	0,01	0,13
210	Volume of packaged final product in m3	in m3	0,0156	63	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				64	1	0,92	0,00	0,00	0,00	0,00	0,02	0,85	0,06	0,20	0,00	0,00	0,04	0,00	0,00	0,00	0,02
	TOTAL					106,42	0,04	0,44	0,00	0,00	1,55	77,80	8,65	26,16	0,74	0,44	3,96	3,42	17,71	0,12	2,06

Table 6-24: Pro rata environmental impact of server; distribution phase

DISTRIBUTION																					
	Product					Energy			Water		Waste		Emissions to Air							to Water	
nr			cat.	NDX		GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
						MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
				61	0	51,50	0,00	0,00	0,00	0,00	1,02	51,36	4,52	12,00	0,05	0,29	2,62	2,62	0,26	0,08	1,36
208	Is it an ICT or Consumer Electronics product <15 l		YES	59	1	18,80	0,02	0,18	0,00	0,00	0,17	8,37	1,47	5,15	0,25	0,05	0,43	0,27	5,74	0,01	0,22
209	Is it an installed appliance (e.g. boiler)?		NO	60	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				62	1	3,17	0,00	0,00	0,00	0,00	0,04	2,05	0,19	0,53	0,03	0,01	0,10	0,05	1,36	0,00	0,05
210	Volume of packaged final product in m3	in m3	0,006347368	63	0	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
				64	1	0,37	0,00	0,00	0,00	0,00	0,01	0,35	0,03	0,08	0,00	0,00	0,02	0,00	0,00	0,00	0,01
	TOTAL					73,85	0,02	0,18	0,00	0,00	1,23	62,12	6,21	17,76	0,33	0,35	3,17	2,94	7,36	0,10	1,65

Table 6-30: Environmental impact of disposal/recycling of an office desktop PC; calculation according to [MEEUP, 2005]

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	value		NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
	Substances released during Product Life and Landfill																			
227	Refrigerant in the product (Click & select)	0	g	1-none																
228	Percentage of fugitive & dumped refriger	0										0,00								
229	Mercury (Hg) in the product	0	g Hg	0																
230	Percentage of fugitive & dumped mercury	0	0	0												0,00				
	Disposal: Environmental Costs perkg final	SUBTOTAL!			157,83	0,00	0,00	0,00	0,00	1687,03	782,06	11,77	23,47	0,43	5,43	43,28	0,00	203,07	13,20	754,54
231	Landfill (fraction products not recovered)	637,63	0,05	88-fixed	43,56	0,00	0,00	0,00	0,00	0,00	781,69	3,25	6,38	0,18	5,38	12,75	0,00	56,72	3,62	206,96
232	Incineration (plastics & PWB not re-used/r	1687	g	91-fixed	113,53	0,00	0,00	0,00	0,00	1687,02	0,00	8,46	16,87	0,24	0,05	30,37	0,00	142,93	9,58	547,57
233	Plastics: Re-use & Recycling ("cost"-side)	112,81	g	92-fixed	0,73	0,00	0,00	0,00	0,00	0,01	0,37	0,05	0,23	0,02	0,00	0,16	0,00	3,42	0,00	0,01
	Re-use, Recycling Benefit	SUBTOTAL!		0	190,93	78,28	3,53	70,60	16,56	87,92	227,33	13,03	66,60	0,97	0,85	9,87	8,14	3,18	44,78	641,48
234	Plastics: Re-use, Closed Loop Recycling (	11,281	0,01	4	0,62	0,06	0,45	0,04	0,34	0,04	0,24	0,02	0,05	0,00	0,00	0,00	0,00	0,01	0,00	1,39
235	Plastics: Materials Recycling (please edit%	101,53	0,09	4	5,06	0,37	2,68	0,24	2,03	0,22	1,43	0,10	0,28	0,00	0,00	0,00	0,02	0,04	0,00	8,35
236	Plastics: Thermal Recycling (please edit%	1015,3	0,9	72	80,27	0,00	0,00	0,00	0,00	0,00	0,00	5,99	7,50	0,10	0,00	0,00	0,00	0,13	0,00	0,00
237	Electronics: PWB Easy to Disassemble ? ((	671,75	YES	98	104,99	77,85	0,41	70,31	14,19	87,65	225,66	6,92	58,76	0,87	0,85	9,87	8,11	3,01	44,78	631,73
238	Metals & TV Glass & Misc. (95% Recycling)	9766,9	0	fixed	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL				-33,11	-78,28	-3,53	-70,60	-16,56	1599,11	554,73	-1,26	-43,12	-0,54	4,58	33,41		-8,14	199,89	-31,58

Table 6-31: Environmental impact of disposal/recycling of a notebook; calculation according to [MEEUP, 2005]

DISPOSAL/RECYCLING

	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	value		NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
	Substances released during Product Life and Landfill																			
227	Refrigerant in the product (Click & select)	0	g	1-none																
228	Percentage of fugitive & dumped refriger	0										0,00								
229	Mercury (Hg) in the product	0	g Hg	0																
230	Percentage of fugitive & dumped mercury	0	0	0												0,00				
	Disposal: Environmental Costs perkg final	SUBTOTAL!			91,99	0,00	0,00	0,00	0,00	1166,91	231,89	6,86	13,73	0,23	1,63	24,91	0,00	118,25	7,70	440,08
231	Landfill (fraction products not recovered)	188,93	0,05	88-fixed	12,91	0,00	0,00	0,00	0,00	0,00	231,62	0,96	1,89	0,05	1,59	3,78	0,00	16,81	1,07	61,32
232	Incineration (plastics & PWB not re-used/r	1166,9	g	91-fixed	78,53	0,00	0,00	0,00	0,00	1166,90	0,00	5,85	11,67	0,16	0,04	21,00	0,00	98,86	6,63	378,75
233	Plastics: Re-use & Recycling ("cost"-side)	85,18	g	92-fixed	0,55	0,00	0,00	0,00	0,00	0,01	0,28	0,04	0,17	0,01	0,00	0,12	0,00	2,58	0,00	0,01
	Re-use, Recycling Benefit	SUBTOTAL!		0	112,30	46,71	2,60	42,11	10,25	52,43	135,73	7,61	39,51	0,58	0,51	5,88	4,85	1,90	26,68	383,79
234	Plastics: Re-use, Closed Loop Recycling (	8,518	0,01	4	0,46	0,05	0,34	0,03	0,26	0,03	0,18	0,01	0,04	0,00	0,00	0,00	0,00	0,00	0,00	1,05
235	Plastics: Materials Recycling (please edit%	76,662	0,09	4	3,82	0,28	2,02	0,18	1,53	0,17	1,08	0,08	0,22	0,00	0,00	0,00	0,01	0,03	0,00	6,31
236	Plastics: Thermal Recycling (please edit%	766,62	0,9	72	45,46	0,00	0,00	0,00	0,00	0,00	0,00	3,39	4,25	0,06	0,00	0,00	0,00	0,07	0,00	0,00
237	Electronics: PWB Easy to Disassemble ? ((	400,28	YES	98	62,56	46,39	0,24	41,90	8,46	52,23	134,47	4,13	35,01	0,52	0,51	5,88	4,83	1,79	26,68	376,44
238	Metals & TV Glass & Misc. (95% Recycling)	2019,9	0	fixed	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL				-20,31	-46,71	-2,60	-42,11	-10,25	1114,48	96,17	-0,75	-25,79	-0,35	1,12	19,02		-4,85	116,35	-18,99

Table 6-32: Environmental impact of disposal/recycling of a 17" LCD monitor; calculation according to [MEEUP, 2005]

DISPOSAL/RECYCLING

nr	Product component	value		NDX	Energy GER	Energy electr	Energy feedst	Water water proces	Water water (cool)	Waste haz.	Waste non-haz.	Emissions to Air GWP	Emissions to Air AD	Emissions to Air VOC	Emissions to Air POP	Emissions to Air HM	Emissions to Air PAH	Emissions to Air PM	to Water Metal	to Water EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
	Substances released during Product Life and Landfill																			
227	Refrigerant in the product (Click & select)	0	g	1-none																
228	Percentage of fugitive & dumped refriger:	0										0,00								
229	Mercury (Hg) in the product	0	g Hg	0																
230	Percentage of fugitive & dumped mercury	0	0	0												0,00				
	Disposal: Environmental Costs perkg final	SUBTOTAL!			166,37	0,00	0,00	0,00	0,00	2104,92	418,02	12,40	24,90	0,42	2,94	45,02	0,00	215,43	13,88	793,71
231	Landfill (fraction products not recovered)	340,38	0,05	88-fixed	23,26	0,00	0,00	0,00	0,00	0,00	417,29	1,74	3,40	0,10	2,87	6,81	0,00	30,28	1,93	110,48
232	Incineration (plastics & PWB not re-used/r	2104,9	g	91-fixed	141,65	0,00	0,00	0,00	0,00	2104,90	0,00	10,56	21,05	0,30	0,06	37,89	0,00	178,33	11,95	683,21
233	Plastics: Re-use & Recycling ("cost"-side)	225,07	g	92-fixed	1,46	0,00	0,00	0,00	0,00	0,01	0,73	0,10	0,45	0,03	0,00	0,33	0,00	6,82	0,00	0,02
	Re-use, Recycling Benefit	SUBTOTAL!		0	118,50	10,05	6,28	8,87	6,40	10,87	29,96	8,12	16,46	0,23	0,10	1,17	1,01	0,59	5,29	94,02
234	Plastics: Re-use, Closed Loop Recycling (|	22,507	0,01	4	1,23	0,12	0,89	0,08	0,68	0,07	0,47	0,03	0,09	0,00	0,00	0,00	0,01	0,01	0,00	2,78
235	Plastics: Materials Recycling (please edit%	202,56	0,09	4	10,10	0,74	5,34	0,49	4,05	0,45	2,85	0,20	0,57	0,00	0,00	0,00	0,04	0,08	0,00	16,67
236	Plastics: Thermal Recycling (please edit%	2025,6	0,9	72	94,78	0,00	0,00	0,00	0,00	0,00	0,00	7,07	8,86	0,12	0,00	0,00	0,00	0,15	0,00	0,00
237	Electronics: PWB Easy to Disassemble ? ((	79,3	YES	98	12,39	9,19	0,05	8,30	1,68	10,35	26,64	0,82	6,94	0,10	0,10	1,17	0,96	0,36	5,29	74,58
238	Metals & TV Glass & Misc. (95% Recycling)	4178,5	0	fixed	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL				47,87	-10,05	-6,28	-8,87	-6,40	2094,05	388,05	4,27	8,44	0,20	2,84	43,86		-1,01	214,84	8,60

Table 6-33: Environmental impact of disposal/recycling of a 17" CRT monitor; calculation according to [MEEUP, 2005]

DISPOSAL/RECYCLING

nr	Product component	value		NDX	Energy GER	Energy electr	Energy feedst	Water water proces	Water water (cool)	Waste haz.	Waste non-haz.	Emissions to Air GWP	Emissions to Air AD	Emissions to Air VOC	Emissions to Air POP	Emissions to Air HM	Emissions to Air PAH	Emissions to Air PM	to Water Metal	to Water EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
	Substances released during Product Life and Landfill																			
227	Refrigerant in the product (Click & select)	0	g	1-none																
228	Percentage of fugitive & dumped refriger:	0										0,00								
229	Mercury (Hg) in the product	0	g Hg	0																
230	Percentage of fugitive & dumped mercury	0	0	0												0,00				
	Disposal: Environmental Costs perkg final	SUBTOTAL!			211,64	0,00	0,00	0,00	0,00	2289,22	1005,90	15,77	31,57	0,59	6,99	57,95	0,00	274,19	17,65	1009,17
231	Landfill (fraction products not recovered)	819,88	0,05	88-fixed	56,02	0,00	0,00	0,00	0,00	0,00	1005,12	4,18	8,20	0,23	6,91	16,40	0,00	72,93	4,65	266,12
232	Incineration (plastics & PWB not re-used/r	2289,2	g	91-fixed	154,05	0,00	0,00	0,00	0,00	2289,21	0,00	11,49	22,89	0,32	0,07	41,21	0,00	193,95	13,00	743,03
233	Plastics: Re-use & Recycling ("cost"-side)	241,16	g	92-fixed	1,57	0,00	0,00	0,00	0,00	0,02	0,78	0,11	0,48	0,03	0,00	0,35	0,00	7,31	0,00	0,02
	Re-use, Recycling Benefit	SUBTOTAL!		0	161,74	14,68	6,75	13,04	7,57	16,06	43,45	11,25	23,35	0,32	0,15	1,75	1,49	0,83	7,92	132,51
234	Plastics: Re-use, Closed Loop Recycling (|	24,116	0,01	4	1,31	0,13	0,95	0,09	0,72	0,08	0,51	0,04	0,10	0,00	0,00	0,00	0,01	0,01	0,00	2,98
235	Plastics: Materials Recycling (please edit%	217,05	0,09	4	10,82	0,79	5,72	0,52	4,34	0,48	3,05	0,21	0,61	0,00	0,00	0,00	0,04	0,08	0,00	17,86
236	Plastics: Thermal Recycling (please edit%	2170,5	0,9	72	131,05	0,00	0,00	0,00	0,00	0,00	0,00	9,78	12,25	0,17	0,00	0,00	0,00	0,21	0,00	0,00
237	Electronics: PWB Easy to Disassemble ? ((	118,75	YES	98	18,56	13,76	0,07	12,43	2,51	15,50	39,89	1,22	10,39	0,15	0,15	1,75	1,43	0,53	7,92	111,68
238	Metals & TV Glass & Misc. (95% Recycling)	13061	0	fixed	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL				49,90	-14,68	-6,75	-13,04	-7,57	2273,17	962,45	4,52	8,23	0,26	6,84	56,21		-1,49	273,36	9,74

Table 6-34: Environmental impact of disposal/recycling of an Igel Compact; calculation ac-cording to [MEEUP, 2005]

DISPOSAL/RECYCLING																				
	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	value		NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
	Substances released during Product Life and Landfill																			
227	Refrigerant in the product (Click & select)	0	g	1-none																
228	Percentage of fugitive & dumped refriger	0										0,00								
229	Mercury (Hg) in the product	0	g Hg	0																
230	Percentage of fugitive & dumped mercury	0	0	0												0,00				
	Disposal: Environmental Costs perkg final	SUBTOTAL!			32,35	0,00	0,00	0,00	0,00	305,05	209,89	2,41	4,80	0,09	1,45	8,94	0,00	41,68	2,70	154,57
231	Landfill (fraction products not recovered)	171,16	0,05	88-fixed	11,69	0,00	0,00	0,00	0,00	0,00	209,83	0,87	1,71	0,05	1,44	3,42	0,00	15,23	0,97	55,55
232	Incineration (plastics & PWB not re-used/r	305,05	g	91-fixed	20,53	0,00	0,00	0,00	0,00	305,05	0,00	1,53	3,05	0,04	0,01	5,49	0,00	25,84	1,73	99,01
233	Plastics: Re-use & Recycling ("cost"-side)	20,071	g	92-fixed	0,13	0,00	0,00	0,00	0,00	0,00	0,07	0,01	0,04	0,00	0,00	0,03	0,00	0,61	0,00	0,00
	Re-use, Recycling Benefit	SUBTOTAL!		0	45,17	14,50	0,63	13,07	3,05	16,28	42,09	3,15	13,25	0,19	0,16	1,83	1,51	0,60	8,29	118,74
234	Plastics: Re-use, Closed Loop Recycling (	2,0071	0,01	4	0,11	0,01	0,08	0,01	0,06	0,01	0,04	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,25
235	Plastics: Materials Recycling (please edit%	18,064	0,09	4	0,90	0,07	0,48	0,04	0,36	0,04	0,25	0,02	0,05	0,00	0,00	0,00	0,00	0,01	0,00	1,49
236	Plastics: Thermal Recycling (please edit%	180,64	0,9	72	24,71	0,00	0,00	0,00	0,00	0,00	0,00	1,84	2,31	0,03	0,00	0,00	0,00	0,04	0,00	0,00
237	Electronics: PWB Easy to Disassemble ? ((	124,41	YES	98	19,44	14,42	0,08	13,02	2,63	16,23	41,79	1,28	10,88	0,16	0,16	1,83	1,50	0,56	8,29	117,00
238	Metals & TV Glass & Misc. (95% Recycling)	2824,9	0	fixed	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL				-12,81	-14,49	-0,63	-13,07	-3,05	288,77	167,80	-0,73	-8,45	-0,10	1,29	7,11		-1,51	41,07	-5,59

Table 6-35: Pro rata environmental impact from disposal/recycling of a terminal server; calculation ac-cording to [MEEUP, 2005]

DISPOSAL/RECYCLING																				
	Product				Energy			Water		Waste		Emissions to Air							to Water	
nr	component	value		NDX	GER	electr	feedst	water proces	water (cool)	haz.	non-haz.	GWP	AD	VOC	POP	HM	PAH	PM	Metal	EUP
		in g			MJ	MJ	MJ	ltr.	ltr.	g	g	kg CO2eq	g SO2eq	mg	ng i-Teq	mg Ni eq	mg Ni eq	g	mg Hg/20eq	mg PO4 eq
	Substances released during Product Life and Landfill																			
227	Refrigerant in the product (Click & select)	0	g	1-none																
228	Percentage of fugitive & dumped refriger	0										0,00								
229	Mercury (Hg) in the product	0	g Hg	0																
230	Percentage of fugitive & dumped mercury	0	0	0												0,00				
	Disposal: Environmental Costs perkg final	SUBTOTAL!			6,76	0,00	0,00	0,00	0,00	72,30	33,52	0,50	1,01	0,02	0,23	1,85	0,00	8,70	0,57	32,34
231	Landfill (fraction products not recovered)	27,327	0,05	88-fixed	1,87	0,00	0,00	0,00	0,00	0,00	33,50	0,14	0,27	0,01	0,23	0,55	0,00	2,43	0,16	8,87
232	Incineration (plastics & PWB not re-used/r	72,301	g	91-fixed	4,87	0,00	0,00	0,00	0,00	72,30	0,00	0,36	0,72	0,01	0,00	1,30	0,00	6,13	0,41	23,47
233	Plastics: Re-use & Recycling ("cost"-side)	4,8346	g	92-fixed	0,03	0,00	0,00	0,00	0,00	0,00	0,02	0,00	0,01	0,00	0,00	0,01	0,00	0,15	0,00	0,00
	Re-use, Recycling Benefit	SUBTOTAL!		0	8,18	3,35	0,15	3,03	0,71	3,77	9,74	0,56	2,85	0,04	0,04	0,42	0,35	0,14	1,92	27,49
234	Plastics: Re-use, Closed Loop Recycling (	0,4835	0,01	4	0,03	0,00	0,02	0,00	0,01	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,06
235	Plastics: Materials Recycling (please edit%	4,3512	0,09	4	0,22	0,02	0,11	0,01	0,09	0,01	0,06	0,00	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,36
236	Plastics: Thermal Recycling (please edit%	43,512	0,9	72	3,44	0,00	0,00	0,00	0,00	0,00	0,00	0,26	0,32	0,00	0,00	0,00	0,00	0,01	0,00	0,00
237	Electronics: PWB Easy to Disassemble ? ((	28,789	YES	98	4,50	3,34	0,02	3,01	0,61	3,76	9,67	0,30	2,52	0,04	0,04	0,42	0,35	0,13	1,92	27,07
238	Metals & TV Glass & Misc. (95% Recycling)	418,58	0	fixed	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
	TOTAL				-1,42	-3,35	-0,15	-3,03	-0,71	68,53	23,77	-0,05	-1,85	-0,02	0,20	1,43		-0,35	8,57	-1,35